INTRODUCTION

In the first appeal of the Port Westward Goal Exception, the Land Use Board of Appeals ("LUBA") warned the Port of Columbia County ("the Port") and Columbia County ("the County") that they may have "bit off more than they can chew, or more than can be practicably accomplished outside of a periodic review," in seeking such a sweeping rezone of farm land to industrial use.[1] 12 years later, that statement remains prescient. The Port's latest application ("the Application) again falls short of justifying the Goal Exception for any of its proposed uses.

Columbia Riverkeeper is a nonprofit organization with a mission to protect and restore the water quality of the Columbia River and all life connected to it, from the headwaters to the Pacific Ocean. For decades, Columbia Riverkeeper has monitored and engaged on industrial proposals at Port Westward because of its location in the ecologically sensitive Columbia River Estuary.

1000 Friends of Oregon (1000 Friends) is a nonprofit, membership organization that works with Oregonians to support livable urban and rural communities, protect family farms, forests and natural areas, and provide transportation and housing choices.

The Staff Report does an excellent job of analyzing the broad flaws with the Port's newest application. And the Staff Report is correct that the "higher intensity" and customary development form (CDF) uses identified in the Application are not supported and cannot be approved. However, the Staff Report still recommends that uses labeled "lower intensity" by the Port can be approved. This is incorrect. Just because the Port has labeled these uses as "lower intensity," does not mean that it has shown that they are in fact compatible with surrounding uses and natural resources. All of the same flaws that the Staff Report identifies for the "higher intensity" uses apply to all of the proposed uses.

The Board must deny this entire application, which plainly fails to meet the standard set by LUBA in *Columbia Riverkeeper v. Columbia County*, LUBA No 2021-097 (May 9, 2022) (hereinafter, "*Riverkeeper III*").[2]

I. The Staff Report is correct that the "higher intensity" and CDF uses cannot be approved under OAR 660-004-0020(2)(d) and ORS 197.723(2)(c)(D).

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[1] *Columbia Riverkeeper v. Columbia County*, 70 Or LUBA 171 (2014).

[2] Columbia Riverkeeper and 1000 Friends of Oregon incorporate by reference prior evidence and testimony submitted by these organizations in prior proceedings regarding this application.

Riverkeeper III is clear that in order for any of the proposed uses in the Goal Exception to be approved, the Port must give a highly detailed analysis of why the proposed use is compatible with surrounding farm uses and natural resources. The Port must show that *any* use allowed by the Goal Exception, even in their worst form, are compatible with surrounding natural resources and farm uses.

At a minimum, this analysis must address: 1) the specific vulnerabilities of surrounding natural resources, 2) the scale and intensity of proposed uses, and 3) the specific impacts of proposed uses. This analysis must be use-specific. It cannot rely heavily on comparisons to existing uses in the area, on the existence of environmental regulations (without explanation of why those regulations address specific impacts or vulnerabilities), or on future conditions of approval.

The Staff Report correctly finds that the Application fails to meet this bar. The Staff Report states that "the characteristics that make [surrounding uses and natural resources] vulnerable to potential adverse impacts from specific industrial uses are not evaluated in sufficient detail."[3] Nor, the Staff Report notes, does the Application explain how environmental regulations address specific industry impacts to the surrounding area, as LUBA instructed the Port to do.[4] Finally, the Staff Report explains, the Applicant also failed to address particular impact concerns upheld by LUBA in the prior remand, including seismic vulnerability and impacts to local hydrology.[5]

For these reasons, the Staff Report recommends denial of the CDF and higher intensity uses proposed by the Port. This recommendation is correct. These proposed uses are plainly inconsistent with the sensitive ecosystems and farm uses in the surrounding area, no matter what conditions are placed on them.

For example, one of the uses the Port describes as a CDF, which the Staff Report recommends denying, is a gypsum wallboard plant. The Port's analysis of the air quality impacts of gypsum wallboard manufacturing consists of acknowledging that it will result in significant particulate matter pollution, but dismissing that as a problem because it would have to comply with federal and state air quality standards.[6] As the Staff Report correctly notes, because the air quality standards referenced are not designed to be protective of the surrounding natural resources or uses, that does nothing to demonstrate compliance with OAR 660-004-0020(2)(d).[7] Further, the

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[3] Staff Report at 13.
[4] *Id.*
[5] Staff Report at 31-36.
[6] CSA Analysis at 4-8 to 4-11.
[7] Staff Report at 21 ("Based on staff's discussions with DEQ air quality representatives on October 1, 2025, the DEQ air permitting program is "protective" of air quality but depends on detailed modeling of specific industrial uses to determine whether state and federal air quality standards are met. DEQ air quality representatives noted that compliance with such standards does not guarantee that the wide range of industrial uses allowed in the Exception Area will be rendered "compatible" with the natural resources or farm/forest uses found in the Surrounding Area.").

Applicant fails to address multiple other impacts of gypsum wallboard manufacturing. For example, one issue with gypsum wallboard manufacturing (which depends on the type of gypsum that is used) is mercury pollution, which can accumulate in the surrounding environment and food chains.[8] The Port does not even acknowledge this as a problem, let alone explain what impact this could have on the surrounding area.

Each of the CDF and high intensity uses analyzed by the Port suffer from the same flaws: cursory and general analysis that does not meet the bar set by LUBA in *Riverkeeper III.* The Board should uphold the staff's recommendation to deny these uses.

II. The Staff Report is incorrect that the "lower intensity" uses can be approved under OAR 600-004-0020(2)(d) and ORS 197.723(2)(c)(D).

The glaring issue with the Staff Report's analysis is that the same flaws it identifies with regards to the "higher intensity" and "customary development forms (CDF)" apply in equal force to the lower intensity development forms. There is not adequate information to even label those development forms as "lower intensity."

The Staff Report's own analysis seems to recognize this problem. It states that "*across all industrial use categories*, the applicant has not identified the specific vulnerabilities of farm/forest uses and natural resources to potential adverse impacts from the CDF or more or less intensive uses and linked these vulnerabilities to specific adverse impacts from the proposed uses."[9] However, it nonetheless recommends approval of the "lower intensity" uses without any clear justification for why these problems are addressed.

Each of the subsections below discusses a different, overarching problem with the Port's analysis that prevent the County from approving any part of this goal exception.

a. The Application arbitrarily limits the impact area to the state boundary.

Under OAR 660-004-0020(2)(d), the Port is required to analyze resource vulnerabilities in the "surrounding area." The Port's analysis uses a 1-mile impact area, except for in the Columbia River, where it cuts the impact area off at the Washington border in the middle of the river. The 1-mile impact area is not justified by the Port's analysis. Without knowing what the potential impacts of uses at the port are, it is impossible to determine whether this impact area is sufficient.

Further, the decision to limit the impact area at the Washington border directly contradicts LUBA's opinion in *Riverkeeper III,* which stated that OAR 660-004-0020(2)(d) "is concerned with impacts on adjoining uses and natural resources in the surrounding area, and is not limited

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[8] Jessica Sanderson, Fate of Mercury in Synthetic Gypsum Used for Wallboard Production, prepared for the United States Department of Energy National Energy Technology Laboratory (2006), https://www.osti.gov/servlets/purl/943310 (Exhibit 1).

[9] Staff Report at 29.

to uses and resources that are located within the county's zoning jurisdiction."[10] The Staff Report recognizes this contradiction, yet dismisses the concern because "the state line is in the middle of the Columbia River, which staff believe is representative of natural resources associated with the Columbia River."[11]

Staff offer no evidence that this is true. And there are, in fact, unique resources on the other side of the state line with specific vulnerabilities that are not represented within the Port's impact area. For example, there are three salmon-bearing tributaries of the Columbia on the Washington side of the river, directly across from the rezone site: Mill Creek, Abernathy Creek, and Germany Creek.[12] All of these tributaries have been a part of ongoing fish habitat restoration efforts. The Washington Department of Fish and Wildlife owns and manages the confluence of Abernathy Creek and the Columbia, and its website notes that endangered chum salmon spawn in that part of the creek.[13]

Salmon spawning grounds and tributaries like these creeks are natural resources with specific vulnerabilities that the Port needs to evaluate.[14] Potential noise, and air and water quality impacts from the proposed uses could affect these resources in specific ways, not addressed in the current analysis. The ongoing restoration efforts and state management in these creeks must also be evaluated.

Further, missing these crucial sensitive resources that are directly across from the exception site makes it clear that there are potentially other resources on the Washington side of the Columbia that have been excluded from the Port's analysis, in direct contradiction to LUBA's instructions. The Port must expand its impact area analysis to this whole area and consider whether there are other potentially impacted resources on the Washington side of the river.

b. The Application does not address specific vulnerabilities of surrounding uses and natural resources.

As the Staff Report acknowledges, the Port lists surrounding natural resources, but it does not explain what the highest vulnerabilities to these resources are.[15] For example, it lists multiple salmon species as being in the area, but provides no analysis of what kind of industrial impacts

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[10] *Riverkeeper III* at 11.
[11] Staff Report at 18.
[12] Kirk L. Krueger, et al., Fish Habitat Restoration and Interannual Variability in Intensively Monitored Watersheds, Frontiers in Ecology and Evolution (2019) (Exhibit 2).
[13] Washington Department of Fish and Wildlife, Abernathy Creek Wildlife Area Unit, https://wdfw.wa.gov/places-to-go/wildlife-areas/abernathy-creek-wildlife-area-unit (Exhibit 3).
[14] *See, e.g.,* Shawn Vestal, WSU Inside, *Quiet, Please: Hatchery Salmon Raised Amid Noise are Less Likely to Return to Spawn*, https://news.wsu.edu/press-release/2026/07/08/quiet-please-hatchery-salmon-raised-amid-noise-are-less-likely-to-return-to-spawn/ (Jul. 8, 2026) (Exhibit 4).
[15] Staff Report at 19.

might affect those salmon in the shallow waters of the Bradbury Slough, the mainline of the Columbia, or the tributaries and spawning grounds across the river. In addition to impacts on water quality from air or water pollution from the site, salmon are extremely sensitive to heat and noise impacts.[16] Yet there is no discussion of these impacts anywhere in the application.

To be complete, the Application would have to assess existing habitat conditions for salmon in this area and how any of the proposed uses might change those habitat conditions in a way that would impact the salmon. For example, for noise, the Application would need to identify existing noise levels, assess what increase in those noise levels would negatively impact salmon, and ensure that all of the proposed uses will not increase noise beyond that level.

Salmon are just one example of the failure to identify specific sensitives for natural resources in the area. The same story is true for all of the resources listed by the Port in their application.

There are also multiple specific natural resources that could be impacted by the proposed use that are not even listed in the application. These include Osprey, red legged frogs (which are an Oregon sensitive species and federal species of concern), and painted turtles, all of which have a strong presence in the Bradbury Slough.[17] Osprey, which nest in the slough, are sensitive to noise. And the Oregon Department of Fish and Wildlife explains that for red legged frogs "[h]ydrologic modifications to riparian and floodplain area, fragmentation and direct mortality associated with roads, suburban development, and other land use changes are likely to have direct effects on populations."[18] Again, these are examples of specific vulnerabilities that the Application fails to address.

Because the Port has not identified vulnerabilities of the surrounding natural resources, the County cannot approve any part of the Application, including the "lower impact" uses. There is

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[16] Shawn Vestal, WSU Inside, *Quiet, Please: Hatchery Salmon Raised Amid Noise are Less Likely to Return to Spawn*, https://news.wsu.edu/press-release/2026/07/08/quiet-please-hatchery-salmon-raised-amid-noise-are-less-likely-to-return-to-spawn/ (Jul. 8, 2026) (Exhibit 4); van der Knaap et al., Marine Pollution Bulletin, *Behavioral Responses of Wild Pacific Salmon and Herring to Boat Noise*, https://www.sciencedirect.com/science/article/pii/S0025326X21012911 (Jan. 2022) (Exhibit 5); Katharine Carter, California Regional Water Quality Control Board, *The Effects of Temperature on Steelhead Trout, Coho Salmon, and Chinook Salmon Biology and Function* (Aug. 2025) (Exhibit 6).

[17] Estuary Partnership, Batwater Station Floodplain Restoration Project, https://www.estuarypartnership.org/our-work/habitat-restoration/batwater-station-floodplain-restoration-project (Exhibit 7); *see also* Oregon Conservation Strategy, Columbia River-Blind Slough Swamp (listing species in this area, including many species not considered by the Port) (Exhibit 25)

[18] Oregon Department of Fish and Wildlife, Northern Red Legged Frog, State Wildlife Action Plan, https://swap.oregon.gov/sgcn/northern-red-legged-frog/ (Exhibit 8).

not adequate evidence to conclude that *any* of the proposed uses can be compatible with these resources because there is no evidence of what these resources require for compatibility.

c. The Application does not address location and siting specific impacts.

Part of LUBA's recommendation to the Port to determine compatibility for the proposed use categories was to determine the "most vulnerable adjoining use or natural resource in the surrounding area" to a given impact and then "assume that the industrial use is located in proximity to that use or resource."[19] The Application does not do this analysis. Nowhere does it explain what the impacts of a given development form would be if located as close as their proposed buffers would allow.

The Staff Report argues that this is fine because the buffers are the Port's effective answer to this issue.[20] However, the problem is that nowhere does the Port explain why the buffers are sufficient to address impacts on the most sensitive surrounding uses or resources to specific impacts. For example, as discussed elsewhere in this comment, many surrounding natural resources are sensitive to noise. Nowhere does the Port explain expected decibel levels from the loudest proposed uses and what setback would be required to make those levels compatible with surrounding uses or natural resources. Nor, for potential particulate pollution, does the Port explain how far that particulate might carry from a given use and thus how far that use would need to be setback from neighboring farms.

d. The Application does not address impacts to area hydrology and the water table.

One of the specific impacts that LUBA addressed in *Riverkeeper III* is the effect that the proposed uses could have to the area's sensitive hydrology and water table. Riverkeeper and 1000 Friends of Oregon have previously provided the County with two expert reports detailing the impacts that development in this low-lying area could have, attached again here. The Port again fails to address the concerns.

LUBA was explicit in *Riverkeeper III* that the Port must analyze both water quality and hydrology impacts from the proposed uses:

> Petitioners are correct that the findings at Record 23 to 25 focus mostly on impacts on water quality rather than hydrology. Neither those findings nor any others cited to us address the issues raised regarding impacts of development on the water table. We agree with petitioners that remand is necessary for the county to adopt findings addressing those issues. See *Norvell v. Portland Area LGBC*, 8 43 Or App 849, 853, 604 P2d 896

[19] *Riverkeeper III at* 28.
[20] Staff Report at 27.

(1979) (findings must address and respond to specific issues relevant to compliance with applicable approval standards that were raised in the proceedings below).[21]

The Port completely fails to do this. The Staff Report acknowledges this, but concludes that the "lower impact" uses can still be approved subject to a condition that their stormwater systems be designed for 100-year storms. This is incorrect and does not address the issue.[22]

The issues identified in the Rhodes and Horner Reports still apply to the Port's most recent analysis. As the Rhodes report explains, necessary fill for development in the exception area will "increase the land surface slopes towards the farmlands to the south and west of the proposed Project area in a permanent manner, so that surface water and groundwater will continue to flow from the Project area to the agricultural lowlands, albeit in a more pronounced manner."[23]

For berry and mint farms, this fill presents immediate compatibility issues.[24] As Rhodes testifies, it will raise the water table in these areas, resulting in wetter roots for the berries and mint, which the Port acknowledges is a problem. No matter how well stormwater systems are designed, they cannot address that core issue of raising the water table with increased fill. The Port fails to assess how many acres of wetlands are likely to be filled in this area, how significantly that will raise the water table, and what impact that will have on surrounding farms.

A further issue with development in this area is that any fill will require wetlands mitigation in the vicinity under the Oregon Department of State Lands' removal-fill program, which requires a ratio of wetland mitigation that often exceeds the acreage that is filled. This wetlands mitigation can further raise the water table, exacerbating the problems for adjacent farmers. For example, for the NEXT refinery, which is proposed adjacent to the exception area at Port Westward, the Beaver Drainage Improvement Company has detailed its concerns regarding the project's proposed wetlands mitigation to its resources, and the farmers that rely on it.[25] The Port needs to consider these concerns and what amount of wetlands mitigation will be required for fill of the

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[21] *Riverkeeper III* at 20.

[22] The Staff appear to acknowledge this by deferring by admitting that based on their conversations with the Public Works Department that "to address the effects of an elevated water table on crops grown within the levee system, a special engineering study would be required. This study could determine the impact of development grading and impervious surfaces (including any hard surfacing or expansion of Hermo Road) on the water table level and suggest methods to minimize any related adverse impacts on mint and berry crop production." Staff Report at 57.

[23] Rhodes Report at 4 (Exhibit 9).

[24] See *Riverkeeper III* LUBA Record 1094 ("Native spearmint dies if [it] is flooded for even a day."); *Riverkeeper III* LUBA Record 2268 ("Drainage is a key to [blueberry] production.").

[25] Halverson Northwest Law Group letter to Oregon Department of State Lands on behalf of Beaver Drainage Improvement Company (Sep. 4th, 2021) (Exhibit 10).

wetlands associated with development in the exception area and how that will impact the adjacent farms.

e. The Application does not adequately address impacts related to stormwater runoff.

In addition to completely failing to address the hydrology issues identified by LUBA in *Riverkeeper III,* the Port still fails to adequately address water quality impacts from potential stormwater runoff. The Staff Report's proposed conditions do not address the problem.

The Staff Report correctly assesses that the Port's stormwater memo does not address stormwater impacts at the level required by *Riverkeeper III.* The memo's primary content is to broadly summarize stormwater permitting requirements in the area. It does not explain how those requirements interact with site conditions in the area, what level of stormwater runoff would be expected on site after compliance with these permits, nor whether it is feasible to design stormwater systems that fully capture all runoff in the event of a storm.

The Rhodes report explains that because of the hydrology of the area, it is impossible to fully contain stormwater on site:

> High water tables preclude infiltrating stormwater, especially during the winter, when soils are usually saturated or occupied by standing water. Precipitation amounts are greater than evaporation and infiltration rates, so any retention ponds would capture more water from precipitation than would be lost by infiltration and evaporation, particularly during winter months, making complete onsite retention impossible. For these reasons, the proposed Project would deliver large amounts of stormwater runoff to adjacent lands and water bodies with considerable frequency.[26]

The County's own Public Works staff seem to agree with this difficulty. The Staff Report notes: Public Works staff noted that the suggested condition of designing stormwater systems to detain a 100-year flood would use a lot of space and may not be practical (Section 4.B, Condition 3.b)."[27]

The Staff Report nonetheless finds that stormwater impacts can be addressed through the following condition:

> Stormwater facilities and erosion control shall be designed in accordance with the standards of the Columbia County Stormwater & Erosion Control Ordinance (No. 2001-10), or its subsequent replacement, with an additional requirement that all conveyance systems be designed for the 100-year design storm regardless of development scale.

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[26] Rhodes Report at 5 (Exhibit 9).
[27] Staff Report at 57.

> [Note: the 100-year may not be necessary if the applicant provides a hydrological study as called for by Public Works].

There are four issues with this condition. First, Staff never explain why a system being designed for a 100-year storm ensures compatibility with the surrounding area in the first place. Second, Staff never explains why it is sufficient for only "stormwater conveyance" systems to be designed for 100-year storms without explanation of where that water will be contained. Third, this condition appears to completely remove the requirement to develop for the 100-year storm if the applicant provides a hydrological study with undefined findings, thus rendering this condition completely ineffective. Finally, there is no assessment of whether this condition is possible to achieve for the proposed uses.

The Staff Report and the Application both also fail to consider stormwater impacts from construction. As the Horner report explained:

> A notable, careless absence in the Compatibility Report is any mention of the potential construction-phase contaminants and impacts, other than a brief mention of the construction stormwater general permit. Poorly managed open ground is prone to erosion, producing particulates and other pollutants transported with them (especially nutrients and oxygen-demanding substances). While most of the proposed development area is isolated from the river by the dike, high water table will prevent substantial below-ground infiltration of particulate-laden storm runoff produced there. If that water interferes with construction activities, it will probably be directed to the river. Doing so without negative impacts there would require thorough sediment reduction. The Compatibility Report does not confront these issues.[28]

The Port's latest application again does nothing to address these issues, and the Staff Report does not resolve it for the "lower impact" uses.

f. The Staff Report does not explain why conditions based on 100-year and 50-year floods ensure compatibility, especially in light of climate change.

The Staff Report never explains why its two proposed conditions related to flooding: stormwater systems being designed for 100-year storms and uses involving EHS receiving FEMA levee accreditation for 50-year flooding, are sufficient. There is never any connection between these conditions, the impacts that the proposed uses could have, and how these conditions make the uses consistent with the surrounding area.

The failure to consider the adequacy of these conditions is exacerbated by the impacts of climate change. Climate change is increasing the severity and frequency of storms in the Columbia

[28] Horner Report at 7 (Exhibit 11).

River basin, meaning that 100-year and 50-year floods will occur much more frequently.[29] Accordingly, storms in the area can be expected to frequently exceed these 50-year and 100-year standards. For example, as 50-year floods become more frequent, the likelihood of any of the proposed uses being flooded out—including ones with EHS on site—raises significantly, and the Staff Report's suggested conditions would do nothing to address it.

g. The Application does not adequately address wetland impacts.

The Horner report explains in depth how fill, stormwater runoff, and changes to hydrology in this area will have detrimental impacts on area wetlands. For example, the report cites a study finding that an increase in impervious services in a basin results in a marked "decline in the biotic diversity of wetlands."[30]

The Port submits an expert report discussing impacts to the wetlands within the exception area. This report is insufficient because it focuses almost exclusively on explaining the existence of permitting requirements without explaining project specific impacts.

Additionally, notably missing from the report, is any discussion of impacts to other wetlands in the surrounding area outside of the exception area. The entire exception and surrounding area is mapped as major waterfowl habitat, and much of it is mapped as wetland areas.[31] The Port must consider the impacts the facility will have to these resources.

h. The Application does not address worst case scenario uses.

LUBA's holding in *Riverkeeper III* requires the Port to show that any use allowed by the goal exception is compatible with surrounding natural resources and farms. Doing this analysis requires looking to the worst possible uses that could be allowed by the Goal exception and analyzing their impacts against the specific vulnerabilities of surrounding natural resources and farms. The Port failed to do this.

For example, looking at one of the "lower intensity" uses, utility peaker plants, the Port and the Staff Report look only at small combined cycle natural gas peaker plants like the ones existing on site to determine that they are low impact. However, the allowed use is for a "utility peaker plant." Nothing in the conditions of approval or use definition dictate the size of that plant, what fuel could be used at the plant, or that it must be combined cycle. This means that, for example,

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[29] Michelle Klampe, Flooding in the Columbia River Basin Expected to Increase Under Climate Change, Study Finds (Feb. 10, 2021), https://news.oregonstate.edu/news/flooding-columbia-River-basin-expected-increase-under-climate-change-study-finds (Exhibit 12).
[30] Horner Report at 15 (Exhibit 11).
[31] Columbia County, Wildlife Game Habitat Map, https://evogov.s3.amazonaws.com/143/media/164213.pdf
Columbia County, Wetland and Hydric Soils Map, https://evogov.s3.amazonaws.com/143/media/164212.pdf.

an applicant could propose a 100+ acre coal or petroleum fired peaker plant that will directly discharge heated cooling water into the slough. This kind of facility would have clear compatibility issues with surrounding natural resources and farms and nothing in the Application controls for this outcome or explains why it is not an issue.

All of the proposed uses face the same issue in the Port's analysis. The Port looks at customary developments, but does not look at the largest, most polluting, highest risk form of these uses that could be allowed in the exception area.

i. The Application does not address recreational use of the slough.

The River and slough are adjacent to the subject site. Thus, uses of these waterbodies are "adjacent uses" for the purpose of OAR 660-004-0020(2)(d). And, as part of its analysis of compatibility with adjacent uses and surrounding natural resources, the Port must assess recreational uses of these water bodies. It has failed to do that.

The Bradbury Slough and the Columbia River are both important sources of recreation in the surrounding area. People use the river and its sloughs for water sports, fishing, and sightseeing. The Bradbury Slough, for instance, has been listed as a worthwhile kayaking destination by multiple organizations.[32] Further development of Port Westward could negatively impact the use of the river and slough for such recreation through scenic, noise, and air quality impacts, none of which are discussed in the Application.

j. The Application does not address vehicle and train traffic impacts.

The Application and Staff Report fail to address the impacts that vehicle and train traffic could have to surrounding natural resources and farm uses.

Added vehicle and train traffic can be a significant detriment to farm uses. For example, a key issue for mint farms in the area is harvest timing. Delays in traffic from trains or vehicle trips can lead to spoliation of the harvest.[33] Nowhere does the Port or the Staff Report analyze potential train or vehicle traffic impacts from the proposed uses nor explain why those impacts would not negatively impact surrounding farm uses. There is no analysis of what roads would be used and what farms rely on those roads, or what emissions from increased vehicle traffic could harm sensitive crops in the area.

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[32] Lower Columbia Estuary Partnership, Water Trail Trip Recommendations, https://www.estuarypartnership.org/explore/water-trail-trip-recommendations#:~:text=Park%20to%20Park&text=The%20Lower%20Gorge%3A%20Secret%20Spots%2C (Exhibit 13); Paddleways, Bradbury Slough, https://www.paddleways.com/us/oregon/water/Bradbury-slough-s1.

[33] Mike Seely, Letter to Columbia County Board of Commissioners (Exhibit 14).

This vehicle and train traffic also presents a risk to the levee that protects the entire surrounding area from flooding. As the Beaver Drainage Improvement Company testified during the NEXT refinery land use hearings, Kallunki Road, which runs between the exception area and the Bradbury Slough sits atop a levee that protects the farms, homes, and existing industry in the area from flooding.[34] Increased rail and heavy-truck traffic crossing that levee could impact it, including through subsistence of the levee. The Port does not analyze this issue.

Increases in vehicle and train trips can also harm surrounding natural resources. Vehicles and trains are sources of noise and air pollution, both of which could impact surrounding natural resources. Vehicle traffic is also responsible for significant salmon mortality as a result of a chemical used in tires, called 6PPD.[35] Increased vehicle traffic in this area could thus result in additional exposure to this chemical in the Bradbury Slough and Columbia River, harming endangered salmon. This is especially true if this vehicle traffic will be using the roads that run along the Columbia or the Bradbury Slough, which is not clear from the Application.

The Staff Report recommends conditions for vehicle and train impacts, but does not connect these conditions to any analysis of actual impacts. For vehicle trips, the Staff Report recommends two conditions:

> To ensure adequate transportation operation, proposed developments and expansions requiring site design review or Use Permitted Under Prescribed Conditions shall not produce more than 332 PM peak-hour trips for the entire subject property without conducting a new Traffic Impact Analysis ("TIA") with recommendations for operational or safety mitigation consistent with the Oregon Transportation Planning Rule 660-012-0060.
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> A traffic study shall be prepared for each proposed future development within the subject property to determine the number of trips generated, likely travel routes, impacts on both passenger car and heavy truck traffic and to ensure that county roadways are improved as needed to adequately serve future development. These TIA reports would also be used to ensure that the number of trips generated and accumulative trips do not exceed the trip cap.[36]

Again, there is no analysis of why these conditions are sufficient to address vehicle impacts to surrounding uses. Across the Application and the Staff Report, for example, there is no explanation for the arbitrary "332 PM peak-hour" trips limitation. Further, these conditions are

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[34] Beaver Drainage Improvement Company, Inc., Letter to the Columbia County Planning Commission (Exhibit 15).
[35] Jeff Rice, Encyclopedia of Puget Sound, *Study Finds Juvenile Coho Salmon at Risk from Deadly Tire Chemical,* https://www.eopugetsound.org/magazine/study-finds-juvenile-coho-salmon-risk-deadly-tire-chemical (Jan. 12, 2026) (Exhibit 16).
[36] Staff Report at 5-5.

self-contradictory and ineffective. The first condition appears to require a Traffic Impact Analysis (TIA) whenever the trip cap is exceeded, and the second condition appears to require a TIA for all projects with the intent of limiting trips to a "trip cap." Nowhere, however, is a trip cap actually imposed. So, it appears these conditions would allow an unlimited number of trips, so long as a TIA is completed.

For train traffic, the Staff Report recommends one condition:

> Railroad crossings shall be managed consistently with federal law regulating crossing to reduce crossing delays. Any proposed use that includes transportation to or from the subject property by rail shall submit a rail plan identifying the number and frequency of trains to the subject property and impacts to rail movements, safety, noise or other identified impacts along the rail corridor supporting the County's transportation system. The plan shall propose mitigation to identified impacts.[37]

Just like for vehicle traffic, however, there is no explanation of why this condition is sufficient. There is no analysis of what level of train traffic a given use may draw nor whether that amount of traffic can, in fact, be compatible with reducing delays and thus impacts to surrounding farms. Requiring a plan that then mitigates supposed impacts lacks clear and objective criteria that ensures consistency and simply defers review of this issue to a later proceeding, in contravention of LUBA's opinion in *Riverkeeper III.* Likewise, the reliance on "federal law regulating crossing" again fails to explain why that law will address the specific potential impacts here or even what the relevant law is.

k. The Application does not address impacts of increased ship traffic.

Uses in the proposed exception area will rely heavily on the deepwater port for import and export—that is the entire justification for the proposed exception. However, nowhere in the Application or the Staff Report is there a discussion of the impacts that this increase in ship traffic in the river and at the dock could have on surrounding natural resources or uses.

Increasing ship traffic to and from the Port will have significant impacts on the surrounding area. Ships are large sources of air pollution, spewing particulate matter and other criteria pollutants that can negatively impact human health, farm uses, and surrounding resources.[38] Ship traffic in the river also has an adverse impact on salmon through noise, spill risks, stranding effects from ship wakes, and displacement.[39] In an assessment of an increase in ship traffic in this same area from the NEXT refinery the National Ocean and Atmospheric Association stated:

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[37] Staff Report at 5-6.
[38] Neighbors for Clean Air, Ports for People, https://neighborsforcleanair.org/ports-for-people/ (Exhibit 17).
[39] W.H. Pearson et al., A Study of Stranding of Juvenile Salmon by Ship Wakes Along the Lower Columbia River Using a Before-and-After Design: Before-Phase Results (Feb. 2006),

> Despite the reduced speed by ships and barges at some known stranding beaches, the increase in the number of vessels arriving and departing the NEXT facility will increase the mortality of juvenile salmonids and larval and egg life stages of eulachon. Ocean-type salmonids (typically, fall Chinook and chum salmon) are susceptible to wake stranding as passing ship wakes displace them from the water onto adjacent beaches. The small size of Chinook and chum salmon fry (35- 55mm) obligates them to migrate near the shoreline to avoid piscine predators where they are highly susceptible to ship wake stranding mortality. These fish are incapable of avoiding these events when they swim or drift near shallow slope beaches and ships pass. Hundreds to thousands of individual salmon and eulachon fry are expected to die or be injured annually, especially during early spring, as small fry and large ship wakes co-occur.[40]

Despite these potential impacts, the Application and the Staff Report lack any analysis of how much vessel traffic could increase at the Port, what level of air, noise, and water pollution would be expected from that increase, and how that increase would impact the surrounding area.

l. The Application does not adequately address seismic risk.

The Application acknowledges that seismic risk is a concern in this area because of its proximity to the Cascadia Subduction Zone and its high risk of soil liquefaction in the event of an earthquake. The Application largely dismisses this concern by pointing to Oregon Structural Special Code (OSSC) seismic design standards. It also proposes a condition for facilities that will contain EHS or are "determined by the County to be necessary to protect public health" to be "constructed to withstand a magnitude 9 earthquake expected from a Cascadian subduction zone earthquake." The Staff Report recommends modification of this condition to read as:

> All facilities that will contain EHS at the threshold quantity (TQ), reporting quantity (RQ), or threshold planning quantity (TPQ) (whichever is least) listed on the EPA List of Lists; any development capable of storing 10 million gallons of liquid, and any structures determined by the county to be necessary to protect public health through the site review process, will be constructed to withstand a magnitude 9 earthquake expected from a Cascadian subduction zone earthquake in accordance with the Oregon Structural Specialty Code (2025, or its subsequent replacement). Substances without a TQ, TPQ, or RQ on the EPA List of Lists shall be determined by an expert opinion issued by a

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https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-15400.pdf (Exhibit 18).

[40] United States National Oceanic and Atmospheric Administration, Endangered Species Act Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the NEXT Renewable Fuels, Oregon, LLC Renewable Green Fuels Facility, Port Westward, Columbia County, Oregon (HUC 170800030900) (NWP-2020-383), https://repository.library.noaa.gov/view/noaa/67390 (Exhibit 19).

professional with a PhD in Chemistry or a registered Professional Chemical Engineer in the State of Oregon. EHS must be secured within a structure that has been seismically improved to OSSC standards. Again, facilities shall be taken as the definition of structure in CCZO Section 100.114.

Both the Staff Report and the Applicant's recommended conditions are insufficient.

First, both the Port's and the Staff Report's limitations on what types of facilities would have to be built to withstand a magnitude 9 earthquake are arbitrarily limited and not justified in the record. Nowhere does the Application explain why facilities that will have EHS at the suggested quantities or facilities that can store up to 10 million gallons of liquid are the only cause for concern when it comes to seismic impacts. Spills of non-hazardous liquids like cooking oil or molasses can have enormous detrimental impacts on the surrounding environment.[41] In 2015, for example, release of cooking oil from a warehouse that was only storing 1,100 gallons of oil devastated a creek in Washington, killing all fish four miles downstream.[42] The Staff Report proposes to allow more than 9,000 times that amount of cooking oil to be stored in this soil liquefaction zone without requiring the facility be built to withstand the inevitable CSZ earthquake. And the catch all for "structures determined by the county to be necessary to protect public health," does not address this problem because it leaves the discretion with the County.

Further, nowhere does the Staff Report or the Port's application explain why only EHS is of concern for spilling, or even what EHS is and what facilities would be covered by the list. Review of the EHS list cited by the Staff Report does not make it immediately clear whether fossil fuel storage facilities like liquified natural gas storage would qualify as EHS. The Port must also consider whether other uses that do not involve EHS would be fire risks in the event of an earthquake. The City of Portland's analysis of risk at the CEI Hub, though limited to fossil fuel storage there, provides a better example of how spill risk in the event of an earthquake can be connected to the actual environmental impacts of the stored material.[43]

Second, nowhere does the Application or the Staff Report discuss whether it is possible for the proposed uses to be built to withstand a magnitude 9 earthquake in a soil liquefaction zone nor what the standards for reviewing future uses for compliance with this condition would be. Soil

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[41] Associated Press, 100,000 Fish Killed After Vegetable Oil Spill in Washington State Creek, https://weather.com/news/news/thousands-fish-killed-vegetable-oil-spill-washington-creek (Aug. 26, 2015) (Exhibit 20); Svati Kirsten Narula, What's Worse Than an Oil Spill? A Molasses Spill, https://www.theatlantic.com/technology/archive/2013/09/whats-worse-than-an-oil-spill-a-molasses-spill/279640/ (Sep. 13, 2013) (Exhibit 21).

[42] Associated Press, 100,000 Fish Killed After Vegetable Oil Spill in Washington State Creek, https://weather.com/news/news/thousands-fish-killed-vegetable-oil-spill-washington-creek (Aug. 26, 2015) (Exhibit 20).

[43] ECONorthwest, Impacts of Fuel Releases from the CEI Hub Due to a Cascadia Subduction Zone Earthquake (January 2022) https://multco.us/file/critical_energy_infrastructure_hub_report_-_full_report/download (Exhibit 22).

liquefaction in this area means that the ground will turn to liquid and sink in on itself in the event of an earthquake. There is a limited list of uses that can be built to withstand such an event and nowhere does the Application explain whether the listed uses can do so.[44]

The Staff Report's suggested condition cites to the OSSC for what it means to be built to withstand a magnitude 9 earthquake, but the OSSC does not provide any clarity. The OSSC does not discuss design standards for specific magnitudes in a high-risk zone like the exception area. This lack of clarity leaves impermissible discretion in future proceedings for the County to determine what can "withstand a magnitude 9 earthquake." For example, fuel tanks may be designed to avoid failure during a CSZ earthquake, but that does not mean they avoid any spillage.[45]

In order to approve any uses that could result in potential spills or fires in the event of an earthquake, the Port must explain which facilities are a spill or fire risk, what would be spilled, why the structural protections would be sufficient to protect from a spill or fire, and whether the proposed use categories are capable of complying with those structural protections. Right now, the Application and Staff Report do none of that.

m. The proposed conditions, again, impermissibly defer necessary determinations.

Multiple other subsections above discuss the Staff Report's failure to explain whether the conditions it imposes are feasible and why they ensure compatibility. The conditions, generally, fall into the same trap as the conditions in *Riverkeeper III.* They attempt to substitute for adequate findings and thus defer findings of consistency to later approvals.

In *Riverkeeper III,* LUBA explained the role of conditions in this goal exception:

> Such conditions of approval can replicate, at a finer scale and to a greater degree, the analysis required under goal exception criteria such as OAR 660-004-0020(2)(d). Such a "belt and suspenders" approach is not error, so long as the local government does not rely on conditions of approval or subsequent permit reviews to substitute for findings fully addressing the goal exception criteria at an appropriate level of detail.[46]

Here, the Staff Report's proposed use of conditions to make up for the identified flaws in the Port's analysis does exactly that. For example, the Staff Report acknowledges that the Port has not adequately addressed stormwater and hydrology issues and proposes a condition, without any

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[44] Pacific Northwest Seismic Network, Liquefaction, https://pnsn.org/education/earthquake-hazards/liquefaction (Exhibit 23).
[45] ECONorthwest, Impacts of Fuel Releases from the CEI Hub Due to a Cascadia Subduction Zone Earthquake (January 2022), at 9 https://multco.us/file/critical_energy_infrastructure_hub_report_-_full_report/download (Exhibit 22).
[46] *Riverkeeper III* at 27.

findings on why that condition is sufficient, to plug that hole. Likewise, the Staff Report acknowledges that "the wide range of proposed allowable uses makes it impossible to determine potential adverse fire impacts on natural resource and farm/forest uses – without more detail regarding the specific industrial uses, their related occupancy classifications, and the funding needed to increase fire protection capacity."[47] Yet the Staff Report proposes the "lower impact" uses can be allowed with a broad fire safety condition.

The CDF framework proposed by the Port, while not relied on by the Staff Report, would also clearly run afoul of LUBA's instructions not to defer compatibility findings. The Port's recommended framework for future approval of specific uses in the five proposed use categories is for the County to determine whether they are less or more intense than the CDF for the category. The Port supplies a flowchart for how the County should determine whether a use is less or more intense. However, the Port does not provide clear and objective markers for determining whether a proposed use is more or less intense. Instead, it leaves that determination largely to the County's discretion. This is especially problematic given the range of uses that could be allowed here.

Take, for example, storage of cooking oil – which is accepted by the Port and the County as a "lower intensity" use. As described above, storage of cooking oil in a soil liquefication zone has potentially catastrophic implications for surrounding resources. In this aspect, it is potentially more intense than other uses in this category. However, nothing in the CDF framework requires a use — even if it has severe implications for one potential impact — to be listed as higher intensity, triggering the more rigid conditions.

n. The Application does not address cumulative impacts of uses across the full 837 acres of the exception area.

One of the biggest flaws with the Application is the failure to address impacts from the Exception if the full site is developed. All of the potential impacts discussed above, in the Staff Report, and in the Application, would be magnified as multiple uses are proposed across the full 834 acres of the exception area. The criteria for a goal exception requires determining that "[t]he proposed *uses* are compatible with other adjacent uses or will be so rendered through measures designed to reduce adverse impacts."[48]

Here, the exception would allow any of the uses proposed by the Port (if the full exception is granted) or any of the "lower intensity" uses listed by the Staff Report. In either case, the impact of the exception on surrounding uses and natural resources cannot be understood without considering what will happen with development of the full 837 acres, as that is the eventual goal.

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[47] Staff Report at 42.
[48] ORS 197.460(2)(c)(D) (emphasis added).

All of the impacts of potential uses at this site must be reviewed for compatibility if they occurred across the entire area. For example, traffic from one of the "lower intensity" uses may be deemed insignificant, but if 40 20-acre projects all get approved in the exception area, and each one produces around 300 PM peak-hour trips (which would avoid any traffic impact analysis requirement), the surrounding area could see an increase of 12,000 PM peak hour vehicle trips from this exception without analysis. This level of traffic increase could greatly impact sensitive harvest practices of nearby farms, increase air and water pollution, and generally render the proposed exception incompatible with the surrounding area.

CONCLUSION

For the reasons provided above, the Columbia County Board of Commissioners must deny the requested goal exception, in full.

Sincerely,



Eve Goldman
Staff Attorney
1000 Friends of Oregon

s/ Audrey Leonard
Audrey Leonard
Staff Attorney
Columbia Riverkeeper

List of Exhibits
Columbia Riverkeeper & 1000 Friends of Oregon
Testimony on Port of Columbia County Rezone Application – Third Remand
November 6, 2026

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Fate of Mercury in Synthetic Gypsum Used for Wallboard Production

Final Report

Prepared by:

Jessica Sanderson
USG Corporation

Gary M. Blythe and
Mandi Richardson
URS Corporation

June 2008

Cooperative Agreement No: DE-FC26-04NT42080

USG Corporation
550 West Adams Street
Chicago, Illinois 60661

Prepared for:

Charles Miller

National Energy Technology Laboratory
U.S. Department of Energy
626 Cochrans Mill Road
Pittsburgh, Pennsylvania 15236

Exhibit List 002

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ABSTRACT

This report presents and discusses results from the project "Fate of Mercury in Synthetic Gypsum Used for Wallboard Production," performed at five different full-scale commercial wallboard plants. Synthetic gypsum produced by wet flue gas desulfurization (FGD) systems on coal-fired power plants is commonly used in the manufacture of wallboard. This practice has long benefited the environment by recycling the FGD gypsum byproduct, which is becoming available in increasing quantities, decreasing the need to landfill this material, and increasing the sustainable design of the wallboard product. However, new concerns have arisen as recent mercury control strategies involve the capture of mercury in FGD systems. The objective of this study has been to determine whether any mercury is released into the atmosphere at wallboard manufacturing plants when the synthetic gypsum material is used as a feedstock for wallboard production. The project has been co-funded by the U.S. DOE National Energy Technology Laboratory (Cooperative Agreement DE-FC26-04NT42080), USG Corporation, and EPRI. USG Corporation is the prime contractor, and URS Group is a subcontractor.

The project scope included seven discrete tasks, each including a test conducted at various USG wallboard plants using synthetic gypsum from different wet FGD systems. The project was originally composed of five tasks, which were to include 1) a base-case test, then variations representing differing power plant: 2) emissions control configurations, 3) treatment of fine gypsum particles, 4) coal types, and 5) FGD reagent types. However, Task 5,could not be conducted as planned and instead was conducted at conditions similar to Task 3. Subsequently an opportunity arose to test gypsum produced from the Task 5 FGD system, but with an additive expected to impact the stability of mercury, so Task 6 was added to the project. Finally, Task 7 was added to evaluate synthetic gypsum produced at a power plant from an additional coal type.

In the project, process stacks in the wallboard plant were sampled using the Ontario Hydro method. In every task, the stack locations sampled included a gypsum dryer and a gypsum calciner. In Tasks 1 and 4 through 7, the stack of the dryer for the wet wallboard product was also tested. Also at each site, in-stream process samples were collected and analyzed for mercury concentration before and after each significant step in wallboard production. These results and process data were used to construct mercury mass balances across the wallboard plants.

The results from the project showed a wide range of percentage mercury losses from the synthetic gypsum feedstocks as measured by the Ontario Hydro method at the process stacks, ranging from 2% to 55% of the mercury in the gypsum feedstock. For the tasks exceeding 10% mercury loss across the wallboard plant, most of the loss occurred across the gypsum calciner. When total wallboard emissions remained below 10%, the primary emission location varied with a much less pronounced difference in emission between the gypsum dryer, calciner and board dryer. For all seven tasks, the majority of the mercury emissions were measured to be in the elemental form (Hg^0). Overall, the measured mercury loss mass rates ranged from 0.01 to 0.17 grams of mercury per dry ton of synthetic gypsum processed, or 0.01 to 0.4 pounds of mercury released per million square feet of wallboard produced from synthetic gypsum. The Coal Combustion Product Production and Use Survey from the American Coal Ash Association (ACAA) indicate that 7,579,187 short tons of synthetic gypsum were used for wallboard production in 2006. Extrapolating the results of this study to the ACAA industry usage rate, we

estimate that mercury releases from wallboard production plants in 2006 ranged between 150 to 3000 pounds for the entire U.S. wallboard industry.

With only seven sets of wallboard plant measurements, it is difficult to draw firm conclusions about what variables impact the mercury loss percentages across the wallboard plants. One significant observation from this study was that higher purge rates of chlorides and fine solid particles from the wet FGD systems appear to produce gypsum with lower mercury concentrations. Any chemical interaction between mercury and chlorides is not well understood; however, based on the information available the lower mercury content in the gypsum product is likely due to the blow down of fine, mercury-rich particles as opposed to a decreased chloride concentration. One possible explanation is that a decrease of fine particles in the FGD slurry allows for less adsorption of mercury onto those particles, thus the mercury remains with the FGD liquor rather than the gypsum product. A more detailed discussion on synthetic gypsum sources and FGD chemistry data can be found in the Experimental section of this report and Table 4. However, higher percentage mercury losses were observed at the wallboard plant for Tasks 3, 5 and 6 with lower feedstock gypsum mercury concentrations that appear to be due to higher chloride and fine particle purge rates at the source FGD systems. This resulted in mercury mass release rates comparable to Tasks 1 and 2 using synthetic gypsum produced in FGD systems on bituminous-coal-fired plants with lower purge rates.

There may also be an effect of the coal type fired at the power plant that produces the synthetic gypsum. A test with gypsum produced at a power plant that fires Texas lignite showed lower percentage and mass mercury losses across the wallboard plant than for gypsum from power plants that fire bituminous or subbituminous coal. Selective catalytic reduction (SCR) used for nitrogen oxide emissions control was expected to increase the mercury concentration of the synthetic gypsum; however, results did not support this assumption.

It should be noted that the results of this project were measured at USG wallboard plants that use indirect-fired kettle type gypsum calciners. Other calciner types, such as flash calciners where gypsum comes into contact with hot flue gas, may have different mercury release characteristics.

Wallboard samples from this project and additional wallboards produced from synthetic gypsum were analyzed for leachate mercury concentration according to the Toxicity Characteristic Leaching Procedure (TCLP). All of the leachates were below detection limits for mercury concentration (<0.3 μg/L) and well below toxicity characteristic thresholds.

A laboratory calcination method was tested to determine if laboratory measurements of mercury lost from raw synthetic gypsum feedstock samples would match the corresponding commercial wallboard plant test results. In general, the results did not accurately predict the commercial wallboard plant test results. A more sophisticated laboratory procedure that better simulates heat and mass transfer in a kettle calciner may be required to produce a more reliable prediction.

Ten natural gypsum samples were compared to the twelve synthetic gypsum samples described above. The highest mercury concentration found in the natural gypsum was 0.03 μg/g compared to the lowest mercury concentration of synthetic gypsum of 0.10 μg/g.

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INTRODUCTION

This report presents and discusses results of the study "Fate of Mercury in Synthetic Gypsum Used for Wallboard Production," performed at a full-scale commercial wallboard plants. The objective of this project is to measure whether any mercury evolves from synthetic gypsum produced by wet flue gas desulfurization (FGD) systems on coal-fired power plants, when that material is used as a feedstock for wallboard production. The project is being co-funded by the U.S. DOE National Energy Technology Laboratory (Cooperative Agreement DE-FC26-04NT42080), USG Corporation, and EPRI. USG Corporation is the prime contractor, and URS Group is a subcontractor.

Background

To address concerns about air quality, the U.S. Congress passed the Clean Air Act Amendments of 1990, which placed significant restrictions on sulfur dioxide emissions from coal-fired power plants. To reduce sulfur dioxide emissions and meet the Clean Air Act standards, many electric utilities installed wet FGD systems on their coal-fired plants. These FGD systems combine the sulfur dioxide gases released during coal combustion with an alkaline reagent such as limestone or lime. In many of these wet FGD systems, the resulting byproduct is oxidized to produce synthetic gypsum. The synthetic gypsum produced is commonly used as a feedstock for wallboard production. The reuse of the synthetic gypsum is environmentally beneficial and is also economically attractive for both the power and wallboard industries.

The Clean Air Interstate Rule, signed by the U.S. EPA in March 2005, will further regulate sulfur dioxide emissions. This rule will cause greater amounts of synthetic gypsum to be created, and potentially cause a large increase in the volume of this material to going to landfills. Establishing wallboard manufacturing plants near both power plants and population centers can reduce the quantity landfilled, while making wallboard a more sustainable product by reducing transportation and use of fossil fuels.

A number of mercury control strategy plans for U.S. coal-fired power generating plants involve the capture of oxidized mercury from flue gases treated by wet FGD systems. For example, in finalizing the Clean Air Mercury Rule on March 15, 2005, the U.S. EPA recognized mercury emissions reduction "co-benefits" possible for coal-fired plants that are equipped with selective catalytic reduction (SCR) for NO_X control and wet FGD systems for SO_2 control. SCR systems on bituminous coal fired plants have been observed to oxidize most of the elemental mercury in the SCR inlet gas. Also, a number of proposed mercury control processes involve using low-temperature catalysts or injected chemicals to oxidize elemental mercury and promote increased mercury removal across FGD systems.

For these processes to be effective at overall mercury control, the mercury must stay in the FGD byproducts and not be re-emitted to the atmosphere or into groundwater. Measurements by URS Group and others have indicated that much of the mercury scrubbed from flue gases in most U.S. wet FGD systems ends up in the solid byproducts. Thus, mercury stability in FGD solid byproducts is an important aspect of mercury capture in FGD systems.

Most FGD systems use lime or limestone reagent and employ forced oxidation to produce gypsum ($CaSO_4 \bullet 2H_2O$) as the solid byproduct. Much of the gypsum byproduct is reused, primarily as a feedstock for wallboard manufacturing. Those that do not produce gypsum instead produce a calcium sulfite hemihydrate ($CaSO_3 \bullet ½H_2O$) byproduct. Most calcium sulfite byproducts are landfilled, although some is reused as mine fill.

Approximately 70% of all of the FGD byproduct reuse in the U.S. is gypsum used as wallboard feedstock. During the year 2005, synthetic gypsum from FGD systems represented approximately 30% of the U.S. wallboard plant feedstock.

This raises new technical questions: What is the fate of mercury in synthetic gypsum in the wallboard plant process? How much mercury is released into the atmosphere during the production of wallboard using synthetic gypsum? Is the amount of mercury released counterproductive to controlling mercury emissions from coal-fired power plants?

Even if mercury is not released in significant quantities during wallboard production, there remains a question as to the stability of mercury in the wallboard product. As an example, at the end of its product life cycle, most wallboard ends up in municipal landfills. What is the stability of mercury in wallboard produced from synthetic gypsum? Will the mercury leach into the acidic aqueous environment in a municipal landfill? This project was intended to collect data from commercial wallboard plants processing FGD synthetic gypsum to help answer these questions.

The Wallboard Production Process

Figure 1 shows an overview of the wallboard production process. In the process, synthetic gypsum is dried to produce "land plaster," which is gypsum that contains no free moisture, only chemically bound waters of hydration. The land plaster is then calcined to produce the "beta" form of calcium sulfate hemihydrate according to the following chemical reaction:

$$2\ CaSO_4 \bullet 2H_2O + \text{heat} \leftrightarrow 2\ CaSO_4 \bullet ½H_2O + 3\ H_2O$$

The beta hemihydrate is also commonly called "stucco" or "plaster of Paris." The stucco is subsequently mixed with water and a number of additives to form a slurry that is extruded between two sheets of paper to form the wallboard. The hemihydrate re-hydrates to form gypsum by the reverse of the reaction shown above. This re-hydration consumes much of the water in the slurry, and causes the gypsum formed to set up as a cohesive solid. The wet board travels down a conveyor belt while it is setting up. After adequate residence time to set up, the board is cut to approximate length, and then dried to remove free moisture (excess water not consumed by the re-hydration reaction). The dried product is cut to final length then stacked for shipping.

The initial gypsum drying and calcining steps described above occur in a section of the plant called the mill. The dryers are typically direct fired with natural gas. Their purpose is to remove the free moisture in the synthetic gypsum (typically 8 to 12% by weight of the raw material) prior to calcining. The dryers consequently operate at conditions below the required gypsum calcining temperature of 262°F (128°C). The solids are dried by direct contact between the wet particles

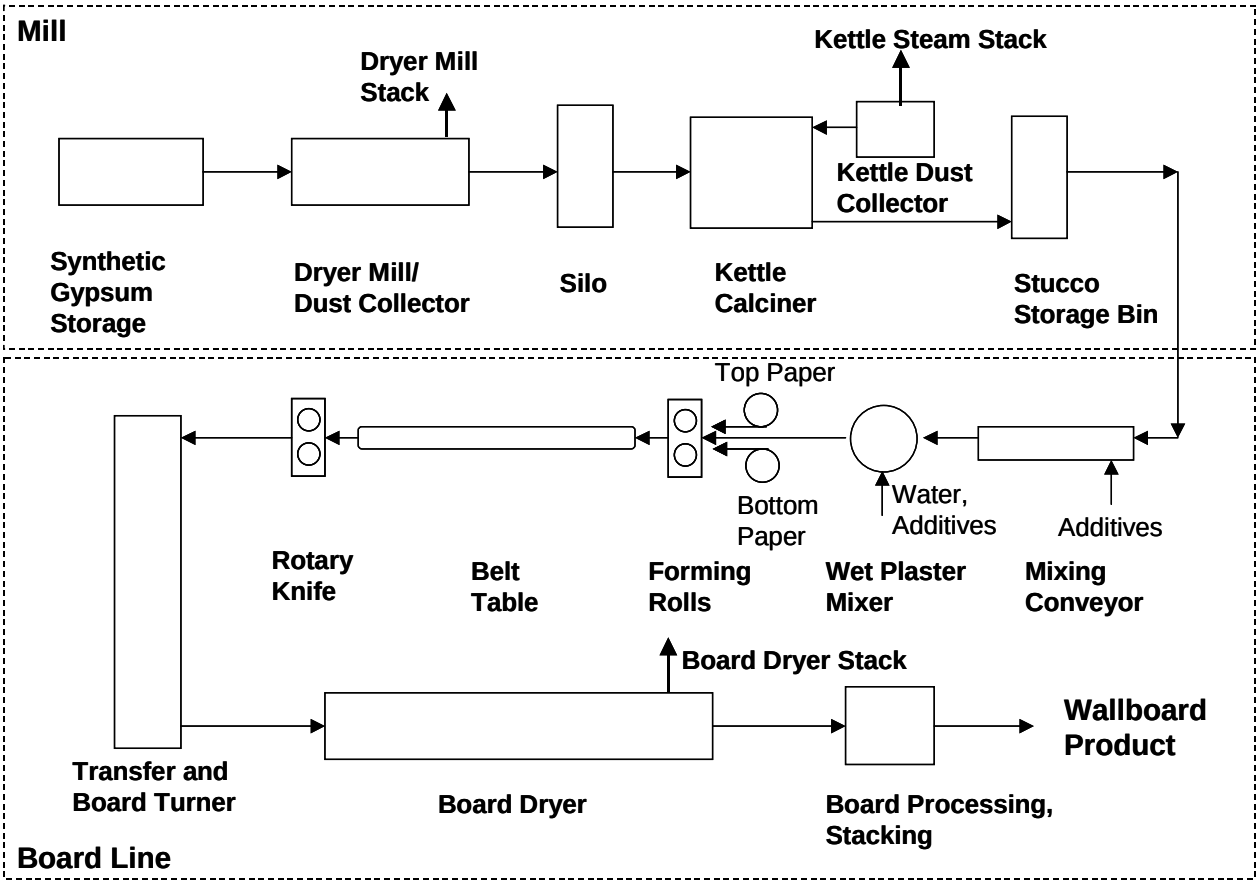


Figure 1. Simplified Schematic of the Wallboard Production Process Using Synthetic Gypsum Feedstock

and the hot flue gas. The moisture-free synthetic gypsum (land plaster) is collected in a fabric filter and placed in intermediate storage silos prior to feeding to the calciners.

In the calcining step, the solids temperature must be raised above 262°F (128°C) to promote release of 1-½ waters of hydration, but must be kept below 325°F (163°C) to avoid forming anhydrous calcium sulfate (no remaining waters of hydration). The calciners used at the wallboard plant tested are indirect-fired kettle calciners, so the vent gas from the process side of the kettle is primarily a mixture of steam and air. A kettle calciner dust collector removes fine stucco particles from this vent gas. The recovered fine particles are recycled to the kettle calciner feed or added to the calciner product stream. The stucco leaving the kettle is cooled and placed in a bin for intermediate storage, to provide a buffer between the mill and board line.

In the board line, the stucco from the silo is fed to a mixer, where "gauging" water is added to form a viscous slurry. The gauging water is typically of high quality (e.g., potable water). A number of proprietary additives are mixed with the wet slurry produced from the stucco.

This wet slurry is continuously extruded between two sheets of paper that are fed from rolls above and below the extruder. One type of paper is used for the face of the wallboard product

and another type is used for the back. The formed board travels down a long conveyor belt that provides residence time for the stucco to re-hydrate and take a set. At the end of this belt, the formed board is cut and inverted so the face paper is facing up.

The board then enters a dryer. The dryer is zoned to operate over a range of temperatures, typically over 400°F (204°C) air temperature at the dryer entrance and about 200°F (93°C) air temperature at the exit. However, the board residence time in the dryer is controlled to limit the temperature of the dried board. This temperature must be limited to avoid any of the set-up solids re-calcining to the hemihydrate form. Thus, the bulk of the rehydrated gypsum in the wallboard product stays well below 262°F (128°C) in temperature. From the dryer, the dried board is cut to final size, has end tape applied, and is stacked for shipment.

Any potential mercury losses during the wallboard process are assumed to occur during the thermal processes, with losses most likely to occur during the calcining step. The synthetic gypsum particles are raised to the highest temperature in the process during this step (above 262°F [128°C]). Losses are also possible from the synthetic gypsum dryer and the finished wallboard dryer, although the maximum temperatures to which the gypsum is raised are lower in the dryers (approximately 170°F to 230°F [77°C to 110°C]).

Project Overview

This project was intended to provide information about the fate of mercury in synthetic gypsum produced by FGD systems on coal-fired power plants, when used as feedstock for wallboard production. Solid samples from various locations in the wallboard process, including the wallboard product, were collected and analyzed for mercury content. Simultaneous flue gas measurements were made using the Ontario Hydro method to quantify any mercury releases to the atmosphere during wallboard production. The project was set up to include five tasks, each of which included a full-scale wallboard plant test conducted while processing synthetic gypsum with unique source conditions. As the project progressed, a sixth and seventh task were added, representing new synthetic gypsum source conditions.

Most of the testing was concentrated in the mill processes where the synthetic gypsum is dried and calcined. Any potential mercury releases from the synthetic gypsum solids are thought to result from thermal desorption. It is in the mill portion of the process where the feedstock sees the highest process temperatures and where the evolution of waters of hydration may promote mercury desorption.

Initially, a limited amount of testing was to be conducted in the downstream board line, where the calcined gypsum is slurried, mixed with proprietary additives and formed into wallboard. The project plan was for the board dryer kiln stack flue gas to only be measured for mercury content at the first test site (Task 1). Lesser mercury release was expected in the board dryer kiln because it is downstream of the mill, and the rehydrated gypsum solids typically see lower temperatures than in the mill. However, once results were available from Task 1 showing appreciable mercury loss from the board dryer kiln stack, stack testing for the board dryer kiln was added to the project scope for Tasks 4 through 7.

Process solid and flue gas mercury concentrations and plant process data were used to calculate mercury balances around each operating wallboard plant, to help confirm measured mercury loss rates.

Samples of synthetic gypsum tested were evaluated in laboratory calcining tests to provide comparison data and to evaluate a lab technique for screening synthetic gypsum samples for mercury loss in the wallboard process. Also, wallboard produced from synthetic gypsum was leached according to the Toxicity Characteristic Leaching Procedure (TCLP) to provide an indication whether wallboard disposed of in municipal landfills will have a tendency to release mercury into groundwater. The TCLP test was chosen based on current regulations; however future studies may include a more comprehensive set of leachate procedures. Samples of natural gypsum were also collected and analyzed for mercury content, for comparison with the mercury content of the synthetic gypsums tested in the wallboard plants.

The project has investigated wallboard produced from a variety of synthetic gypsum sources, all from FGD systems on coal-fired power plants but from different coal types, power plant emissions control configurations, and FGD conditions. The project was originally structured in five tasks. As shown in Table 1, each involved one commercial wallboard plant test.

Table 1. Planned Project Test Matrix

Task	**1**	**2**	**3**	**4**	**5**
Synthetic Gypsum Source:					
Power Plant	A	A	B	C	D
Coal Type	High sulfur bituminous	High sulfur bituminous	High sulfur bituminous	Texas lignite	High sulfur bituminous
FGD Reagent	Limestone	Limestone	Limestone	Limestone	Lime
Forced Oxidation Mode	In Situ	In Situ	In Situ	In Situ	External
Gypsum Fines Blow Down?	No (or Low Rate)	No (or Low Rate)	Yes	No	Yes
SCR Operating?	Yes	No	Yes	No	TBD*
USG Wallboard Plant Tested	1	1	2	3	1

*To be determined later based on the time of the year of the test

To investigate five different synthetic gypsum feedstocks, testing was to be conducted at three different USG wallboard plants, since no one plant uses all five as a feedstock. The relationship between synthetic gypsum types and USG plants originally planned for investigation is also shown in Table 1. Note that the power plants and USG wallboard plants are not identified by name, only by letter or number codes, in accordance with an agreement for anonymity at the beginning of the project.

The first four tasks included tests on synthetic gypsum feedstocks produced from:

- Task 1 – The base case, a power plant that fires medium- to high-sulfur bituminous coal and that has an SCR for NO_X control, a limestone forced oxidation (LSFO) FGD system that

produces wallboard grade gypsum byproduct, and has only limited blow down of chlorides and gypsum fines from the FGD system.

- Task 2 – The same power plant included in Task 1, but without the SCR operating (SCR catalyst bypassed). Since SCR catalysts have been observed to promote mercury oxidation, taking the SCR out of service might impact the amount of mercury captured in the FGD byproduct and could impact mercury losses during wallboard production,

- Task 3 – A high-sulfur, bituminous LSFO plant with SCR that operates with a relatively high chloride and gypsum fines blow down rate, and

- Task 4 – A plant that fires Texas lignite rather Eastern bituminous coal, and that does not have SCR.

Each of these variables was thought to impact the amount of mercury in the synthetic gypsum feedstock and/or possibly impact the stability of that mercury in the wallboard production process. The effects of these variables, as anticipated at the beginning of the project, are further discussed in the Experimental section.

As shown in the table, the project plan was for the fifth task to investigate a synthetic gypsum feedstock produced by a power plant that fires Eastern high-sulfur bituminous coal and that has an SCR for NO_X control, but it was not certain whether the SCR would be in operation when the gypsum to be tested would be produced. The major variable to be evaluated in Task 5 was the effect of FGD reagent. While the other four tasks tested gypsums produced from FGD systems that use limestone reagent with in situ (in the FGD absorber reaction tank) forced oxidation, Task 5 was to test gypsum produced from an FGD system that uses lime reagent and forced oxidizes the byproduct in a tank external to (downstream of) the absorber loop.

However, the logistics for conducting Task 5 using gypsum from Power Plant D proved to be difficult. USG Wallboard Plant 1 normally processes a blend of gypsum from Power Plants A and D, with Power Plant D material comprising less than half. And, since the gypsum from Power Plant A was expected to have a higher mercury content than that from Power Plant D, a blend of the two was deemed to be inappropriate for Task 5. Because of space limitations at the wallboard plant, it proved very difficult to stockpile enough material to allow the wallboard plant to gradually transition to processing 100% material from Power Plant D. After an extended period over which the wallboard plant unsuccessfully attempted to achieve that goal, it was decided to modify the project plan for Task 5.

The highest mercury percent losses measured in the first four tasks were in Task 3, where the gypsum was produced by a power plant that fires high-sulfur Eastern bituminous coal, has an SCR in service, uses limestone FGD reagent, and incorporates a high chloride and gypsum fines blow down rate as part of the gypsum dewatering scheme. It was decided to test synthetic gypsum from a second system (Power Plant E) with a similar configuration in Task 5, to see if similarly high mercury losses would be measured. One difference between Tasks 3 and 5 is that for Task 5, the power plant that produced the synthetic gypsum did not have its SCR in service

(i.e., catalyst bypassed). However, based on results from Tasks 1 and 2, this was not thought to be a significant factor.

After conducting Task 5, it was apparent that mercury losses were very similar to the Task 3 results, on both a percentage and mass basis, and thus higher than the losses measured as part of Tasks 1, 2 and 4. As part of another DOE Cooperative Agreement, DE-FC26-04NT42309, (subsequently referred to as DOE Project 42309) an FGD additive was tested for improving net capture of oxidized mercury by wet FGD systems. This additive, Evonik Degussa Corporation's TMT-15, is further described in the Experimental section of this report. As part of DOE Project 42309, full-scale TMT-15 tests were conducted at Power Plant E. This offered the opportunity to test synthetic gypsum from Power Plant E with TMT-15 addition at Wallboard Plant 4, for comparison to the previous Task 5 results without TMT addition. DOE-NETL agreed to co-fund this additional test, and Task 6 was added to the project.

After Task 6 was completed, USG began processing synthetic gypsum from a power plant that fires Powder River Basin (PRB) coal. Although Task 4 in the original test matrix had involved testing gypsum from an FGD system on a power plant that fires a low-rank coal – Texas lignite – this new wallboard plant feedstock offered the opportunity to test synthetic gypsum from a third coal type. Again, DOE-NETL agreed to co-fund this additional test and Task 7 was added to the project.

The revised project test matrix is shown in Table 2, including the change to testing gypsum from Power Plant E rather than Power Plant D in Task 5, and the addition of Tasks 6 and 7. One difference between Tasks 5 and 6 besides TMT-15 addition is that for Task 5, the SCR was not in service (bypassed) on Power Plant E when the synthetic gypsum was produced, while for the Task 6 gypsum it was in service. However, based on results from Tasks 1 and 2, and by comparison of Task 3 and Task 5 results, this was not thought to be a significant factor.

This report presents and discusses the results of the wallboard plant tests conducted in all seven tasks. Previous Topical Reports have presented in detail and discussed the results of individual tests conducted as part of Tasks 1 through 7[1-7], including Ontario Hydro measurements in the dryer mill, kettle calciner, and board kiln, process sample mercury content, process data, and mercury balance results. This final report discusses these results at a summary level; the reader can review each of the Topical Reports as needed to find more details about individual tests.

Laboratory evaluations were also planned as part of the project, including simulated gypsum kettle calciner tests, analyses of a range of synthetic and natural gypsums for mercury content, and mercury leaching from wallboard product samples by TCLP. These results have not been previously reported, and so are included in this final report.

Report Organization

The remainder of this report is organized into four sections: Experimental, Results and Discussion, Conclusion, and References. The section entitled Experimental describes the experimental methods used to conduct the mercury testing at a commercial wallboard plant as part of the seven tasks, including stack testing, process sampling, and off-site chemical analyses. Also included in the Experimental section are further descriptions of the four power plants and

Table 2. Revised Project Test Matrix

Task	1	2	3	4	5	6	7
Synthetic Gypsum Source:							
Power Plant	A	A	B	C	E	E	F
Coal Type	High-sulfur bituminous	High-sulfur bituminous	High-sulfur bituminous	Texas lignite	High-sulfur bituminous	High-sulfur bituminous	Powder River Basin
FGD Reagent	Limestone	Limestone	Limestone	Limestone	Limestone	Limestone	Limestone
Forced Oxidation Mode	In Situ	In Situ	In Situ	In Situ	In Situ	In Situ	In Situ
Gypsum Fines Blow Down?	Low	Low	High	None	High	High	Variable
SCR Operating?	Yes	No	Yes	No	No	Yes	Yes
TMT-15 Addition to FGD?	No	No	No	No	No	Yes	No
USG Wallboard Plant Tested	1	1	2	3	4	4	5

their FGD systems that produced the synthetic gypsums tested at the wallboard plants, and descriptions of laboratory procedures used during the project. The Results and Discussion section presents results from the full-scale wallboard plant tests, and from the laboratory evaluations described above. The Conclusion section provides conclusions that can be made from the results of these commercial wallboard plant mercury tests, and associated laboratory tests.

EXPERIMENTAL

A description of the project test matrix was provided in the Introduction section. This section begins with an explanation of the rationale used for choosing these six FGD synthetic gypsums as a wallboard plant feedstock for the seven tasks. The remainder of the section presents details of how the wallboard plant mercury tests were conducted, descriptions of the power plants and FGD systems that produced the synthetic gypsums tested, and how the various laboratory tests were conducted as part of this project.

Rationale for Selecting the Synthetic Gypsums Tested

The first wallboard plant test involved measuring the fate of mercury in synthetic gypsum from a high-sulfur, bituminous-coal-fired power plant equipped with an operating SCR and with an LSFO FGD system that employs only limited fines blow down from the FGD system (Power Plant A). This combination was selected for the first test because the synthetic gypsum produced at Power Plant A has a relatively high mercury content. Higher mercury content was expected to enhance the accuracy of the tests. Furthermore, previous laboratory testing funded by EPRI[8] and initial full-scale tests by USG[9] suggest that small measurable mercury losses could be expected from this feedstock during wallboard production. For these reasons, it was thought that testing this material as the base case could be a USG worst-case scenario for potential mercury losses during wallboard production.

The second wallboard plant test involved measuring the fate of mercury in synthetic gypsum from the same source as the first test (Power Plant A) except the SCR was bypassed. Previous testing has shown that, at least for some plants that fire high-sulfur bituminous coal, having an SCR in service tends to increase the percentage oxidation of mercury in the flue gas upstream of an FGD system, and to increase the percentage capture of mercury in the FGD system.[10,11] Many plants that are equipped with SCR only operate them during the "ozone season," from May 1 through September 30 each year, and bypass the SCR catalyst the remainder of the year. For such plants, one might expect that synthetic gypsum produced from their FGD systems would contain more mercury with the SCR operating during the ozone season than that produced during the remainder of the year.

The third wallboard plant test involved measuring the fate of mercury in synthetic gypsum from a high-sulfur bituminous-coal-fired power plant equipped an operating SCR and with an LSFO FGD system that employs aggressive chloride and fines blow down from the FGD system (Power Plant B). Gypsum fines blow down is believed to be an important variable and will be discussed over the next few paragraphs. Most synthetic gypsum used as a wallboard plant feedstock is subject to a number of quality control specifications by the wallboard manufacturer including maximum moisture content, minimum gypsum content, maximum chloride content, and particle size distribution. These parameters are specified because they impact energy consumption at the wallboard plant, solids handling properties, and wallboard product properties such as weight, strength and paper adhesion.

A number of FGD variables affect the ability to meet the solids particle size distribution specification. These variables include the gypsum crystal residence time in the FGD absorber

loop, FGD reagent chemical composition, and the amount of physical abrasion to which the crystals are exposed as they are recirculated and dewatered. Some FGD systems cannot meet the wallboard manufacturer's particle size specification unless they separate a portion of the byproduct containing the smallest particle sizes. This separation is typically accomplished with hydrocyclones. The separated fines are either discarded or sold for other uses. Many FGD systems need to purge a portion of the hydrocyclone overflow as a means of limiting chloride buildup in the FGD liquor. These plants blow down gypsum fines as part of the chloride purge. In a few FGD systems, there is no need to separate the fines and/or purge chlorides, and all of the fines are included in the byproduct sent to the wallboard plant.

Laboratory testing conducted by URS for EPRI indicated that the mercury concentration in gypsum fines can be as much as an order of magnitude higher than in the larger particles.[8] This might suggest that mercury precipitates or adsorbs at gypsum surfaces, since the fines have a much higher surface area to mass ratio than larger particles. However, recent results from DOE laboratory evaluations suggest that mercury primarily adsorbs on fine particles of impurities, which enter the FGD system with fly ash or with the FGD reagent.[12] Upwards of half of the mercury removed by the FGD system can be in the fines. Thus, by purging FGD liquor to reduce chloride concentrations, the concentration of fines is simultaneously reduced, significantly lowering the mercury concentration in the synthetic gypsum byproduct going to the wallboard plant.

Since Power Plant A providing the feedstock for Task 1 employs only a limited fines blow down rate, and operates with relatively high FGD liquor chloride concentrations, it was expected to have a higher mercury content in the synthetic gypsum byproduct than would a similar plant with higher blow down rates. This byproduct might thermally evolve more mercury in the wallboard mill than would a byproduct with the fines removed and a lower total mercury concentration. Also, Power Plant A was known to fire a coal blend with a relatively high mercury content. This first case was chosen to represent conditions that, for the reasons described above, were believed most likely to show measurable mercury losses during the wallboard production process. It was anticipated that the other synthetic gypsum feedstocks might show reduced mercury evolution, but full-scale testing was required to confirm or deny such assumptions.

Task 2 involved testing at Wallboard Plant 1 and with gypsum from Power Plant A, as during Task 1, but with material produced while the SCR was not in service (catalyst bypassed). As for the material tested as part of Task 1, the Power Plant A FGD system was operated with low chloride and fines blow down rates. It was expected that with the SCR out of service, the synthetic gypsum produced from the Power Plant A FGD system would contain less mercury than during the ozone season, with the SCR in service. It was thought that if less mercury were contained in the gypsum produced with the SCR out of service, it might correspondingly reduce the amount of mercury thermally evolved in the wallboard plant.

The plant providing the feedstock for Task 3 test employs a high chloride and fines blow down rate; it was therefore expected to have lower mercury content in the synthetic gypsum byproduct than would a similar plant with a low fines blow down rate (e.g., Power Plant A). Because of this, the Power Plant B byproduct might thermally evolve less mercury in the wallboard plant than a byproduct with more of the fines included and a higher total mercury concentration.

The fourth wallboard plant test involved measuring the fate of mercury in synthetic gypsum from a power plant that fires Texas lignite fuel (Power Plant C). The testing in Tasks 1 through 3 was conducted at wallboard plants processing synthetic gypsum from high-sulfur, bituminous-coal-fired plants. Most synthetic gypsum processed in wallboard plants comes from bituminous coal sources. However, a growing amount of wallboard is produced from synthetic gypsum produced in scrubbed power plants that fire low rank coals such as lignite or Powder River Basin (PRB) fuels.

Low rank coals differ from high-sulfur bituminous coals in a number of manners that impact mercury in the synthetic gypsum. For example, low-rank coals typically have lower chloride content than bituminous coals, which results in lower mercury oxidation percentages in the FGD inlet flue gas. This could result in lesser amounts of mercury being removed in the FGD systems. However, from the standpoint of mercury concentrations in the synthetic gypsum, this effect is offset to some degree by the fact that the lower rank coals typically have lower sulfur content, and hence produce less gypsum per mass of coal fired.

There is evidence, at least from one laboratory evaluation, that synthetic gypsum from low-rank coals behaves differently when dried and calcined in a wallboard plant than gypsum from bituminous coal. In a laboratory study conducted for EPRI, calcining simulations were conducted on five different synthetic gypsum samples. In these studies, synthetic gypsum samples from a Texas lignite fired power plant and from a PRB-fired plant showed measurably lower percentage mercury losses than three samples from high-sulfur, bituminous coal plants.[8] This observed difference may have been coincidental, since the number of samples from each coal type was small. However, these results suggested that coal rank would be an important variable to investigate as part of this project. Therefore, Tasks 4 and 7 measured mercury losses while producing wallboard from synthetic gypsum produced at power plants that fire Texas lignite and PRB, respectively.

The fifth wallboard plant test involved measuring the fate of mercury in synthetic gypsum from a FGD system similar to that which provided the material tested in Task 3 (Power Plant E). Originally, Task 5 was to be conducted with lime rather than limestone as the FGD reagent used to produce the synthetic gypsum tested. However, as described in the Introduction, the logistics were not favorable for conducting a wallboard test on 100% material from Power Plant D, so Task 5 was conducted with synthetic gypsum from an FGD system similar to that which provided the material tested in Task 3. This was condition was tested again with another synthetic gypsum source because of the relatively high mercury percentage loss across the wallboard plant measured in Task 3.

The sixth wallboard plant test involved measuring the fate of mercury in synthetic gypsum from the same power plant (Power Plant E) that produced the material tested in Task 5, except an additive, TMT-15, had been used in the FGD system while the Task 6 material was produced. In wet FGD absorbers, the oxidized form of mercury (Hg^{+2}) is absorbed from the flue gas into the FGD liquor, while water insoluble elemental mercury (Hg^{0}) is typically not removed. Once absorbed, the Hg^{+2} can follow as many as three pathways for leaving the FGD system. These include: 1) Undergoing reduction reactions while in the FGD liquor to form Hg^{0}, which, being

insoluble is released and re-emitted into the FGD outlet flue gas; 2) Being retained in the FGD liquor, and potentially becoming a regulatory compliance issue in FGD blow down liquor; or 3) Being retained in the FGD byproduct solids. DOE Project 42309 investigated the use of FGD additives to rapidly precipitate mercury in FGD liquor as a solid salt, to minimize pathways 1 and 2. One additive tested, trimercapto-s-triazine, tri-sodium salt (TMT), is commercially available from Evonik Degussa Corporation as a 15-wt% aqueous solution (TMT-15). TMT-15 has reportedly been used in Europe in wet FGD systems on a number of waste incineration plants and several coal-fired power plants to precipitate dissolved mercury as a stable salt, lower liquid-phase mercury concentrations, and minimize re-emissions.[13] While TMT-15 has been used in Europe in FGD applications, it has not seen widespread use in U.S. plants. DOE Project 42309 provided an opportunity to evaluate the use of TMT-15 for these purposes on pilot- and full-scale wet FGD systems on U.S. coal-fired units.

The reaction of TMT with heavy metals is based on the soluble tri-sodium salt chemically binding to heavy metals via sulfur groups. In the process, high-molecular-weight organo-metallic compounds are produced which have a very low aqueous solubility. They precipitate as solid substances and can be separated from the liquor by filtration. In the FGD slurry sent to dewatering, fine particles of mercury-TMT compound can be transferred to the chloride/fines blow down stream, returned to the absorber and/or partly included with the byproduct gypsum. TMT-metal compounds are reportedly quite stable with respect to temperature. According to Evonik Degussa, temperatures in excess of 410°F (210°C), which is well above the gypsum calcining temperature, are needed to begin to decompose the mercury-TMT salt, and TMT-metal compounds easily meet the leachability limits of the TCLP.

It was anticipated that any mercury bound as a TMT salt that remains in FGD byproduct gypsum would remain stable and not be volatilized into the flue gas in significant percentages when the gypsum is processed in a wallboard plant. Task 6 of this project was intended to determine the effectiveness of TMT-15 for this purpose when added to an FGD system.

The seventh wallboard plant test involved measuring the fate of mercury in synthetic gypsum from a power plant that fires Powder River Basin (PRB) fuel (Power Plant F). The source is similar to the material tested in Task 4 but is another type of low rank coal. The rationale for selecting low rank coals is described in more detail above in the description for the fourth wallboard test.

Commercial Wallboard Plant Test Procedures

Commercial wallboard plants often operate with a blend of feedstock from a number of FGD systems. Rarely does one power plant generate enough synthetic gypsum to feed the entire production of a modern wallboard plant, so most wallboard plants process synthetic gypsum from two or more power plants. Each synthetic gypsum has unique processing conditions within the wallboard plant process. Therefore, to minimize excessive swings in wallboard plant operating conditions, most plants blend the available feedstock to produce an “average” material for processing.

For these seven tests, the intent was for the wallboard plant to be operated on 100% feedstock from Power Plants A, B, C, E or F. It would be more difficult to elucidate the effects of power

plant and FGD variables on mercury losses during wallboard production if synthetic gypsum blends were being processed during measurements. Also, the feedstock to the mill typically contains recycled material, which can include recycled wallboard, wallboard samples, material recycled from the calciner during shut downs, etc. Because recycle consists of material from a variety of sources, it was felt that recycle would add variability to the incoming feed mercury concentration and possibly its stability. Therefore, the wallboard plant tests were conducted with no recycle feed to the plant during any of the sampling runs.

Two days of wallboard plant testing were typically conducted, with the first day testing in the mill and the second day in the board line as described below. Figure 2 illustrates the wallboard production process.

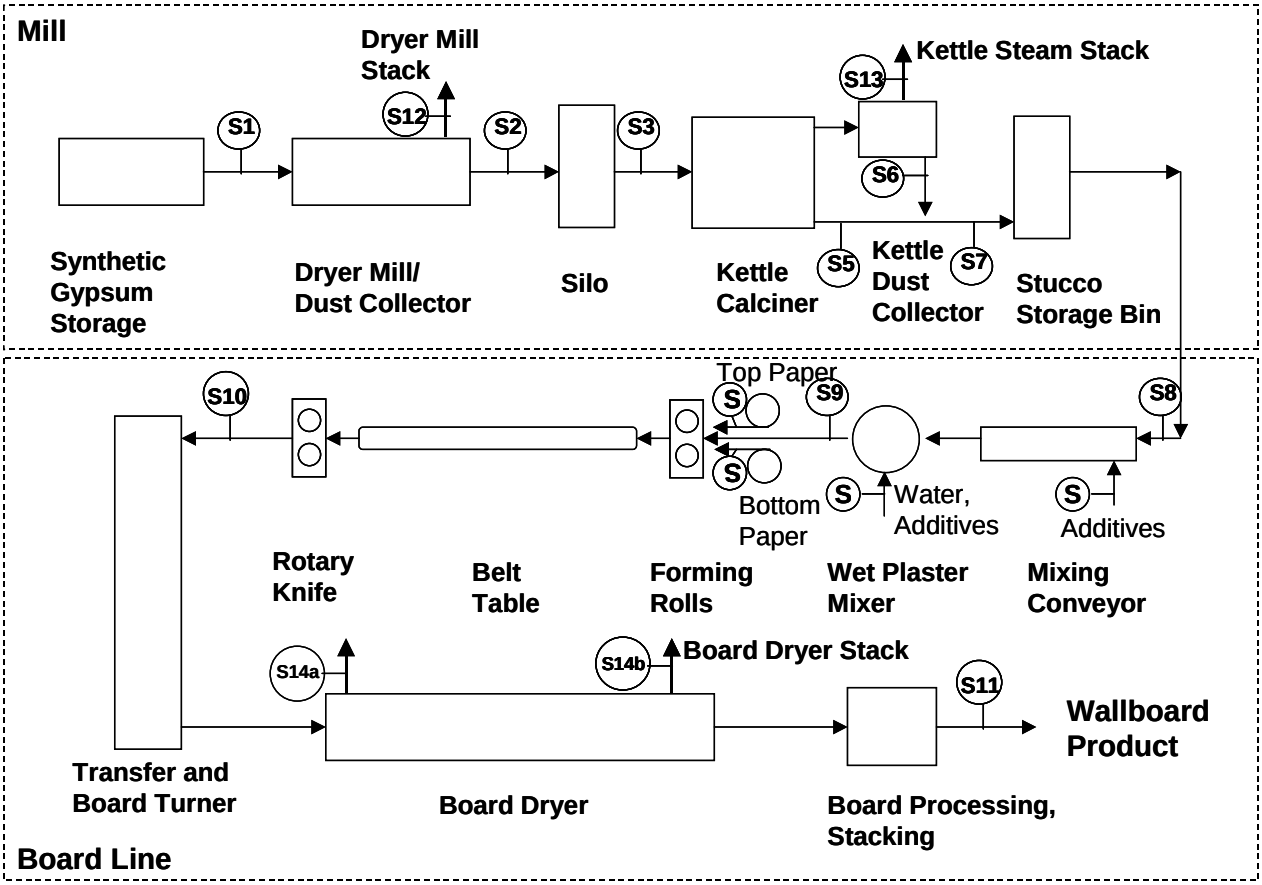


Figure 2. Schematic of Wallboard Plant Showing Sampling Locations

Process streams that were typically sampled as part of the test, as described below, are marked with "S" followed by a number that represents a sample location. The sample locations varied some from test to test, though. Not all of the wallboard plants have sampling ports at every location shown in Figure 2, and some had sample points not shown in the figure. Figure 2 shows two stacks on the board dryer kiln, but Wallboard Plants 1, 2 and 5 have only a single stack. Also, as was discussed in the Introduction, the board dryer kiln stack was not sampled during Tasks 2 and 3.

Day 1 – Mill Testing

Stack Sampling

On the first test day, simultaneous gas measurements were conducted using the Ontario Hydro method[14] on a raw gypsum dryer stack and a downstream kettle calciner dust collector (steam) stack. Wallboard Plants 1 and 2 have two separate process trains consisting of a dryer and kettle calciner while Wallboard Plants 3 and 4 have only one dryer feeding two kettle calciners. Wallboard Plant 5 was operating only one dryer and one kettle calciner during most of the testing period. In each test, one dryer stack and one kettle calciner stack was sampled (in the same process train at Wallboard Plants 1 and 2). As noted in the previous Topical Reports for this project, the Ontario Hydro method was modified slightly for sampling at the kettle calciner steam stack, as described below. Triplicate Ontario Hydro method sampling runs were made at each of these two locations.

The kettle calciners are indirect-fired vessels. The gaseous stream from the calciner that could contain mercury from the synthetic gypsum is the "steam stack," which is a mixture of the water calcined from the gypsum when forming stucco ($CaSO_4 \bullet ½H_2O$) and aeration air introduced at the bottom of the kettle. The other stack from the kettle calciner contains the flue gas from the burners, which are natural gas fired. This stream is not expected to have measurable mercury content, nor would it be attributable to mercury in the land plaster feed.

The steam stack gas is significantly wetter than coal flue gases, for which the Ontario Hydro method was developed and validated. Consequently, the method was modified slightly to ensure proper sampling and speciation under these conditions by adding impinger volume to the Ontario Hydro sampling train to collect the large amount of condensed moisture expected, and/or by reducing the run time to limit the total amount of water collected. The dryer mill is direct fired, so its stack gas is a true flue gas and the standard Ontario Hydro Method was appropriate for sampling this stream.

Process Sampling

During each of the three Ontario Hydro method sampling runs, process samples were collected from the dryer feed solids, dryer product solids (land plaster to intermediate silo), calciner feed (land plaster from intermediate silo), and the stucco as it is fed to the product stucco storage bin. These four streams represent the feeds and products for the dryer mill and kettle calciner. However, during Task 7 conducted at Wallboard Plant 5, it was not possible to collect samples of the kettle calciner feed material and product stucco to the storage bin. At some plants, two or three additional solid stream samples were collected: the solids collected from the kettle calciner dust collector, which are either blended with the calciner product or recycled back to the kettle calciner; calciner product stucco prior to having the dust collector solids added; and solids collected in a "miscellaneous" dust collector, which can be added to the kettle calciner feed or product streams. These additional sample types were analyzed and reported for mercury concentration, but these data were generally not used for mercury balance or mercury loss calculations because the relative proportions of each fed to the product stucco bin could not be measured. The exception was for Task 7, since a sample of the mixed product going to the stucco storage bin could not be sampled.

All of these process solids samples were collected as "grab" samples during the middle part of each Ontario Hydro run. No attempt was made to collect time-integrated samples, e.g., by collecting small sample aliquots at periodic intervals throughout the Ontario Hydro sampling periods and compositing the aliquots into a single sample. It was generally expected that the incoming raw gypsum would be homogenous enough that one grab sample per run would adequately represent the feedstock and other process solids. The entire set of grab samples was subsequently analyzed for mercury content, moisture content, and other parameters by URS and USG.

Process data were collected for each of the three runs, including dryer and calciner feeder speeds and operating temperatures. These data were recorded by URS personnel and/or mill operators periodically during the sampling periods, or downloaded from plant data acquisition systems.

Day 2 – Board-Line Testing

Stack Sampling

On the second test day, during Tasks 1 and 4 through 7, triplicate Ontario Hydro Method measurements were conducted on the board dryer kiln stack gas. The timing of the second day measurements was to approximately correspond with the processing of stucco material calcined the previous day, taking into account the residence time in the stucco storage bins between the mill and board line.

As mentioned above, the board dryer kilns at Wallboard Plants 3 and 4 (Tasks 4 through 6) are somewhat different than at Wallboard Plants 1, 2 and 5 (Tasks 1 through 3, and 7), in that they have two flue gas stacks, one on the wet wallboard feed end (the "wet end") and one on the wallboard product end (the "dry end"). Consequently, for Tasks 4 through 6, during each board dryer kiln sampling run two Ontario Hydro measurement runs were conducted simultaneously, one on each stack. For Tasks 1 and 7, only one stack measurement location was sampled, in triplicate.

Process Sampling

In Tasks 1 and 4 through 7, during each of the triplicate Ontario Hydro runs, samples were collected of the feed stucco, the slurry fed to the board forming machine, and the wet and dry product wallboard. Only one sample of each was collected for each Ontario Hydro run, but the timing of when these samples were collected was staggered to account for the residence time of the board line. In Tasks 2 and 3, no Ontario Hydro measurements were made on the board dryer kiln, so process samples were collected in three sets about two hours apart. The timing of the first sample set was adjusted to roughly correspond with when material from the previous day's mill test was being processed on the board line.

Water and a number of proprietary additives are added to the stucco when mixing the slurry prior to the board forming step. The water, each of these additives, and the paper used during board forming were also sampled once during Tasks 1 and 3 through 7, to evaluate their impact on the

mercury content of the slurry and the wallboard. Triplicate samples of the additives and paper were not deemed to be necessary, as each is fed from a large silo, storage tank, or rolls that should have been relatively homogenous over the course of the three Ontario Hydro runs. Note that, because the composition and dosages of the additives are considered proprietary, the results from sampling additives and the paper were reported only as their percent contribution to the total mercury content in the wet board. No individual additive feed rate or mercury concentration data were reported, nor were the chemical compositions or names of these additives.

As for the mill testing effort, key process data were collected throughout each sampling run. These data were typically recorded manually from process control software screens, intermittently during each of the three Ontario Hydro runs. At some of the wallboard plants it was possible to make screen prints of these process data over time from the process control software. For the board line, these data typically included the stucco feed rate, water and additive feed rates (not included in this report), board production rate, and the dryer flue gas temperatures.

As the second day of the sampling effort was completed, the process and Ontario Hydro method samples were recovered, stabilized, and labeled. The following day they were shipped to URS and USG laboratories for analyses. Field blanks and reagent blanks for the Ontario Hydro method samples were included with the sample sets as a quality assurance/quality control measure.

All of the mill and board-line process samples collected were analyzed by URS for mercury content, by cold vapor atomic absorption after digestion in a hydrofluoric/aqua regia acid mixture. USG analyzed separate aliquots of the same samples for mercury content with a direct mercury analyzer (thermal desorption followed by cold vapor atomic absorption). These analytical procedures are described in greater detail later in this section. A number of samples were analyzed by USG for other parameters including gypsum moisture content (free moisture and combined moisture, or waters of hydration), particle size distribution, specific surface area, and chloride content.

The mercury concentration analytical results, along with plant process data, were used to construct mercury balances across the mill and the board line for each task. The mercury balances show the amount of mercury entering and leaving the plant in each process stream, including mercury losses in process vent stacks, and overall mercury mass balance closures.

Synthetic Gypsum Source Descriptions

The sources of synthetic gypsum used to make wallboard during these seven tasks were described in general in the Introduction and the rationale for selecting each was provided in the Experimental section of the report. However, coal, power plant and FGD process data have also been collected from the power plants producing the synthetic gypsums tested. These data are reported in the following paragraphs.

Coal Properties

It was generally not possible to coordinate with the power plants to collect coal samples and FGD data from the time periods when the commercial wallboard test feedstocks were produced. The wallboard tests were typically scheduled for times when the wallboard plant could accommodate the requirements of these tests (no recycle feed, 100% feed from one power plant, etc.) and were run with inventory on hand from the power plant of interest. Thus, it was not possible to pinpoint exactly when the synthetic gypsum tested was produced, and it is unlikely that the power plants would have had coal and FGD samples from those time periods available.

Therefore, example coal data for these power plants are shown below in Table 3. With one exception, these example coal data are from samples taken at the power plant sites after the wallboard tests were conducted, but the data are expected to be representative of the coal fired during production of the synthetic gypsum tested. The exception is for Task 6, where there was close coordination between the power plant and USG to separate and test synthetic gypsum produced during the TMT-15 additive test. For Task 6, the coal sample was collected during the time the synthetic gypsum treated with TMT-15 was produced. Also note that for the Task 3, Power Plant B coal data are reported from the two largest of several gypsum-producing units at that station.

The data in Table 3 show that the coals fired at Power Plants A, B and E are medium- to high-sulfur bituminous coals. As expected, the coal fired at Power Plant A (Tasks 1 and 2) has a higher mercury content than the coal fired at the other power plants, and correspondingly produced synthetic gypsum with the highest mercury content tested. Another notable outlier among the bituminous coal properties is the chlorine content of the coal fired at Power Plant E (Tasks 5 and 6), which is considerably lower than the chlorine content of the other bituminous coals represented. The lower chlorine content in the coal contributes to lower levels of chlorides in the FGD slurry at Power Plant E. This effect is compounded by a relatively high chloride blow down rate. The effect of chloride content in the FGD slurry will be discussed in more detail in the FGD Chemistry Data section below.

Power Plant C (Task 4) fires Texas lignite, which has considerably lower heat content and higher moisture content than the bituminous coals. It also has a lower sulfur content and lower chlorine content than the bituminous coals represented in the table. The lower sulfur content results in less gypsum produced per mass of coal fired.

Power Plant F (Task 7) fires PRB, which has a heat and moisture content between those of bituminous coal and Texas lignite. It has the lowest sulfur content of the coals represented in the table, and a very low chloride content.

Table 3. Typical Power Plant Coal Data

Task Number, Power Plant	Heating Value (Btu/lb as received)	Total Moisture (wt %)	Ash (Wt % as received)	Sulfur (Wt % as received)	Sulfur (lb SO_2/ MMBtu)	Hg (Dry ppm)	Chlorine (Dry ppm)
Tasks 1& 2, Power Plant A	12,211	5.23	17.8	2.41	3.9	0.337	1,197
Task 3, Power Plant B, Unit X	13,137	8.82	9.83	2.88	4.4	0.101	1,095
Task 3, Power Plant B, Unit Y	12,932	11.4	9.92	2.71	4.2	0.101	910
Task 4, Power Plant C	6,859	34.9	11.6	1.11	3.2	0.135	<5
Task 5, Power Plant E	12,488	13.0	8.84	3.12	5.0	0.078	70.9
Task 6, Power Plant E	12,575	12.3	9.26	3.13	5.0	0.087	66.3
Task 7, Power Plant F	8,366	29.2	6.46	0.33	0.77	0.082	15-20

Power Plant and FGD Descriptions

Key features of the power plants and FGD systems that produced the synthetic gypsums tested as part of this project were previously described in the Introduction. This subsection provides further descriptions of the power plants and FGD systems, and presents example FGD chemistry data. As for the coal data discussed above, the FGD chemistry data were collected after the wallboard plant tests were conducted for all except Task 6, but are expected to be representative of FGD operation during the periods when the synthetic gypsums tested were produced. Each power plant and its FGD system are briefly discussed below.

Power Plant A

Power Plant A has a large, pulverized coal unit (>500 MW) equipped with a wet FGD system. It has an SCR that currently operates only during the ozone season (May 1 through September 30), and a cold-side electrostatic precipitator (ESP) for particulate collection. The FGD system has a single open spray tower module with an integral reaction tank (the reaction tank forms the base of the absorber vessel). Forced oxidation air is sparged into the reaction tank. The blow down slurry from the absorber goes through one set of hydrocyclones for primary dewatering, and the underflow goes to a washed, horizontal belt filter for secondary dewatering to produce wallboard-grade gypsum. Most of the hydrocyclone overflow is returned to the absorber, but a portion is treated and discharged from the system as a means of controlling chloride levels.

Power Plant B

Power Plant B is a multi-unit station, and all of the units have SCR (ozone season operation only), cold-side ESPs, are scrubbed, and produce wallboard-grade gypsum. The FGD absorber reaction tanks are separate from the absorber vessels. Some FGD systems use dibasic acid (DBA) as a performance additive but others do not.

Each of the FGD systems has a single-stage hydrocyclone primary dewatering system, where most of the overflow is returned to the absorbers for that system. The underflow from each is sent to a common secondary dewatering system for the station. A significant portion of the overflow is sent to a settling pond and then discharged, as a means of controlling both chloride and fines concentrations in the FGD systems. The common secondary dewatering system employs washed, rotary drum filters to produce wallboard-grade gypsum.

Power Plant C

Power Plant C is a multi-unit station, and all of the units have cold-side ESPs followed by dual-loop wet FGD systems. None of the units have SCR. Each of the FGD systems has multiple absorber modules. The lower-loop reaction tank is integral to the absorber vessel, while the upper loop reaction tank is external, with two adjacent absorbers sharing one upper-loop reaction tank. Forced oxidation air is added to both absorber loop reaction tanks. The blow down from the FGD absorber is from the lower loop; the blow down from the upper loop is fed to the lower loop. Limestone reagent is added to both loops, but the lower loop is controlled to a lower pH than the upper loop. DBA is used as a performance additive in all three FGD systems.

Each unit has a dedicated thickener for primary dewatering. The thickener overflow is returned to the absorbers, with little or no fines blow down. The thickener underflow is sent to a common secondary dewatering system, which uses washed horizontal belt filters.

Power Plant E

Power Plant E is also a multi-unit station. There are two units with gypsum producing wet FGD systems; one unit has an SCR (ozone season operation only), while the other does not. Both units have cold-side ESPs for particulate control. The gypsum-producing wet FGD systems have single open spray tower absorbers per unit with integral reaction tanks. No FGD performance additives are used.

Blow down from the gypsum producing FGD systems goes through two stages of hydrocyclones for primary dewatering. A significant portion of the overflow from the primary hydrocyclone stage is blown down to a pond to control fines and chloride levels in the FGD system, while the remainder is returned to the absorber. The underflow from the primary hydrocyclones goes to secondary hydrocyclones; the underflow from the secondary hydrocyclones feeds washed, horizontal belt filters (one per unit) that produce the gypsum byproduct.

A unique feature about Power Plant E is that in one of the two gypsum producing FGD systems, calcium sulfite hemihydrate blow down from another FGD system at the site is added to the reaction tank and converted to gypsum. This reduces the amount of calcium sulfite byproduct that must be landfilled from this station, and increases the amount of gypsum produced. The calcium sulfite conversion was in operation while the gypsum was produced for Task 5 of this project, but was not in service while the Task 6 material was produced. Also, for Task 5 gypsum from both LSFO units was included, while for Task 6 the gypsum from only one unit was tested at the wallboard plant.

Power Plant F

As mentioned above, Power Plant F fires PRB. The power plant has two units, each of which has a cold-side ESP for particulate control and a single-loop, spray/tray absorber limestone forced oxidation FGD system, with the forced oxidation conducted in the reaction tank integral with the FGD absorber for each unit. The FGD system has the potential to blow down gypsum fines as part of the slurry dewatering and wastewater blow down treatment processes. The power plant is equipped with a selective catalytic reduction (SCR) system for NO_X emissions control, and the SCR was in service during the time period the gypsum tested was produced.

FGD Chemistry Data

Typical FGD chemistry data from the five power plants that produced the synthetic gypsum tested as part of this project as shown in Table 4. As with the coal data, FGD chemistry data are shown for the two largest of multiple FGD systems at Power Plant B (Task 3). Task 6 (Power Plant E) is the only with FGD chemistry data collected during the actual time period the gypsum tested was produced, when the TMT-15 additive was in use.

The table shows general absorber recycle slurry conditions (pH, slurry temperature, wt% solids in the slurry), slurry solid conditions (wt% inert [acid insoluble] material, observed sulfite oxidation percentage, and limestone utilization), and FGD liquor composition. The FGD liquor analyses include major cations (calcium, magnesium and sodium), major anions (chloride, carbonate, sulfate and sulfite), and mercury.

For each site the absorber recycle slurry pH and temperature were measured as the sample was collected. All FGD liquor samples and FGD solid mercury samples were filtered and preserved as the samples were collected, for off-site analyses. The remaining FGD solid sample analyses were conducted on whole slurry samples that were filtered and analyzed off site.

The data in the table show that the systems operate over a range of pH values (approximately pH 4.8 to 6.2) as needed to maintain both high SO_2 removal performance and high limestone utilization. As would be expected for systems that produce high-purity, wallboard-grade gypsum, the sulfite oxidation percentages and limestone utilization percentages are quite high.

The FGD liquor analyses mostly show low sulfite ion concentrations, as would be expected for forced oxidation FGD liquors. The liquor chloride concentrations are quite interesting. At Power Plant A, where the FGD chloride and fines blow down rate is relatively low, the liquor chloride concentration is cycled up to a relatively high concentration of nearly 20,000 mg/L (ppm), while the FGD systems with higher chloride and fines blow down rates (Power Plants B and E) have correspondingly lower liquor chloride concentrations. The chloride concentration at Power Plant E (about 500 mg/L) is lower than that at Power Plant B (about 2,000 mg/L) predominantly because of the lower chloride content of the coal at Power Plant E (see Table 3). Power Plant C also has relatively low chloride concentrations in the FGD liquor (about 2,000 mg/L), but this is a result of the very low chlorine content in the Texas lignite fuel and not a function of fines blow down rates.

Table 4. Example FGD Absorber Slurry Analysis Results

Task	**1 & 2**	**3**	**3**	**4**	**4**	**5**	**6**	**7**
Power Plant	**A**	**B, Unit X**	**B, Unit Y**	**C, Lower Loop**	**C, Upper Loop**	**E**	**E**	**F**
Date	10/4/2006	11/8/2006	11/8/2006	11/8/2005	11/8/2005	7/13/2006	7/20/2006	8/16/2007
Time	15:27	8:36	11:20	10:05	10:35	8:56	8:03	11:45
SCR status	Bypassed	Bypassed	Bypassed	None	None	On	On	On
pH	5.65	4.76	4.88	5.60		6.15	6.01	5.65*
Temperature, ^{o}C	51.8	53.4	52.6	59.4		55	53.3	57*
Slurry solids, wt%	16.7	13.2	11.5	22.5	17.1	16.1	16.3	17.0
Slurry Solid Results:								
Inerts, wt%	6.8	2.5	3.1	1.9	2.2	4.1	4.5	3.0
Sulfite oxidation, %	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Limestone utilization, %	98.1	100.6	99.5	96.3	99.2	95.6	97.1	98.2
Slurry Liquor Results:								
Ca^{++}, mg/L	4,212	843	734	683	936	1,133	1,069	586
Mg^{++}, mg/L	4,529	1,170	1,123	3,948	6,491	1,322	1,550	9,905
Na^{+}, mg/L	1,685	0	0	637	1,047	122	365	1,649
Cl^{-}, mg/L	19,700	1,801	1,767	1,932	2,362	431	463	7,392
$CO_3^{=}$, mg/L	0	0	0	30	28	464	698	119
$SO_3^{=}$, mg/L	15	1	1	36	452	<10	<8	10
$SO_4^{=}$, mg/L	2,308	3,557	3,731	12,620	15,340	3,297	3,921	29,969
Mercury, μg/L	2.47	51.0	82.4	14.4	69.4	61.7	60.4	6.4
Gypsum Byproduct Results:								
Mercury in Bulk Product, μg/g	1.07	0.11	0.11	0.49	-	0.13	0.12	1.03

*Typical value

Power Plant F has the second highest chloride content of the FGD systems sampled, in spite of firing a very low chloride coal. Because of the low sulfur content in the PRB fuel, very little chloride leaves the FGD system in the relatively small quantity of gypsum produced, so chloride concentrations tend to cycle up over time.

It is interesting to note that the absorber liquor mercury concentrations show apparent correlation with the amount of fines/chloride blow down from the FGD systems. At Power Plant A with a low fines/chloride blow down rate, the liquor mercury concentration was relatively low at 2.5 µg/L, while at Power Plants B and E with higher blow down rates, the liquor mercury concentrations were much higher, in the range of 50 to 80 µg/L. Figure 3 is a plot of data from Table 4 that shows the apparent correlation of liquid-phase mercury concentrations in the FGD liquors with liquor chloride concentrations (an indicator of chloride purge rates) and with acid insoluble inerts in FGD slurry solids (an indicator of fines purge rates).

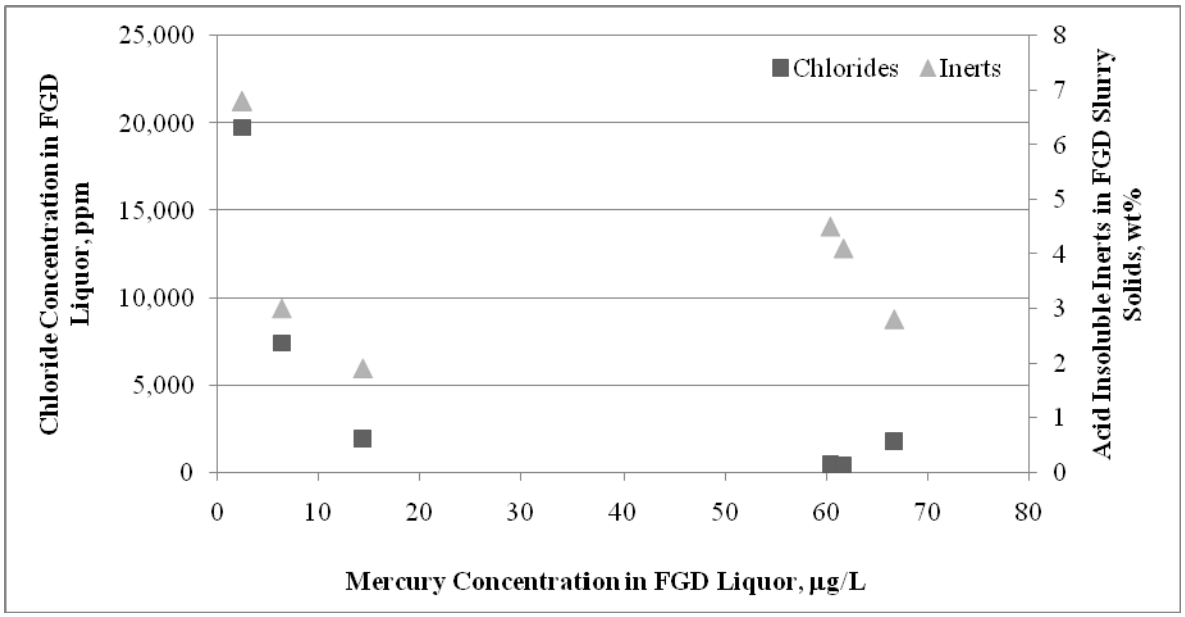


Figure 3. Observed Relationship Between Mercury Concentration in FGD Liquor and Chloride Concentration in FGD Liquor and Inert Weight Percent in FGD Slurry (average of two values used for Power Plant B, and lower-loop value used for Power Plant C)

An increase in the blow down rate from an FGD system results in a noticeable reduction in the concentration of both chlorides and inerts. However, the relative proportions of sulfur and chloride in the coal also have an impact and thus the apparent correlation between blow down rate and other parameters evaluated becomes more pronounced when limited to a single coal type. Figures 4 through 6 are plots of the data only for power plants firing high-sulfur bituminous coal (Tasks 1, 2, 3, 5 and 6) and illustrate the apparent correlations between mercury concentrations in the FGD liquor and chloride concentration in FGD liquor, acid insoluble inerts in FGD slurry solids, and mercury content in raw gypsum, respectively.

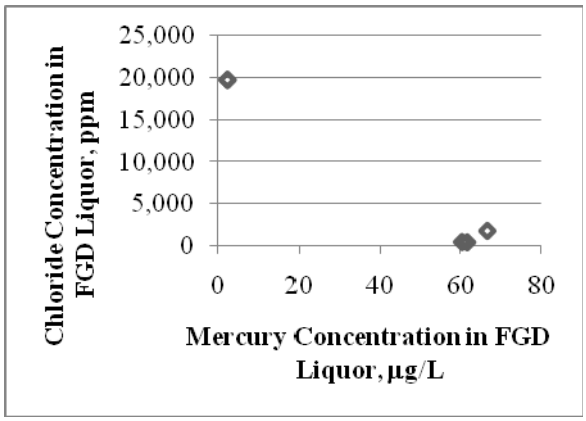


Figure 4. Observed Relationship Between Mercury Concentration in FGD Liquor and Chloride Concentration in FGD Liquor for Samples from Power Plants firing High-sulfur Bituminous Coal (Tasks 1, 2, 3, 5 and 6)

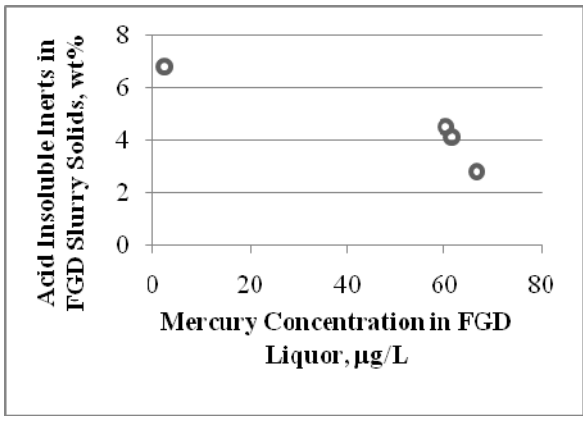


Figure 5. Observed Relationship Between Mercury Concentration in FGD Liquor and Acid Insoluble Inerts in FGD Slurry Solids for Samples from Power Plants firing High-sulfur Bituminous Coal (Tasks 1, 2, 3, 5 and 6)

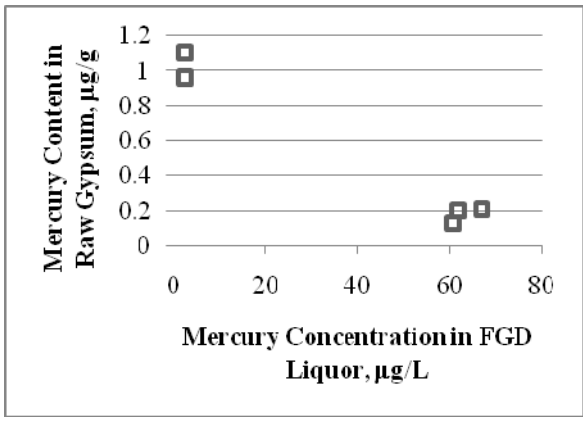


Figure 6. Observed Relationship Between Mercury Concentration in FGD Liquor and Mercury Content in Raw Gypsum for Samples from Power Plants firing High-sulfur Bituminous Coal (Tasks 1, 2, 3, 5 and 6)

One theory is that mercury adsorbs from the liquor onto fine particles in the slurry. At high blow down rates there are fewer fines in the FGD slurry to adsorb mercury from the liquor, and correspondingly the FGD liquor mercury concentrations may remain higher. It is not known whether this mercury chemistry in the FGD liquors influences mercury release rates in the wallboard process. This concept will be discussed later in this report, though.

Laboratory Procedures

Mercury Analyses

Analysis of Process Samples (URS Analyses)

All of the wallboard plant test process solid samples (e.g., synthetic gypsum, land plaster, stucco) and all additives were digested in a concentrated acid matrix. Each sample was digested in duplicate along with one digestion spike (a spike of mercury added to a sample aliquot prior to its digestion). Each sample aliquot was weighed out into a Teflon microwave digestion vessel along with 3 mL of nitric acid, 3 mL of hydrochloric acid, and 3 mL of hydrofluoric acid. This was baked in a hot water bath for eight hours or longer at 95ºC (203ºF). Then 15 mL of boric acid was added and the mixture was cooked again for 60 minutes. The digestate was recovered using deionized (DI) water into a 100 mL volumetric flask, diluted to volume, then transferred to a Nalgene bottle. There, 2.5 mL of potassium permanganate was added (or an alternate amount as needed to keep the solution purple in color). The digested samples were analyzed via a flow injection method by cold vapor atomic absorption (CVAA) with a Perkin Elmer FIMS 100 analyzer. Each sample analysis set typically included several process samples, a reference gypsum material (a gypsum sample with a known mercury content), a digestion blank (all of the digestion chemicals and procedures but no process sample), and a digestion blank spike (digestion blank with a known quantity of mercury added). Before running each sample on the FIMS 100, 0.5 mL of hydroxylamine sulfate was added to reduce the potassium permanganate. Each sample was filtered as it was injected using a Gelman Acrodisc 0.45-μm syringe filter to ensure no solids were injected into the analyzer with the sample. A calibration curve was run each analysis day using known mercury concentrations added to an exact matrix ratio of the acids, potassium permanganate and hydroxylamine sulfate used in the sample digestion.

Natural gypsum samples were digested in the same manner but were analyzed with a Leeman Labs, Inc. Hydra AF Gold Plus flow injection cold vapor atomic fluorescence (CVAF) analyzer. The CVAF analyzer has a lower working mercury detection limit than the FIMS 100 (0.5 nanograms/L [ppt] versus 0.1 μg/L [ppb]. This corresponds with method detection limits of approximately 4 ng/g for CVAF versus 20 ng/g [0.02 μg/g] in the original solid sample for the FIMS 100, considering that dilution of the digestate is typically required with the AF analyzer.

None of the samples were analyzed for methyl mercury or other organic mercury compounds, as this can be a difficult and complicated measurement and was not included in the project scope. Other National Energy Technology contractors are investigating methyl mercury concentrations in coal utilization byproducts including FGD gypsum, as part of project numbers DE-FC26-03NT41727 (EERC) and DE-AC26-05NT42110 (Frontier Geosciences).

Analysis of Process Samples (USG Analyses)

Wallboard plant test process solid samples (e.g., synthetic gypsum, land plaster, stucco) were also analyzed for mercury concentration by USG Corporation, in their Research and Development laboratories, using a Milestone Inc. DMA-80 Direct Mercury Analyzer. This analyzer thermally decomposes the sample, catalytically reduces the mercury, amalgamates it

with gold, then desorbs the mercury from the gold for analysis by atomic absorption. There is no separate digestion step, as is required for the wet injection methods used in the URS analyses.

Analysis of Ontario Hydro Impinger Solutions

The Ontario Hydro method analysis sets include a filter, a probe and nozzle rinse solution, and three different types of impinger solutions: 1M potassium chloride, 5% v/v nitric acid/10% v/v peroxide, and 10% v/v sulfuric acid/4% v/v potassium permanganate. Each sample or solution type was digested according to the preparatory steps outlined in the method.[14] The filters were digested and analyzed by the same methodology as described above for the wallboard plant process samples. Probe and nozzle rinse and impinger solution digestion and analyses are briefly described below.

Each impinger sample was digested in duplicate. At least one digestion spike was run for every sample type per sampling location, or for every ten samples if there were more than ten samples per location. The digestates were analyzed with the Perkin Elmer CVAA analyzer as described above. The analyzer calibration curves were run with standards prepared in matrix matches for each impinger solution type.

TCLP Analyses

Wallboard samples were leached with an extraction fluid according to the TCLP method.[15] All of the samples required the use the Solution No. 1 from the method (5.7 mL glacial acetic acid and 64.3 mL 1-N sodium hydroxide diluted to 1.0 L with DI water). The TCLP extraction used a 1:20 solid to extraction fluid ratio. The samples were rotated for 18 ±2 hours. Liquid was filtered from the solids using vacuum filtration and 1 mL of nitric acid was added to the final sample to preserve the leachates for metals analyses. TCLP leached samples were analyzed for mercury concentration after preparation according to a modified EPA Method 7470. To each sample 2.5 mL of sulfuric acid, 1.25 mL of nitric acid, 5 mL of 5% aqueous potassium permanganate, and 4 mL of potassium persulfate were added to 30 mL of a diluted sample at 1/2. Before running on the FIMS 100, 1 mL of hydroxylamine sulfate was added to reduce the potassium permanganate.

Aliquots of the TCLP solutions were also sent to a third party laboratory (ACZ Laboratories) for analyses of other RCRA metals (arsenic, barium, cadmium, chromium, lead, selenium, and silver). Method blanks and spikes were included in the sample sets sent out for analysis.

Laboratory Gypsum Calcining Tests

Laboratory Calcining Procedure

As part of the project, URS conducted a number of laboratory gypsum calcining tests. The tests were intended to simulate a kettle calciner, with the hope that a laboratory procedure could be developed that would allow the prediction of mercury losses for a particular synthetic gypsum feedstock in a commercial wallboard plant calciner. The laboratory procedure represented a refinement of a procedure first developed as part of an EPRI project.[8]

The laboratory calcining simulation test set up is presented in Figure 4. The test involved calcining a fixed bed of synthetic gypsum solids in a temperature-controlled oven. The free moisture and evolved 1.5 waters of hydration were captured during the test procedure. The weight of the moisture captured was compared to a theoretical weight of expected moisture capture to determine if calcination occurred completely. The theoretical weight of moisture expected to evolve was calculated using the percent free moisture of the gypsum, the weight of the aliquot of gypsum tested, and the calculated weight of the evolved 1.5 waters of hydration. Any evolved mercury was captured using sorbent traps consisting of granulated Norit Darco® carbon. A few interim modifications were made as the testing progressed; the description below matches the final set up.

A pre-weighed aliquot of wet synthetic gypsum feedstock was placed in a Teflon column containing a quartz filter. The synthetic gypsum percent moisture content was used to calculate the actual dry mass of synthetic gypsum calcined. A thermocouple was inserted through the bottom of the column and placed approximately ¼-in. (6-mm) into the fixed bed of wet synthetic gypsum solids. The purpose of this thermocouple was to monitor the actual temperature of the solids to ensure proper calcination. A thermocouple was also placed in a "tee" fitting just downstream of the column, to monitor the effluent air temperature. A small amount of Pyrex wool was placed on top of the fixed bed of synthetic gypsum to disperse the air as it enters the column and hold the fixed bed in place. Figure 5 is a schematic of a packed Teflon column.

The packed Teflon column was placed in an oven preset to 300°F (149°C). Air was fed via FEP tubing into the oven, passed through the 12-ft stainless steel coil of tubing to preheat the air, then entered the column and contacted the fixed bed of synthetic gypsum. Next, the air exited the column and oven, then passed through sealed glass Pyrex bottles placed in series in an ice bath to collect the free moisture and the 1.5 waters of hydration evolved during the gypsum drying and calcining processes. The dried effluent was passed through a carbon tube containing two 0.25-g beds of granulated Darco® sorbent, then through a rotameter to verify flow.

Once the temperature of the fixed bed of solids reached 300°F (149°C), the solids were allowed to calcine for an additional 30 minutes. After 30 minutes of calcination time, the first sorbent tube was quickly replaced with a clean sorbent tube. The second carbon tube measured potential mercury losses for an additional 30 minutes. Carbon Tube #1 was meant to capture all of the mercury that evolved from room temperature to 300°F (149°C) and during 30 min of calcination.

The purpose of Carbon Tube #2 was to simulate residence time effects in a kettle calciner and capture mercury that may continue to evolve after 30 minutes at 300°F (149°C). After removal, the carbon tubes were capped with Teflon tape to prevent mercury losses.

At the end of each test, the calcined solid and water from the water catch were recovered immediately into sealed glass containers. The post-test weights of the calcined solids and of the captured water were recorded. The water sample was preserved with a few drops of concentrated nitric acid and analyzed for mercury.

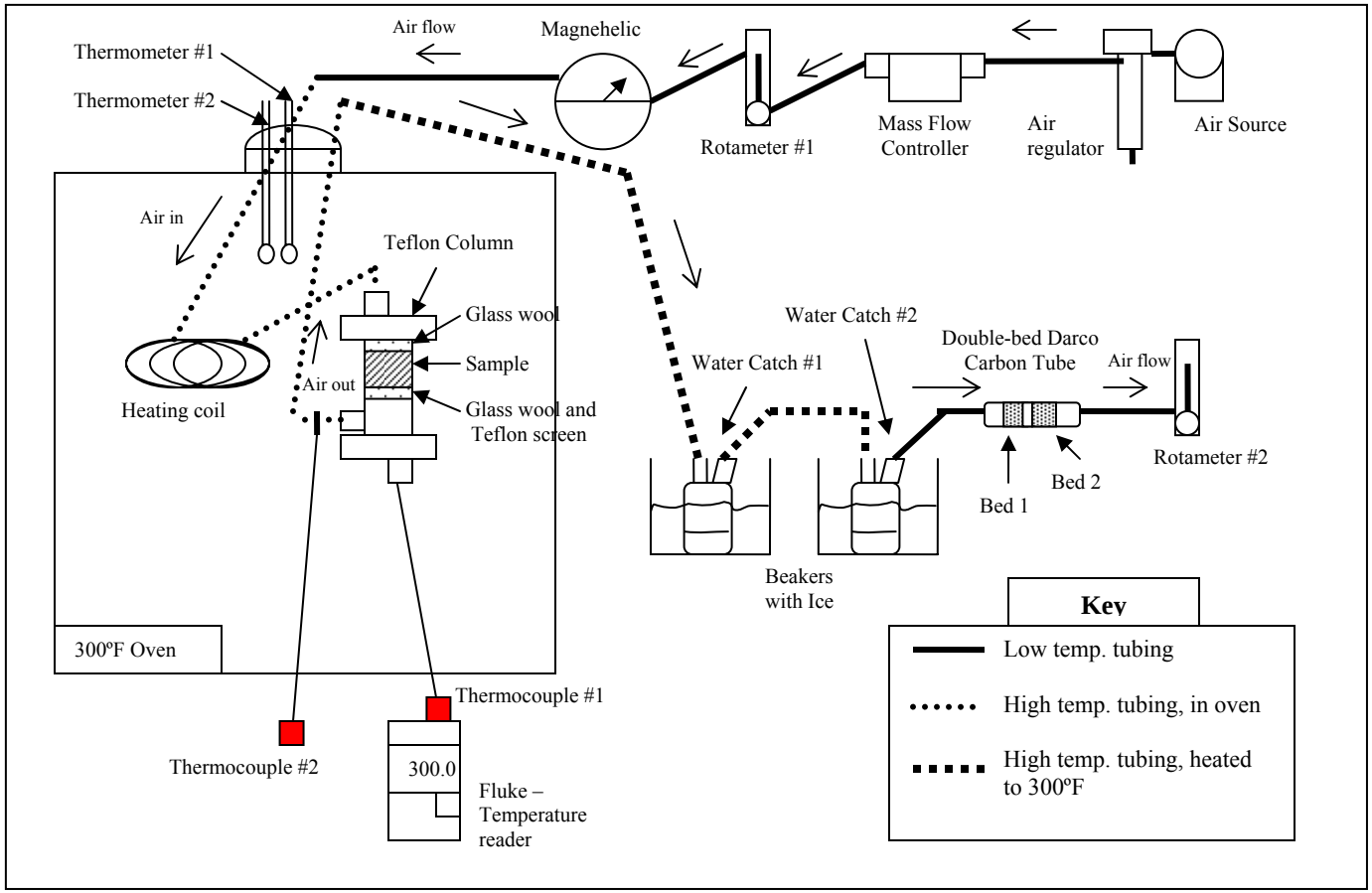


Figure 7. Schematic of Laboratory Calcining Simulation System

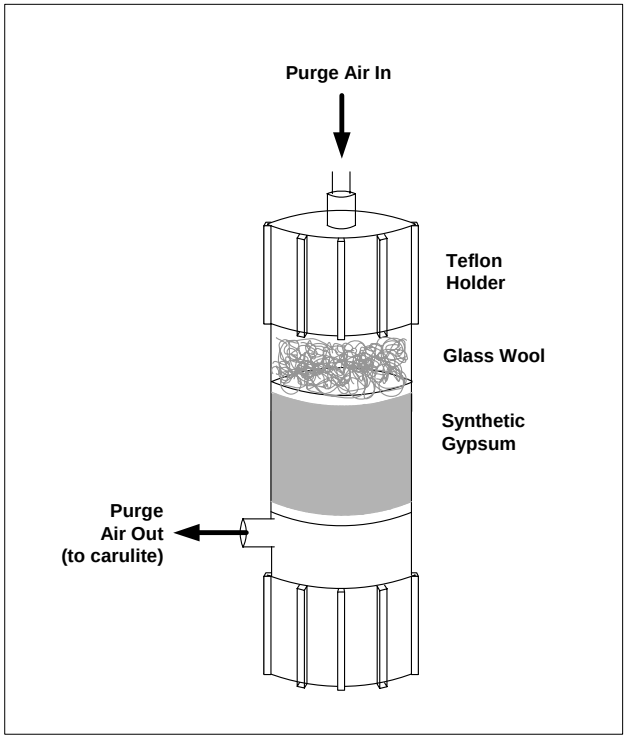


Figure 8. Schematic of the Calcining Simulation Teflon Tube Set Up

Air was delivered and controlled using a regulator and a mass flow controller. The target flow rate for all tests was 0.5L/min. System leaks were monitored via a rotameter placed downstream of the mass flow controller (inlet flow) and a rotameter placed downstream of the carbon tube (outlet flow). System pressure was monitored with a Magnehelic® placed upstream of the column just outside the oven. A Magnehelic® reading higher than 10 in. H_2O (2.5 kPa) indicated there was a plug in the system, most likely caused by compaction of the gypsum sample or a downstream carbon tube. If the Magnehelic® read zero a leak in the system was indicated. A thorough check of the system was performed to find and correct the cause of any such problems before a test was started. The pressure was also monitored to ensure high backpressure from the Teflon column would not bias the results by affecting mercury partial pressures. Acceptable pressures ranged from 4 to 7 in. H_2O (1.0 to 1.7 kPa).

To check for cross-contamination and test procedure integrity, a blank test was performed before and after each test series with a new gypsum feedstock. A blank test was set up exactly like the sample test except there was no synthetic gypsum solid sample in the Teflon column. A blank test was recovered in the same manner as the gypsum-containing tests. These blank tests would also check for mercury contamination in the materials used to pack the Teflon column such as the quartz filter and the pyrex wool.

The synthetic gypsum feedstock samples from four of the six commercial wallboard tests were evaluated using in these laboratory calcining test described above. The results of these tests are summarized in the following section of this report. Modifications had to be made to the

laboratory calcining test apparatus and procedure as the testing progressed to correct various problems; these modifications are described along with the test results. Each test was run in duplicate to test the reproducibility of the test procedure.

Laboratory Calcining Test Analytical Procedures

As discussed above, three sample types were recovered and analyzed for mercury content, in order to evaluate mercury losses during the laboratory calcining test procedure. Samples analyzed for mercury content included an aliquot of the calcined sample, the two carbon traps that were placed downstream of the calcined solids, and the water catches containing the evolved free moisture and waters of hydration. The calcined solids were analyzed by CVAA according to the digestion and analysis procedures described above for wallboard plant process samples. Analyses of the carbon traps and condensed waters of hydration are described in the following paragraphs.

Each of the two sorbent beds from the sorbent tubes was transferred to glass digestion vials. The glass wool used to hold the beds in place was digested with the appropriate carbon bed, the first two pieces of glass wool were digested with the first carbon bed and the last piece of glass wool was digested with the second carbon bed. To each vial, 15 mL of nitric acid and 5 mL of hydrochloric acid were added, and the samples were cooked at 65^{o}C for two hours, then allowed to cool to room temperature. The sample was transferred to a 100-mL volumetric flask using DI water, and 2.5 mL of 5% potassium permanganate was added to each sample. Before mercury analysis by CVAA, 1 mL of hydroxylamine sulfate was added to each sample, and a 10 mL aliquot of each sample was filtered using a 0.45-µm syringe filter. Each sample was analyzed in duplicate.

The water catch samples were analyzed using EPA Method 7470 digestion procedure. Due to the limited sample quantity only a few were digested in duplicate.

RESULTS AND DISCUSSION

This section summarizes and discusses technical results from the project. The first subsection presents and discusses results from measurements during the seven commercial wallboard plant tests. These results include gypsum and wallboard product sample analysis results, Ontario Hydro flue gas measurement results, mercury loss results, and plant process data. The remaining subsections present and discuss results from the laboratory investigations conducted as part of this project, including laboratory calcining experiments, analyses of natural and synthetic gypsums for mercury content, and TCLP analyses on a number of wallboard samples made from synthetic gypsum.

Commercial Wallboard Test Results

Table 5 summarizes the results from the seven wallboard tests conducted as part of this project, while Table 6 summarizes corresponding wallboard plant process data collected during these tests. Not all of the process data used to calculate mercury loss percentages (e.g., board-line speed in feet of board per minute) are shown in Table 6 because these parameters are considered business confidential.

Mercury Release Rate Data

The results summary in Table 5 shows that, as expected, Power Plant A produced synthetic gypsum with the highest mercury content of the five sources tested. It was surprising that the gypsum mercury concentration was measured to be higher in Task 2 than in Task 1. It was expected that with the SCR in service when the gypsum was produced for Task 1, a higher mercury oxidation percentage in the FGD inlet flue gas would have led to higher gypsum mercury content. Since this was not observed, another effect such as higher coal mercury content may have accounted for the higher mercury concentration in the gypsum produced for Task 2 while the SCR was bypassed.

Also as expected, the gypsum produced by Power Plants B and E, with high chloride and fines blow down rates, had considerably lower gypsum mercury content than the gypsum from Power Plant A. The gypsum from Power Plant C, which fires Texas lignite, had a mercury content between these two extremes.

The gypsum from Power Plant F, which fires PRB coal, had a mercury content in the same range as from Power Plant A, or approximately 1 μg/g. This may seem surprising, since PRB has very low chloride content and generally produces flue gas with a low percentage of oxidized mercury, the predominant form removed in wet FGD systems. However, while the coal fired at Power Plant A has nearly three times the amount of mercury as the PRB fired at Power Plant F when expressed on an equivalent Btu input basis, the Power Plant A coal also has five times the sulfur content. Hence, considerably more gypsum is produced per equivalent Btu input at Power Plant A than at Power Plant F, which tends to dilute the mercury captured in the Power Plant A FGD gypsum. If it were not for the presumably lower mercury oxidation percentage in the flue gas at Power Plant F, one might have expected the Power Plant F gypsum to have a higher

Table 5. Summary of Commercial Wallboard Test Results

Task Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Test Dates	7/27-7/28/2004	12/1-12/2/2004	9/21-9/22/2004	2/16-2/18/2005	3/21-3/22/2006	9/13-9/14/2006	8/14-8/15/2007
Power Plant/FGD Conditions:							
Power Plant	A	A	B	C	E	E	F
Coal Type	High-sulfur bituminous	High-sulfur bituminous	High-sulfur bituminous	Texas lignite	High-sulfur bituminous	High-sulfur bituminous	Powder River Basin
SCR in Service	Yes	Bypassed	Yes	No SCR	Bypassed	Yes	Yes
FGD Fines/Chloride Blow Down	Low rate	Low rate	High rate	None	High rate	High rate	Variable[a]
TMT-15 Addition	No	No	No	No	No	Yes	No
Wallboard Plant Data:							
Wallboard Plant	1	1	2	3	4	4	5
Raw Gypsum Mercury Content, μg/g[b]	0.96 ± 0.03	1.10 ± 0.04	0.21 ± 0.02	0.53 ± 0.01	0.20 ± 0.04	0.13 ± 0.00	1.06 ± 0.06
Moisture Content, wt%, mean for three runs	11.9	11.1	11.3	12.6	10.9	6.3	7.2
Product Wallboard Mercury Content, μg/g[b]	0.95 ± 0.02	0.93 ± 0.03	0.07 ± 0.00	0.48[c]	0.12 ± 0.01	0.09 ± 0.00	0.72 ± 0.01
Mercury Loss by Ontario Hydro Method, percentage of inlet mercury to each process step:							
-Across Dryer Mill, %[b]	1.1 ± 0.9	0.3 ± 0.1	1.0 ± 0.3	0.8 ± 0.1	1.8 ± 0.4	4.1± 1.9	0.6 ± 0.4
-Across Kettle Calciner, %[b]	2.3 ± 1.0	2.6 ± 0.0	41 ± 2	0.8[c]	50 ± 6	45 ± 1	15 ± 2
-Across Board Dryer Kiln, %[b]	1.9 ± 0.6	5.5 ± 2.4[d]	14 ± 6[d]	0.3[c]	1.4 ± 1.2	5.8 ± 5.6	3.2 ± 1.0[c]
-Overall Loss across Wallboard Plant, %[b]	5.1 ± 1.7	8.3 ± 2.0[d]	46 ± 16[d]	1.8[c]	51 ± 5	55 ± 6	18 ± 2[c]
Observed Mercury Loss based on Raw Gypsum and Wallboard Product Mercury Concentrations, %[b]	2.0 ± 5.0	16 ± 8	66 ± 2	8.7[c]	40 ± 21	32 ± 2	32 ± 3
Total Mercury Loss from Process Stacks, g/hr	4.1 ± 1.7	2.7 ± 0.1	8.2 ± 0.5	0.26[c]	2.0 ± 0.2	1.4 ± 0.2	4.2 ± 0.6[c]
Mercury Loss Rate, lb/MM ft^2 of wallboard	0.1	0.1	0.2	0.01[c]	0.2	0.1	0.4[c]
Mercury Loss Rate, g/ton of dry gypsum processed	0.05	0.08	0.09	0.01[c]	0.09	0.06	0.17[c]

[a]FGD system wastewater treatment plant has filter press for removing fine particles from hydrocyclone overflow liquor, so fines and chlorides can be blown down independently

[b]Mean value for three runs ± 95% confidence interval of mean, unless noted otherwise; loss percentages across dryer mill, kettle calciner and board dryer kiln are based on feed material to each step, so percentages cannot be summed to the wallboard product overall loss percentage shown

[c]Mean value for two runs

[d]Board kiln stack not measured by Ontario Hydro method; includes estimated value for board line losses based on solids analyses

Table 6. Summary of Wallboard Test Process Conditions

Task Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Power Plant Providing Gypsum	A	A	B	C	E	E	F
Wallboard Plant	1	1	2	3	4	4	5
Dryer Mill Dust Collector Outlet Temperature, ^{o}F	178	172	168	145	170	149	177
Dryer Mill Dust Collector Outlet Flue Gas Moisture, vol %	16	15	12	12	12	9.1	14
Kettle Calciner Temperature, ^{o}F	300	300	300	302	300	300	305
Kettle Calciner Dust Collector Outlet Temperature, ^{o}F	262	261	264	260	250	251	280
Kettle Calciner Dust Collector Outlet Flue Gas Moisture, vol %	56	56	79	56	49	49	52
Board Kiln Wet Zone Temperature, ^{o}F	437	437	450	492	588	475	468
Board Kiln Dry End Temperature, ^{o}F	224	224	341	271	-	-	396
Board Wet End Stack Temperature	*NA	NA	NA	245	269	235	NA
Board Wet End Stack Flue Gas Moisture, vol %	NA	NA	NA	18	25	23	NA
Board Dry End Stack Temperature, ^{o}F	225	Not measured	Not measured	203	195	164	237
Board Dry End Stack Flue Gas Moisture, vol %	41	Not measured	Not measured	20	8.4	8.5	49

*NA – not applicable due to single stack on board dryer kiln
Note: $^{o}C = (^{o}F - 32)/1.8$

mercury concentration. Instead, the combined effects of coal sulfur, coal mercury, mercury oxidation percentage in the flue gas, and fines/chloride blow down rates result in similar mercury concentrations in the synthetic gypsum produced from these very different coal types.

The mercury loss data in the table represent the means from triplicate measurements by the Ontario Hydro method during each test, except as noted. The percentage lost was calculated by dividing the mercury loss rate from the process vent stack (e.g., dryer mill dust collector stack) as quantified by the Ontario Hydro result by the product of the feed rate to the process times the feed stream's measured mercury concentration. Also shown is a 95% confidence interval about the mean of the three calculated percentages.

The exceptions are for Tasks 4 and 7. During the Task 4 test, the plant was having difficulty processing 100% synthetic gypsum from Power Plant C. Although all three dryer mill measurement runs were completed while processing synthetic gypsum from Power Plant C, by the third kettle calciner measurement run the plant had switched to a blend of material from Power Plant C and from another source. This switch also impacted the third set of board-line measurements. For this reason, the Task 4 results for the kettle calciner and board kiln represent the mean of only two measurements, and no 95% confidence intervals are shown. For Task 7, the results of one Ontario Hydro run on the board-line dryer kiln stack were invalidated by broken glassware in the analytical laboratory. Consequently, for Task 7 the board-line and overall mercury loss results based on Ontario Hydro measurements are for two runs only.

Mill Plant (Dryer Mill and Calciner) Results

Looking at the dryer mill results, the mercury loss data for all seven tasks show small but measurable mercury losses across the dryer mills, which remove free moisture from the synthetic gypsum feedstock. Most of the task results showed a 1 to 2% mercury loss across the dryer mill.

At the beginning of the project, it was expected that if significant mercury losses were observed at the wallboard plants, most would occur across the kettle calciners, since this is where the process solids (called land plaster at the feed to the kettle) are heated to the highest temperature (about 300^{o}F [149^{o}C]). As shown in Table 5, there was a wide range of mercury loss across the kettle calciners in the six tests, with values ranging from less than 1% to 50% loss of the mercury in the land plaster.

The lowest percentage mercury loss across a kettle calciner was in Task 4 where the gypsum feedstock was from Power Plant C, which fires Texas lignite. This result supports the results of earlier EPRI-funded, laboratory-scale simulated calcining tests which showed low mercury loss from synthetic gypsums from Texas lignite and PRB coal fired plants.[8] However, the Task 7 results with synthetic gypsum from Power Plant F firing PRB coal did not support the EPRI results as well, showing a mercury loss percentage across the kettle calciner (15%) between the two extremes seen for the bituminous coal synthetic gypsums (2.3% to 50%).

The results from Tasks 1 and 2 show consistent and relatively low percentage mercury losses of about 2 to 3% across the kettle calciner when processing synthetic gypsum from Power Plant A. Whether the SCR was in service or not when the gypsum was produced had no apparent effect.

The synthetic gypsums from Power Plant B and Power Plant E (Tasks 3, 5 and 6) showed substantial percentage losses across the kettle calciner, ranging from 41 to 50% loss. Since these synthetic gypsums had lower mercury content, the mass of mercury lost was not much greater than in Tasks 1 or 2 when expressed in terms of grams per ton of dry synthetic gypsum processed (this effect is discussed further below).

One variable that appears to correlate with percentage mercury loss from the synthetic gypsums across the kettle calciner is the amount of chloride and fines blow down that occurs in the wet FGD system producing the gypsum. Gypsum from the power plant with no chloride/fines blow down in the FGD system (Power Plant C) had the lowest percentage mercury loss, while the gypsum from the power plant with a low chloride/fines blow down rate (Power Plant A) also showed very low loss percentages. Gypsums from the power plants with high FGD chloride and fines blow down rates (Power Plants B and E) showed the greatest percentage loss across the kettle calciners. The reason for this apparent correlation is not obvious, and could not be elucidated from the data collected as part of this project. One speculation is that the lower concentration of mercury in the gypsum produced from the systems with higher chloride and fines blow down rates is more weakly adsorbed than mercury adsorbed to fine particles.

The Task 6 results show a similar percentage mercury loss across the kettle calciner as was measured during Task 5. This suggests that the addition of TMT-15 to the FGD system had little impact on the stability of mercury in the synthetic gypsum when it is used for wallboard production. However, it should be noted that results from DOE Project 42309 indicate a possible interference in the effectiveness of TMT-15 in the Power Plant E FGD liquor.[16] For example, expected results such as reduced mercury concentrations in the FGD slurry liquid phase, increased mercury concentrations in the gypsum fines, and reduced mercury concentrations in the bulk gypsum solids were not seen. Furthermore, an expected reduction in concentration of other divalent transition metals that should be precipitated by TMT-15 was not seen. Consequently, the results of Task 6 should not be interpreted as conclusively indicating that TMT-15 or other mercury precipitation additives cannot improve the stability of mercury in treated gypsum when that material used for wallboard manufacturing feedstock.

For all seven tasks, most of the mercury emissions from the mill were measured to be in the elemental form (Hg^0). This is not shown in Table 5, but can be seen in the individual topical reports. These results are contrary to what was expected at the beginning of this project given that it is predominantly water-soluble oxidized mercury (Hg^{+2}) that is removed in wet FGD systems, while elemental mercury is virtually insoluble and not removed at significant percentages. The cause of this phenomenon has not yet been determined. Note that in the elemental form, mercury is not expected to readily deposit

near the point of emission but ascends into the atmosphere and contributes to the overall global cycle.[17]

Board Plant (Board Kiln) Results

There was considerable variability in the percentage mercury loss across the board dryer kilns, with calculated losses ranging from less than 1% to 14%. There was also considerable variability within the three measurements during each test. For Tasks 5 and 6, the 95% confidence interval about the mean was nearly as large as the mean value itself (e.g., Task 5 had a mean mercury loss percentage across the board dryer kiln of 1.4%, but the 95% confidence interval about that mean was ± 1.2%). This indicates considerable uncertainty in these mean loss values.

Also, as mentioned above, in the Task 2 and 3 tests no Ontario Hydro method measurements were made on the board dryer kiln stack. Therefore the percent mercury losses across the board line shown for these tasks were estimated from the mercury content of the stucco feed to the board line compared to the mercury content in the final board product. As discussed below, there are inherent errors associated with quantifying mercury losses by this method. For example, if the timing of the stucco feed sample and the wallboard product sample collection do not properly account for the residence time of the entire board line, variations in the inlet stucco mercury concentration could lead to errors.

Consequently the Task 2 and 3 results for mercury loss across the board dryer kiln may have considerably more error than the Ontario Hydro results from the other tasks and associated uncertainties. Particularly for Task 3, where the estimated mercury loss percentage across the board line of 14% was considerably higher than for the other five tests, this estimated value is suspect. If the Task 2 and 3 results are not considered, the calculated mercury losses across the board dryer kilns ranged from less than 1% to 6%.

There are two other details to note about the percentage loss values across the board line shown in the table. One is that the percentage loss values were calculated based on the mercury concentration in the feed to the board line, not in the original gypsum feed to the wallboard plant. For the tests where there were significant losses across the kettle calciner, the gypsum concentrations in the feed to the board line were only about half of the gypsum concentrations in the feed to the mill. Consequently, the percentages shown across each process step shown in Table 5 cannot be summed to calculate the fourth value in the table, the overall mercury loss percentage across the wallboard plant.

Another thing to note about the percentage mercury loss values across the board line is that a number of additives are mixed with the stucco feed to the board line, and paper is added on both sides of the board as it is formed. The paper and some of the additives have some mercury content, and so they contribute a small amount to the mercury found in the product wallboard. The mercury content of the additives and paper was accounted for in calculating the percentage mercury loss across the board line.

Entire Plant (Dryer Mill, Calciner and Board Kiln) Results

The overall mercury losses across the wallboard plant were calculated by summing the mercury mass losses as measured by the Ontario Hydro method from the dryer mill, kettle calciner, and board line process stacks. The exception was for Tasks 2 and 3, where the losses across the board line had to be estimated from solids analyses. The number of process trains was taken into account to make this calculation. For example, if the plant had one dryer mill, two kettle calciners, and one board line, the mercury loss across the one kettle calciner measured was doubled to account for the other train. For Task 7, the mill was producing stucco at a lower rate than the board line was consuming stucco to produce wallboard. For the Task 7 results, the board line mercury loss rate was adjusted to the same throughput basis as the mill production. For all seven tasks, the effects of mercury in additives and paper added at the board line were factored into the calculation.

The overall mercury loss rates compare similarly to the kettle calciner loss rates: Task 4 showed the lowest loss rate at less than 2%, while Tasks 3, 5 and 6 showed the highest loss rates at 46 to 55%. Tasks 1 and 2 showed relatively low overall loss percentages in the range of 5 to 8%. Separating out the tasks in which high-sulfur bituminous coal was fired (Tasks 1, 2, 3, 5, and 6), these percentages appear to correlate with the level of chloride and fines blow down from the FGD systems that produced these synthetic gypsums (see Figure 9).

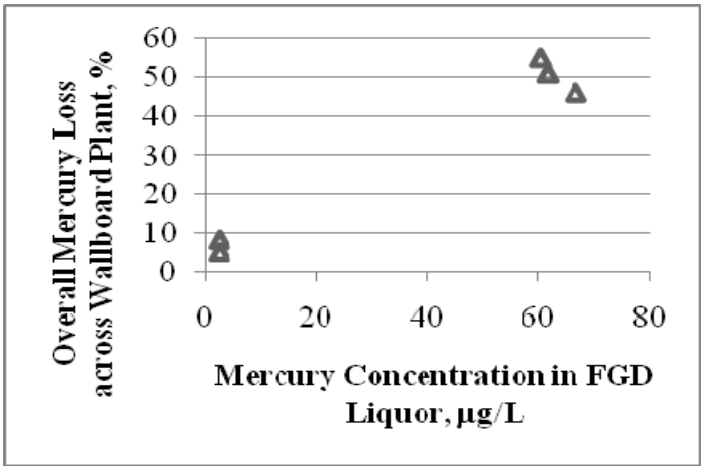


Figure 9. Observed Relationship Between Mercury Concentration in FGD Liquor and Overall Mercury Loss across Wallboard Plant, % for Samples from Power Plants firing High-sulfur Bituminous Coal (Tasks 1, 2, 3, 5 and 6)

In Table 5, below the overall mercury loss rate percentage based on the Ontario Hydro measurements is a second overall mercury loss percentage based on raw gypsum and wallboard product mercury concentrations. Theoretically, these two percentages should be equal. As can be seen in the table, there was not always good agreement between the two methods. Of the two, the loss rate quantified by the Ontario Hydro method measurements in the process stacks is believed to be more accurate, as it represents a direct measurement of losses.

The loss percentage calculated from raw gypsum feedstock and wallboard product mercury concentrations is calculated as the difference between the two concentration values. Small errors in either or both of these values can lead to significant errors in the result. Several factors can contribute to such errors. For example, the process samples were grab samples taken at a single point of time during each Ontario Hydro stack measurement, and may not accurately represent the average feed or product mercury concentrations over the entire two-hour run time. Also, normal variability in chemical analysis results can contribute to errors. If the raw gypsum mercury analysis result has a small positive (high) bias and the wallboard product mercury analysis has a small negative (low) bias, the percentage mercury loss across the wallboard plant will be overstated.

The last three rows in Table 5 show mercury loss rates on a mass basis, and relative to the amount of wallboard produced and relative to the amount of synthetic gypsum processed. The mass rate data show that the overall mercury losses (considering two trains of kettle calciners and/or dryer mills at several of the wallboard plants) are relatively low, ranging from 0.3 to 8.2 g/hr. Assuming 8,000 hours of wallboard plant operation per year, these numbers correspond with annual mercury release rates of 5 to 144 lb/yr. However, the five wallboard plants tested vary considerably in wallboard production rate, so it is appropriate to normalize the results to the amount of wallboard produced or the amount of raw gypsum processed at each plant.

When expressed in units of pounds of mercury released per million square feet of wallboard, the rates range from 0.01 lb/MM ft^2 for Task 4 to 0.4 lb/MM ft^2 for Task 7. Note that these results are purposely shown with only one significant digit of accuracy, as wallboard production rates and weight of raw gypsum per square footage of wallboard produced are both business confidential values. Also, caution must be used when comparing to industry production rates since the results are specific to wallboard produced with synthetic FGD gypsum.

Surprisingly, Task 7 results showed the highest mercury loss rate on this basis, since the overall percentage loss was much lower than was measured in Tasks 3, 5 and similar to 6. However, the mercury concentration in the raw synthetic gypsum processed during the Task 7 test was five to eight times higher than the concentrations in the synthetic gypsums processed during Tasks 3, 5 and 6. Also, the board line was producing thicker, ⅝-inch board during the Task 7 test whereas most of the other tasks were conducted while producing ½-inch board. This variation slightly skews the Task 7 results high when reported in these units.

The final row in Table 5 shows the mercury release rate in units of grams per ton of dry synthetic gypsum processed by the wallboard plant. The values range from 0.01 g/ton for Task 4 to 0.17 g/ton for Task 7. The Coal Combustion Product Production and Use Survey from the American Coal Ash Association (ACAA) indicates that 7,579,187 short tons of synthetic gypsum was used for wallboard production in 2006. Extrapolating the results of this study to the ACAA industry usage rate, we estimate that mercury emissions

ranged between 150 to 3000 pounds for the wallboard industry. When expressed in these units, it is apparent that even though the percentage loss rates measured during Tasks 3, 5 and 6 were the highest, the normalized mercury loss rates were similar to those of Tasks 1 and 2. The values for Tasks 3, 5 and 6 ranged from 0.06 to 0.09 g/ton, while the values for Tasks 1 and 2 ranged from 0.05 to 0.08 g/ton. The fact that the concentration of mercury was lower in the gypsum from the FGD systems with high chloride/fines blow down rates largely offset the higher percentage mercury losses compared to the gypsum from the FGD system with a low chloride/fines blow down rate. Only the results from Task 4, which tested gypsum with a mid-range mercury concentration, no fines blow down from the FGD system, and a low percentage mercury release rate showed a markedly lower mass release rate of 0.01 g/ton. Again, the Task 7 results showed the highest loss rates when reported in these units, due to the relatively high mercury concentration in the synthetic gypsum and mid-range mercury loss percentage.

Process Data

Table 6 compares the process data collected during the seven tests. As mentioned above, not all of the process data used in mercury release rate calculations are shown in the table (e.g., board-line speed) due to their business confidential nature. The process data included in the table show that the dryer mills tend to run at temperatures well below the gypsum calcining temperature (262^{o}F [128^{o}C]), as would be expected, with stack temperatures in the range of 145 to 178^{o}F (63 to 81^{o}C). The stack flue gas moisture content was in the range of 9 to 16 volume percent.

The kettle calciners at all five wallboard plants are controlled to nominally 300^{o}F (149 ^{o}C), which is well above the temperature where gypsum calcines to form calcium sulfate hemihydrate [stucco] (262^{o}F [128^{o}C]) but below the temperature where the other one-half water of hydration is calcined to form anhydrite (325^{o}F [163^{o}C]). The moisture content of the kettle calciner dust collector exit gas is very high, ranging from 49 to 79 volume percent, due to the waters of hydration being lost and the kettle calciners being indirect fired (i.e., there is no flue gas mixed with the calciner exit gas).

The flue gas temperatures in the wet end (feed end) of the board dryer kilns are relatively high (437^{o}F to 588^{o}F [225^{o}C to 309^{o}C]), but because the board is wet the re-formed gypsum does not get hot enough to calcine. At the dry end (board exit), the temperatures are considerably lower. Wallboard Plants 1 and 5 were measured to have a relatively high moisture content in the single board dryer kiln stack (greater than 40%) compared to either stack at Wallboard Plants 3 and 4 (20% or less). The board kilns are direct fired (hot flue gas comes in direct contact with the wet board). The higher flue gas moisture content at Wallboard Plants 1 and 5 is likely reflective of their having new, more highly fuel-efficient board kilns. With a more efficient kiln, less fuel would be consumed in the burner and there would be less flue gas to dilute the moisture released from the wet board.

Laboratory Gypsum Calcining Simulation Results

As described in the Experimental section, laboratory simulations were conducted to see if such a procedure could be used to predict mercury losses in full-scale, commercial kettle calciners. The procedure started with wet synthetic gypsum samples, so a combination of the dryer mill and kettle calciner processes were simulated. Mercury losses were quantified by collecting desorbed mercury in carbon traps with two carbon beds in series. One carbon trap tube was in service during the initial drying of the wet sample, heating to 300^{o}F, and calcining of the material at that temperature for 30 minutes. A second carbon trap tube was then substituted for the initial tube, and the calcining continued for another 30 minutes. The total mercury loss during the drying/calcining procedure was taken as the mercury recovered on both beds of both tubes.

The results of eleven laboratory simulations that were conducted are discussed in chronological test order below. The results from these simulations are summarized in Table 7.

Initial Calcining Simulation

Task 3 Feedstock, Calcining Test #1

This was the only test performed before modifications were made to the apparatus and test procedure. Approximately 50 g of wet feedstock sample collected during the first mill Ontario Hydro run (OH run 1) was tested. Before the test was started, the air flow rate was measured at the inlet and outlet of the oven using a bubble meter and a “dry cal” meter at 0.51 L/min. To determine whether the flow stayed constant throughout the test, the flow was measured at the outlet of the carbon trap tube using a bubble meter. The measurement did not stay constant throughout this test; the flow started at 0.47 L/min then dropped to 0.37 L/min with the first carbon tube and 0.41 L/min with the second carbon tube.

After the gypsum sample container was connected to the air source in the oven at the beginning of the test, the solids were heated to 300ºF (149ºC). To speed this process, the oven temperature was adjusted up to 395ºF (202ºC) until the measured solids temperature reached 300ºF (149ºC). This took 3.5 hours. However, the air temperature at the exit of the gypsum sample container was measured as high as 384ºF (196ºC). The solids temperature in the container apparently remained at a lower temperature because the calcining process is endothermic.

Results for this test are presented in Table 7. The total percentage of the mercury in the raw sample desorbed during the test was 29%. In contrast, the corresponding Task 3, OH run 1 commercial wallboard test result showed a total of 42% mercury loss across the dryer mill and kettle calciner, the two operations simulated in this laboratory procedure. Although this is not exact agreement, it was seen as promising that a relatively high percentage loss was seen in the laboratory simulation.

Table 7. Laboratory Synthetic Gypsum Calcining Simulation Results Summary

Synthetic Gypsum Sample Source	% of Free Plus Combined Moisture Loss Recovered	Hg in Water Catch (ng)	% of Hg on Tube 1, Bed 2	% of Hg on Tube 2, Bed 2	Total Hg in Sample (ng)	Total Desorbed Hg (ng)	Total % Desorbed from Sample	Corresponding Commercial Wallboard Test Result, % Hg Desorbed Across Dryer Mill and Kettle Calciner
Task 3 OH[a] Run 1 Test #1	83%	73	21%	34%	7,290	2,150	29%	42%
Task 3 OH Run 1 Test #2	81%	<41	11%	25%	3,570	1,180	33%	42%
Task 3 OH Run 1 Test #3	91%	<45	10%	33%	3,540	423	12%	42%
Task 1 OH Run 1 Test #1	70%	<47	21%	5.8%	21,900	3,330	15%	5%
Task 1 OH Run 1 Test #2	76%	<52	9.5%	4.4%	22,300	2,920	13%	5%
Task 2 OH Run 2 Test #1	109%	33	1.1%	3.3%	24,600	5,630	23%	3%
Task 2 OH Run 2 Test #2	106%	<30	1.5%	3.1%	24,800	4,680	19%	3%
Task 4 OH Run 1 Test #1	84%	<23	1.4%	5.7%	10,500	3,560	34%	2%
Task 4 OH Run 1 Test #2	101%	<18	1.5%	5.2%	10,500	3,520	34%	2%
Task 4 OH Run 3 Test #1	109%	-[b]	1.3%	4.3%	9,880	4,300	44%	2%
Task 4 OH Run 3 Test #2	108%	<20	1.1%	3.9%	9,520	4,820	51%	2%

[a]OH – Ontario Hydro run during the full-scale wallboard stack test
[b]This sample was contaminated

Modifications were made to the calcining test set up and procedures after this first test. The oven temperature was held to no greater than 315ºF (157ºC), and rotameters were placed after the mass flow controller and after the carbon tube to provide continuous inlet and outlet air flow indication. The test duration would increase with the oven temperature limited to 315ºF (157ºC), but this limit was imposed to prevent overheating of the solids in the container and the production of anhydrite, which could potentially bias the results. The two rotameters were to indicate any leaks as they happened without having to disturb the system by hooking up a bubble meter to spot-check flow rates. Also, the sample size was decreased from 50g to 25g to decrease the amount of water in the moisture trap and limit moisture carryover into the carbon tube. Four tests were conducted after these initial modifications to the calcining system, before any subsequent modifications were made.

Second Round of Calcining Simulation Tests

Task 3 Feedstock, Calcining Test #2

The sample weight tested was 24.5g; all subsequent tests were conducted with sample weights in the range of 24 to 25 g. The air flow rate remained constant throughout the test at around 0.44L/min, as measured at the outlet of the carbon tube. The amount of time required to heat the solids to 300ºF (149ºC) was 4.5 hours, only one hour longer than the previous test. The temperature of the solids never exceeded 302ºF (150ºC).

As shown in Table 7, the modified sample size decreased the amount of mercury found in the water trap. The total amount of mercury desorbed was 33% of the original sample mercury content, which reasonable matched the previous test results (29%) and was within 9 percentage points of the full-scale test result (42%).

Task 3 Feedstock, Calcining Test #3

Because modifications had been made to the system, the Task 3 feedstock from OH run 1 sample was tested a third time. The air flow rate remained constant at 0.48 L/min as measured at the outlet of the carbon tube. The amount of time required to heat the solids to 300ºF (149ºC) was once again 4.5 hours, and the temperature of the solids never exceeded 300ºF (149ºC).

Results for the Task 3 Calcining Test #3 are presented in Table 7. This test result was inconclusive because only 12% of the mercury in the original sample was measured to have been desorbed, which showed poor agreement with the previous two test results (29% and 33%) and even poorer agreement with the full-scale test result (42%).

Blank Tests Results

As mentioned in the Experimental section, each different feedstock tested was bracketed with blank tests to check the cleanliness of the experimental set-up and procedure and ensure mercury carry-over from test to test was not happening. A blank test had been run before the first Task 3 sample calcining test. The results of that blank test showed that the water trap catch result was clean; the result was less than the method detection limit for mercury content (<29 ng). However, the mercury content of Carbon Tube 1, Bed 1 was high at 305 ng. This may have been due to

contamination in the system from previous experiments. The results of the blank test conducted after Task 3 Feedstock, Calcining Test #3 showed that the water catch and the carbon tubes were all clean (mercury concentrations below method detection limits).

All other blank test results (conducted prior to switching sample types) were clean throughout the remainder of the testing.

Task 1 Feedstock, Calcining Test #1

Wallboard plant feedstock sample collected during the first Ontario Hydro run was tested. The carbon tube outlet air flow rate remained relatively constant throughout the test at 0.48-0.50 L/min. The amount of time required to heat the solids to 300ºF (149ºC) was 4 hours, and the temperature of the solids never exceeded 300ºF (149ºC).

As shown in Table 7, the total amount of desorbed mercury was 15% of the original sample mercury content. This result does not match the corresponding Task 1 Ontario Hydro run 1 full-scale mercury loss percentage, but compared to Task 3 Feedstock, Calcining Tests #1 and #2, it shows the right directional effect. That is, this test showed a reduced percentage mercury loss compared to the first two Task 3 Feedstock Calcining Test results, as did the Task 1 full-scale test results compared to the Task 3 full-scale results.

Task 1 Feedstock, Calcining Test #2 (duplicate test)

The air flow rate at the outlet of the carbon tube remained constant at 0.47 L/min. The amount of time required to heat the solids to 300ºF (149ºC) was close to 4 hours. The temperature of the solids never exceeded 306ºF (152ºC). Results for this test show that the total amount of desorbed mercury was 13% of the original sample content, which reasonably matches the Test #1 result (15%).

Problems were still observed with the results of the four tests conducted after the initial modifications described above. These problems included low free- and combined-moisture recovery percentages in the water trap, and the amount of mercury captured on the second bed of the sorbent traps was higher than the desired value of less than 5% of the total mercury measured on Bed 1. These two problems might have been related. Complete moisture capture may be important to the performance of the carbon tube because moisture can potentially affect the ability of the carbon to capture and hold mercury on Bed 1, which can lead to elevated mercury capture in the second carbon bed. A higher percentage of mercury captured on the second bed of the carbon traps raises the issue of whether or not complete mercury capture was achieved by the two beds in series.

Low moisture recovery suggests that the solids were not completely calcined to the hemihydrate form, or that the water knockout was not condensing all of the moisture in the air stream. Since the solids temperatures were maintained well above the gypsum calcining temperature for a full hour, the efficiency of the water trap was suspected as the problem. To correct these problems, a second water trap was installed to make sure all of the water lost due to calcining was captured, and the carbon tube bed sizes were increased from 0.25 g to 0.5 g to compensate for potential

water capture by the carbon bed. All the remaining simulation tests were run with this configuration.

Third Round of Calcining Simulation Tests

Task 2 Feedstock, Calcining Test #1

Feedstock sample collected during the second Ontario Hydro run (OH run 2) was tested. The air flow rate remained constant at 0.48 L/min at the outlet of the carbon tube. The amount of time required to heat the solids to about 300ºF (149ºC) was 4 hours, and the temperature of the solids never exceeded 297ºF (147ºC). Results for this test, as presented in Table 7, show that the water captured was 109% of the theoretical value. Therefore, it is apparent that no moisture penetrated the water trap, and that the solids were completely calcined. For both carbon tubes the amount of mercury found on the second bed was less than 5% of the total mercury captured on Bed 1. The total amount of mercury desorbed from the original sample was measured at 23%. This represents poor agreement with the corresponding Task 2, Ontario Hydro run 2 result for percentage mercury loss across the dryer mill and kettle calciner (3%).

Task 2 Feedstock, Calcining Test #2 (duplicate test)

The air flow rate remained constant at 0.48 L/min. The amount of time required to heat the solids to 300ºF (149ºC) was 4 hours, and the temperature of the solids never exceeded 301ºF (149ºC). The water captured was 106% of the theoretical amount. For both carbon tubes the amount of mercury on the second bed was less than 5% of the total mercury captured on Bed 1, as desired. The total amount of desorbed mercury was 19% of the mercury content of the original sample. This is close to the Test 1 result described above (23%), but again showed poor agreement with the Task 2 full-scale result (3%).

Task 4 Feedstock, Calcining Test #1

Feedstock sample collected during the first Ontario Hydro run (OH run 1) was tested. The air flow rate remained constant at 0.47 L/min, the amount of time required to heat the solids to 300ºF (149ºC) was 4 hours, and the temperature of the solids never exceeded 302ºF (150ºC). The water captured was only 84% of the theoretical amount, which is outside the desired water recovery of 90 to 110%. The water trap containers' tare and final weights were weighed on different balances, so this may account for the low apparent water recovery. For both carbon tubes the amount of mercury on the second bed was less than 5% of the total mercury captured on Bed 1, as desired. The total amount of mercury desorbed was 34% of the mercury content of the original sample. This represents very poor agreement with the corresponding Task 4, Ontario Hydro run 1 full-scale results, which showed approximately 2% mercury loss across the dryer mill and kettle calciner.

Task 4 Feedstock, Calcining Test #2 (duplicate test)

The air flow rate remained relatively constant at 0.47-0.48 L/min. The amount of time to heat the solids to 300ºF (149ºC) was about 4 hours, and the temperature of the solids never exceeded 303ºF (151ºC). The water captured was 101% of the theoretical amount, and for both carbon

tubes the amount of mercury on the second bed was less than 5% of the total mercury captured on Bed 1. The total amount of desorbed mercury was 34% of the mercury content of the original sample, which matches the results from Test #1 but represents very poor agreement with the full-scale result of approximately 2%.

Task 4 Blended Feedstock, Calcining Test #1

As mentioned in the Experimental section, during Ontario Hydro run 3 (OH run 3) the feedstock to the wallboard plant was changed to a blended material of the feedstock tested during Ontario Hydro runs 1 and 2; therefore, the blended feedstock from OH run 3 was tested in these laboratory calcining tests. The air flow rate remained relatively constant at 0.47-0.48 L/min, the amount of time required to heat the solids to 300ºF (149ºC) was four hours, and the temperature of the solids never exceeded 301ºF (149ºC). The water catch container was determined to have been contaminated with mercury; therefore, the amount of mercury on the water could not be determined. The amount of water captured was 109% of the theoretical value. For both carbon tubes the amount of mercury on the second bed was less than 5% of the total mercury captured on Bed 1. The total amount of desorbed mercury was 44% of the mercury content of the original sample. This represents very poor agreement with the corresponding Task 4 Ontario Hydro run 3 full-scale result (2%).

Task 4 Blended Feedstock, Calcining Test #2 (duplicate test)

The air flow rate remained constant at 0.47 L/min, the amount of time required to heat the solids to 300ºF (149ºC) was 3.5 hours, and the temperature of the solids never exceeded 302ºF (150ºC). Results for the Task 4 Calcining Test #2, as presented in Table 7, show there was no mercury found in the water catch. The amount of water captured was 108% of the theoretical amount, and for both carbon tubes the amount of mercury on the second bed was less than 5% of the total mercury captured on Bed 1. The total amount of desorbed mercury was 51% of the mercury content of the original sample, which reasonably matches the results from Test #1 (44%), but is in very poor agreement with the full-scale result of approximately 2%.

Comparing the mercury loss results of the Task 4 laboratory calcining tests simulation to the results of the Task 3 calcining tests shows that the trend for relative mercury losses seen in the laboratory simulation are opposite those of the full-scale results. The Task 4 simulations showed 34% to 51% mercury loss while the full-scale results showed approximately 2% loss. In comparison, the Task 3 simulations showed 12 to 33% loss, while the corresponding full-scale result showed a greater loss of 42%.

At this point it became apparent that the laboratory calcining test was a poor predictor of mercury losses in full-scale dryer mills and kettle calciners. There are several possible explanations for this observation. One is that the full-scale kettle calciners operate as a moving bed, with significant solids fluidization and with a solids residence time of about one hour. Because the solids are continually added to the indirect-fired vessel maintained at temperature, they quickly achieve and maintain that temperature over the one-hour residence time. In contrast, the laboratory simulation was conducted on a fixed bed of solids, which took 3.5 to 4.5 hours to reach a temperature of 300ºF (149ºC). Other variables may impact the full-scale versus laboratory simulation mercury loss percentages, such as the relative velocities of the air and land

plaster solids, the relative mass rates of air and land plaster solids in the calciner, the contact time and relative mixing between the air and solids, etc.

After considering all of these potentially important variables, it became apparent that to improve the laboratory simulation the apparatus would need to look like a small pilot-scale kettle calciner rather than a simple bench-top test setup. Consequently, further revisions to the laboratory simulation were not attempted. The conclusion from this effort is that a simple laboratory oven calcining test is not a good predictor of mercury loss rates in a commercial kettle calciner.

Mercury Analyses of Additional Gypsum and Wallboard Samples

One objective of this project was to collect data on mercury concentrations in a variety of synthetic gypsums used as wallboard manufacture feedstock, for comparison with mercury concentrations in natural gypsum feedstock. It was decided to collect ten samples each of synthetic gypsum feedstock and natural gypsum feedstock from USG wallboard plants around the country. Since six samples of synthetic gypsum feedstock were collected during the first six commercial wallboard tests conducted as part of this project, only four additional synthetic gypsum feedstock samples were needed to make ten. When Task 7 was added to the project in 2007, this resulted in an 11th synthetic gypsum sample. Because of a change in feedstock to the kettle calciner and board line during the third measurement runs in Task 4, this made for a 12th synthetic gypsum sample (the blended feedstock from Run 3).

The results of the four additional synthetic gypsum analyses are shown in Table 8. As has been the convention in this project, the power plants supplying the synthetic gypsum and the corresponding wallboard plants using each feedstock are identified only with a code letter (power plant) or number (wallboard plant). Note that three of the wallboard plants listed in Table 8 were included in this project, but with different feedstocks or feedstock blends than were tested in Tasks 1 through 6.

Table 8. Mercury Analysis Results for Additional Synthetic Gypsum Feedstock Samples and Wallboard Produced from These Feedstocks

Power Plant	Wallboard Plant	Mercury Concentration in Synthetic Gypsum (μg/g dry basis)	Mercury Concentration in Product Wallboard (μg/g dry basis)	Apparent Mercury Loss Across Wallboard Plant (%)
G	4	0.10	0.07	32
C (70%) H (30%)	3	0.29	0.21	26
D (25%) I (75%)	1	0.99	0.40	59
J	5	0.23	0.20	13

The four wallboard plants were asked to collect representative samples of their feed material and of their product wallboard on a given day of operation. Both the feedstock samples and the corresponding wallboard samples were analyzed for mercury concentration.

The four synthetic wallboard samples were measured to contain approximately 0.10 to 1.0 μg/g of mercury, which is about the same range as was measured in Tasks 1 through 7 (0.13 to 1.1 μg/g). The four corresponding wallboard samples each had less mercury content than the feedstock samples, suggesting mercury loss percentages of 13% to 59% across the wallboard plants. This is again similar to the Task 1 through 7 results (2% to 55%). However, recall that using solid sample mercury analysis results to quantify mercury losses across wallboard plants can be prone to significant errors due to sample and analytical variability. For example, it was nearly impossible to ensure that a wallboard product sample was timed to exactly correspond with the mill feedstock previously sampled.

Table 9 shows the results of mercury analyses of natural gypsum feedstocks from ten USG plants that process only natural gypsum rock (no synthetic gypsum in the feed blend). The results are shown expressed in units of nanograms per gram (ppb) and μg/g (ppm), the latter to be comparable to the units shown for the synthetic gypsum analyses. The natural gypsum samples showed very low mercury concentrations, in the range of <0.004 to 0.026 μg/g. Even the highest natural gypsum mercury concentration was only about one-fourth of the lowest of the twelve synthetic gypsum mercury concentrations. Because the natural gypsum samples were expected to have very low mercury concentrations, no corresponding wallboard samples were requested from these ten plants.

Table 9. Mercury Analysis Results for Natural Gypsum Wallboard Feedstock Samples

	Average of Duplicate Analyses of Each Sample	
Natural Gypsum Sample Source	**(ng/g)**	**(μg/g)**
Wallboard Plant 6	11	0.01
Wallboard Plant 7	19	0.02
Wallboard Plant 8	13	0.01
Wallboard Plant 9	23	0.02
Wallboard Plant 10	23	0.02
Wallboard Plant 11	<4	<0.01
Wallboard Plant 12	10	0.01
Wallboard Plant 13	26	0.03
Wallboard Plant 14	<4	<0.01
Wallboard Plant 15	<4	<0.01

TCLP Results on Product Wallboard Samples from Commercial Wallboard Plants

Wallboard made from synthetic gypsum has an appreciable mercury content (ranging from 0.07 to 0.95 μg/g as measured in this project). A question has been raised as to how stable this mercury might be when the wallboard reaches the end of its product lifecycle and is disposed of in municipal landfills.

The potential of wallboard material to contaminate groundwater was tested on twelve wallboard samples produced from synthetic gypsum (two samples were tested from Task 4 due to the change in feedstock material), using the TCLP methodology. The TCLP leachates were analyzed for up to eight RCRA metals (arsenic, cadmium, chromium, lead, selenium, mercury, and [for some samples] barium and silver). The results of these analyses are summarized in Table 10.

Table 10. TCLP Results for Commercial Wallboard Samples Produced from Synthetic Gypsum at USG Plants

Task No.	Power Plant	Wallboard Plant	As (μg/L)	Ba (μg/L)	Cd (μg/L)	Cr (μg/L)	Pb (μg/L)	Se (μg/L)	Ag (μg/L)	Hg (μg/L)
1	A	1	3.0	NA[a]	0.60	1.7	<0.5	24	NA	<0.3
2	A	1	2.8	NA	10.9	1.5	<0.5	30	NA	<0.3
3	B	2	5.0	NA	2.9	4.7	<0.5	38	NA	<0.3
4 (Runs 1&2)	C	3	2.1	NA	1.1	2.7	0.5	334	NA	<0.3
4 (Run 3)	C (70%) G (30%)	3	1.6	NA	0.70	2.1	<0.5	215	NA	<0.3
5	E	4	3.0[b]	43[b]	5.0	4.7[b]	0.9[b]	24[b]	<0.05	<0.3
6[c]	E (with TMT)[c]	4[c]	<0.5	34[b]	2.4	13[b]	1.0[b]	45[b]	<0.05	<0.3
7	F	5	2.6	57	0.6	2.4	<0.5	151	<0.05	<0.3
-	G	4	<0.5	36[b]	4.5	11[b]	0.9[b]	29[b]	<0.05	<0.3
-	C (70%) H (30%)	3	<0.5	66[b]	0.6	10[b]	0.7[b]	133	<0.05	<0.3
-	D (25%) I (75%)	1	3.4	55[b]	1.6	11[b]	1.8[b]	59[b]	<0.05	<0.3
-	J	5	<0.5	36[b]	1.3	11[b]	1.0[b]	43[b]	<0.05	<0.3
Maximum Concentration for the Toxicity Characteristic (μg/L)			5,000	100,000	1,000	5,000	5,000	1,000	5,000	200

[a]NA – not analyzed
[b]Data flagged - blank levels were greater than 30% of result and results shown in table were not corrected for blank contribution
[c]This sample was run through the TCLP process in duplicate - results are reported as an average

The result show that none of the 12 wallboard samples produced measurable mercury concentrations in the leachate (<0.3 μg/L), and that leachate mercury concentrations are about three orders of magnitude, or more, lower than the maximum concentration allowed for mercury for the toxicity characteristic (200 μg/L).

Table 10 also shows results for other RCRA metals for the TCLP leachates from the twelve wallboard samples. Some of the leachate samples showed evidence of contamination in the blanks for some metals, as noted in a footnote to the table, but even with blank contamination all of the values were well below the maximum concentration allowed for the toxicity characteristic. Only for selenium did any of the samples approach the toxicity characteristic maximum concentration (one sample from Task 4 was measured at 33% of the maximum toxicity characteristic concentration and three more samples were within 13 to 22%).

These results suggest that mercury leaching from wallboard produced from synthetic gypsum will not be an issue if that wallboard is disposed of in municipal landfills. They also suggest that there will not be an issue with any of the RCRA metals with respect to exceeding maximum toxicity characteristic concentration, which, if exceeded could classify these materials as a hazardous waste.

CONCLUSIONS

Commercial Wallboard Test Results

The use of synthetic gypsum in making wallboard has long benefited the environment by recycling the FGD gypsum byproduct, decreasing the need to landfill and increasing the sustainable design of the wallboard product. In the future, increasing numbers of FGD systems will be operating in the U.S. in response to EPA's Clean Air Interstate Rule, signed on March 10, 2005, which calls for further reductions in sulfur dioxide emissions from coal-fired power plants. Correspondingly, greater amounts of synthetic gypsum will be produced either for re-use or landfill. The Clean Air Mercury Rule, signed by EPA on March 15, 2005 but then vacated by the D.C. Circuit Court on February 8, 2008, took into account the expectation that significant mercury emission reductions will be obtained as a "co-benefit" of increased control of SO_2 (and NO_X) emissions. This study investigated the potential for mercury to be released in the atmosphere at wallboard manufacturing plants when synthetic gypsum material is used as a feedstock for wallboard production.

Results, summarized in Table 5, are now available from seven full-scale wallboard plant tests, conducted as Tasks 1 through 7 of this project. Task 1 tested synthetic gypsum from a power plant that fires medium- to high-sulfur bituminous coal, has an SCR and an LSFO FGD system, and employs limited chloride and gypsum fines blow down (the FGD system operates at a relatively high liquor chloride concentration, and most of the fines remain with the bulk gypsum byproduct). Task 2 tested synthetic gypsum from the same power plant but produced while the SCR was not in service (catalyst bypassed). Task 3 tested synthetic gypsum from a power plant configuration similar to that tested in Task 1, but with a high chloride and fines blow down rate from the gypsum byproduct (low chloride concentrations in the FGD liquor and presumably fewer fines in the gypsum byproduct). Task 4 tested synthetic gypsum from a power plant that fires Texas lignite, has no SCR and no gypsum or chloride fines blow down. Task 5 tested synthetic gypsum from a power plant configuration similar to that tested in Task 3, in that the FGD system employs a high chloride and fines blow down rate, while Task 6 tested the same gypsum source but while the plant was using the TMT-15 additive in the FGD scrubber module. Finally, Task 7 tested synthetic gypsum from a power plant that fires PRB coal and has an SCR.

The results showed a wide range of percentage mercury losses from the synthetic gypsum feedstocks as measured by the Ontario Hydro method at the process stacks, ranging from 2% to 55% of the mercury in the gypsum feedstock. For the tasks exceeding 10% mercury loss across the wallboard plant, most of the loss occurred across the gypsum calciner. When total wallboard emissions remained below 10%, the primary emission location varied with a much less pronounced difference in emission between the gypsum dryer, calciner and board dryer.

With only seven sets of wallboard plant measurements available, it is difficult to draw firm conclusions about what variables impact the mercury loss percentages across the wallboard plants. Coal properties and FGD conditions evaluated in this study are summarized in Tables 3 and 4, respectively. For the bituminous coal synthetic gypsums it appears that the amount of blow down of chlorides and fine solid particles from the wet FGD systems has an impact, with higher purge rates at the FGD system leading to higher percentage mercury losses at the

wallboard plant. This effect is seen when comparing the high percentage mercury losses measured in Tasks 3, 5 and 6 (46 to 55%) with the lower percentage losses in Tasks 1 and 2 (5 to 8%).

But, higher purge rates also appear to produce gypsum with lower mercury concentrations, so the effect of fines blow down rates on mercury mass release rates are tempered. In order to determine the reason for the higher percentage mercury loss, further research to understand the physical and/or chemical association of the mercury with the gypsum particles is necessary to elucidate the mechanism of release. The oxidation state, phase and/or species of the mercury, along with potential surface phenomenon could all have some effect on the release of mercury. A better understanding of the mercury chemistry in the FGD system may provide some answers. One speculation is that, although lower concentrations of mercury are seen in the gypsum produced from systems with higher chloride and fines blow down rates, that mercury is more weakly adsorbed than mercury adsorbed to fine particles. Future work to characterize mercury losses from synthetic gypsum used for wallboard production should characterize FGD operation and chemistry conditions including coal type, fines blow down rate, chloride and other ion concentrations, gypsum particle size and even temperature and pH.

Results from this study indicate that there may be an effect of the coal rank fired at the power plant that produces the synthetic gypsum. Task 4 tested synthetic gypsum produced at a power plant that fires Texas lignite (a low rank fuel), and the results show lower mass and percentage mercury losses across the wallboard plant (approximately 2%) than for synthetic gypsum produced by power plants that fire bituminous coal. The Task 7 results did not support this trend, though. In testing with synthetic gypsum produced at a power plant that fires PRB coal (a low rank coal), the percentage mercury loss measured was well above that in Task 4, and in the middle of the range seen for synthetic gypsum produced by plants that fire bituminous coal.

Comparing the results from Tasks 1 and 2, little effect of having an SCR in service versus a bypassed SCR was seen in synthetic gypsum mercury concentrations or in percentage mercury loss across the wallboard plant (5% versus 8%). Similarly, no significant effect of whether the SCR was in service or bypassed was seen when comparing Task 5 and Task 6 results (55% versus 51%).

The hypothesis that led to the addition of Task 6 to the scope of this project was that an additive such as TMT-15 could precipitate mercury from the wet FGD liquor as a fine, thermally stable salt. This was expected to produce a benefit of reduced mercury release when the synthetic gypsum is used to produce wallboard. The results from Task 6 did not show such a benefit from TMT-15 addition. The percentage loss of mercury from the synthetic gypsum across the wallboard plant was measured to be very similar in Tasks 5 and 6, indicating no effect of TMT-15 (51% without TMT addition versus 55% with TMT).

It should be noted that information presented in Reference 16, found in the Reference section of this paper, showed that TMT-15 did not produce many expected results when added to the wet FGD system at Power Plant E. It appears that there was an interfering species or effect in the Power Plant E wet FGD system that prevented the TMT-15 additive from performing as intended. Thus, the results from Task 6 should not be interpreted as conclusively indicating that

TMT-15 has no effect on mercury release during wallboard production from synthetic gypsum. Under better circumstances, the anticipated effects of TMT-15 on mercury release during wallboard production may be realized.

In the results of all seven tasks, most of the mercury emissions from the mill were measured to be in the elemental form (Hg^0). These results are contrary to what was expected at the beginning of this project given that it is predominantly water-soluble oxidized mercury (Hg^{+2}) that is removed in wet FGD systems, while elemental mercury is virtually insoluble and not removed at significant percentages. The cause of this phenomenon has not yet been determined.

Overall, the measured mercury loss mass rates for these six tests ranged from 0.01 to 0.17 grams of mercury per dry ton of synthetic gypsum processed, or 0.01 to 0.4 pounds of mercury released per million square feet of wallboard produced. The individual results from Tasks 1 through 7 of this project would predict mercury emissions from the U.S. wallboard industry ranging from 0.2 to 2.7% of current power industry emissions.

However, the results from this project still represent a relatively small subset of the power plants, coal types, FGD conditions and wallboard plant conditions corresponding with synthetic gypsum use for wallboard production. Actual U.S. wallboard industry mercury emissions may vary from estimates made based on these results.

It should be noted that the results of this project were measured at USG wallboard plants that use indirect-fired kettle type gypsum calciners. Other calciner types, such as flash calciners where gypsum comes into contact with hot flue gas, may have different mercury release characteristics. In an indirect-fired kettle type gypsum calciner the gypsum does not come into direct contact with flue gas. An indirect-fired kettle calciner more gradually heats the gypsum as opposed to a flash calciner in which the calcination process occurs in a matter of seconds. In general, indirect-fired kettle type gypsum calciners are known to produce a more consistent product but flash calciners are considered to be more energy efficient. The different time-temperature profile to which the gypsum is exposed in these two calciner types may impact mercury release rates.

Laboratory Test Results

Laboratory simulated gypsum calcining tests, using a laboratory oven to calcine wet gypsum samples, did not produce mercury release rates similar to the full-scale test results. Not only did the percentage mercury losses not match the full-scale test results, but the trends in the results did not match. For example, the laboratory calcining tests with Task 4 wet gypsum samples showed the highest percentage mercury loss during the lab calcining tests, while the Task 4 full-scale results showed the lowest percentage loss of the six full-scale tests. It was concluded that a more sophisticated test apparatus would be needed to properly simulate mercury losses in a kettle calciner, one that better matches the residence time, heat transfer and mass transfer characteristics of a full-scale kettle calciner.

Laboratory analyses of additional synthetic gypsum and natural gypsum samples showed that natural gypsum has about one to two orders of magnitude lower mercury concentrations than synthetic gypsum. Within the analyses of the ten natural gypsum feedstock materials mercury concentrations ranged from <4 to 26 ng/g as provided in Table 9 of this report.

Wallboard produced from synthetic gypsum has mercury present in concentrations ranging from 0.09 to 0.95 μg/g as provided in Table 5 of this report. However, the results of TCLP testing of twelve wallboard samples suggest that mercury leaching from such wallboard will not be an issue when it is disposed of in municipal landfills at the end of its product use cycle.

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EDITED BY
Lei Xu,
Chinese Academy of Fishery Sciences (CAFS), China

REVIEWED BY
Susan Harrell Yee,
United States Environmental Protection Agency, United States
James S. White,
United States Geological Survey (USGS), United States

*CORRESPONDENCE
Kirk L. Krueger
kirk.krueger@dfw.wa.gov

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Fish habitat restoration and interannual variability in intensively monitored watersheds

Kirk L. Krueger[1]*, Daniel Auerbach[1], Eric J. Ward[2], Joseph H. Anderson[3], Robert E. Bilby[4], Timothy Quinn[1], Edward R. Pittman[1], William Dezan[1], William J. Ehinger[5], Michael L. McHenry[6], James S. Lamperth[7] and Marisa N. C. Litz[3]

[1]Habitat Science Division, Washington Department of Fish and Wildlife, Olympia, WA, United States, [2]Northwest Fisheries Science Center, National Marine Fisheries Service, Seattle, WA, United States, [3]Fish Science Division, Washington Department of Fish and Wildlife, Olympia, WA, United States, [4]Weyerhaeuser Corporation, Seattle, WA, United States, [5]Washington Department of Ecology, Lacey, WA, United States, [6]Lower Elwha Klallam Tribe, Port Angeles, WA, United States, [7]Fish Science Division, Washington Department of Fish and Wildlife, Kelso, WA, United States

The Western Washington Intensively Monitored Watersheds (IMW) study was designed to assess the cumulative effects of extensive stream habitat restoration over long durations at 'watershed' geographic extents. We conducted annual surveys from 2004 through 2024 at hundreds of randomly selected reaches ("sites") throughout 10 independent watersheds ("streams") clustered into 3 regional complexes. Our objectives were to describe cumulative change in habitat measures that are common aims of fish habitat restoration and to test for differences between watersheds with different restoration efforts. In most cases, we did not observe the expected directional changes in habitat measures summarized to whole-watershed extents nor did we observe the expected differences relative to the level of restoration effort. However, we did observe high interannual variation in fish habitat measures. The magnitude of these year-to-year fluctuations was frequently much greater than observed long-term trends. Despite physiographic differences among study watersheds, all watersheds exhibited substantial spatial variation among sites in the degree of interannual variation, indicating a widely shared pattern of within-watershed heterogeneity in habitat stability. Our results underscore the importance of anticipating and accounting for year-to-year changes in stream habitat when assessing habitat conditions and planning and implementing fish habitat restoration.

KEYWORDS
salmon, habitat, restoration, temporal, variability, watershed

1 Introduction

Restoration and enhancement of streams and watersheds is an important focus of natural resource management (Wohl et al., 2015), and monitoring is essential to evaluate whether restoration investments are yielding desirable outcomes (Palmer et al., 2007). However, there have been few empirical evaluation demonstrating that restoration projects individually or cumulatively achieve their goals (Johnson et al., 2005; Palmer et al., 2005;

Bernhardt and Palmer, 2011) often due to insufficient monitoring (Bernhardt et al., 2007; Roni et al., 2008). Improved understanding of why past efforts have not been as effective as anticipated can improve the success of future restoration. The state of Washington has established regulations meant to protect the processes that create and allow access to fish habitat across most private, state, county, and municipal lands (e.g., Forest Practices Act – RCW 76.09, Hydraulic Code – RCW 77.55, Growth Management Act – RCW 36.70A), and billions of dollars have been invested in restoration projects that include treatment types such as culvert removal and replacement, channel realignment, floodplain reconnection, bank armor removal, and placement of engineered logjams or other large woody debris. Many stream habitat restoration projects include more than one type of treatment and projects are often part of a watershed restoration plan that can take many years to complete. However, most assessments of restoration effectiveness in the region have examined outcomes of individual projects, often including only one treatment type, over short durations of 1–5 years (Roni et al., 2008; O'Neal et al., 2016; ISRP, 2025). Such studies have provided valuable information regarding the local influence of particular restoration treatments on channel form, but assessment of longer-term cumulative effects at watershed extents remains a critical research need to inform restoration planning, funding, and monitoring programs (Bilby et al., 2024; Bisson et al., 2024).

Watershed-scale studies that include habitat monitoring may be the best means of reliably assessing relations between habitat restoration and fish population responses because many complex relations that affect fish freshwater survival occur at watershed extents (Roni, 2005). Yet long-term data collection at whole-watershed, riverscape scales (Fausch et al., 2002) poses major logistical challenges, and few such studies have been undertaken. To address this need, the Washington Salmon Recovery Funding Board (SRFB) began funding the Western Washington Intensively Monitored Watersheds (IMW) study in 2003. The IMW study is a long-term, multi-watershed experiment conducted by a collaboration of federal, state, tribal, and private industry scientists that couples the collection of instream and other habitat data with salmon life cycle monitoring in each of several adjacent watersheds at 3 regionally separated "complexes" (Bennett et al., 2016). The IMW study was designed to detect responses attributable to restoration by concentrating restoration and monitoring in adjoining similar watersheds (Figures 1–3).

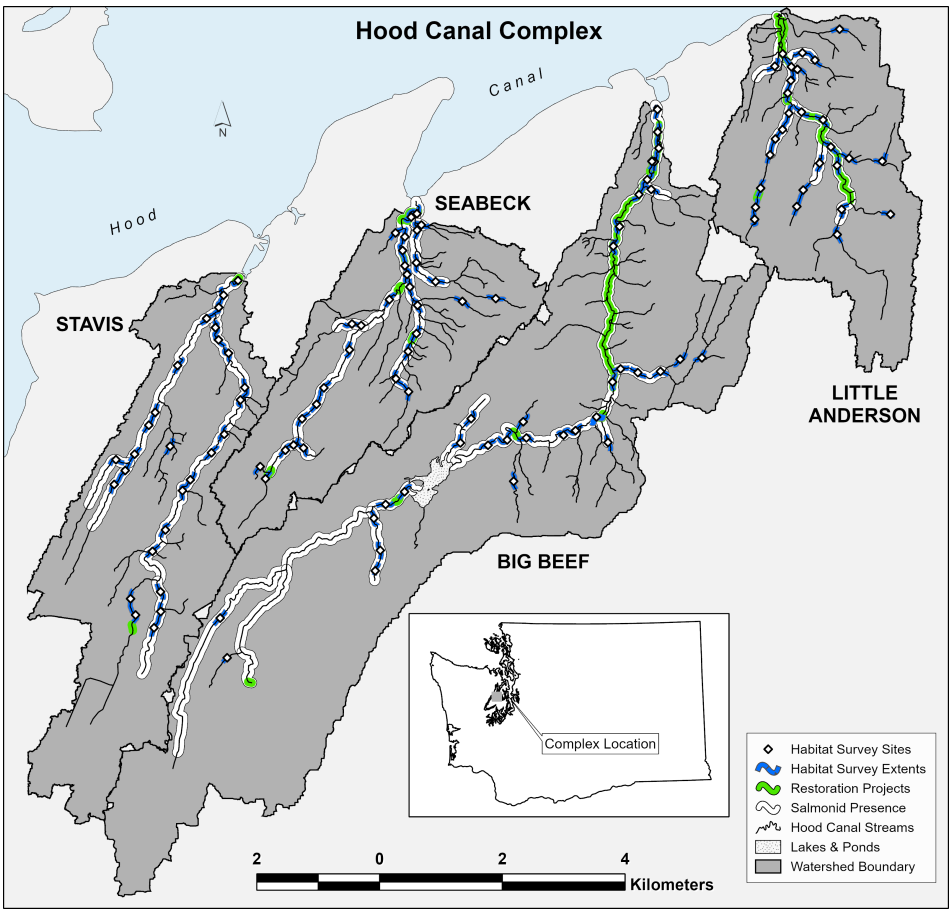


FIGURE 1
Map of the Little Anderson, Big Beef, Seabeck, and Stavis creek watersheds showing locations and spatial extents of restoration sites (green circles) and reaches (green fill), survey sites (blue fill), extent of observed presence of Coho salmon and steelhead (white fill), in streams, lakes, and ponds in the Hood Canal complex.

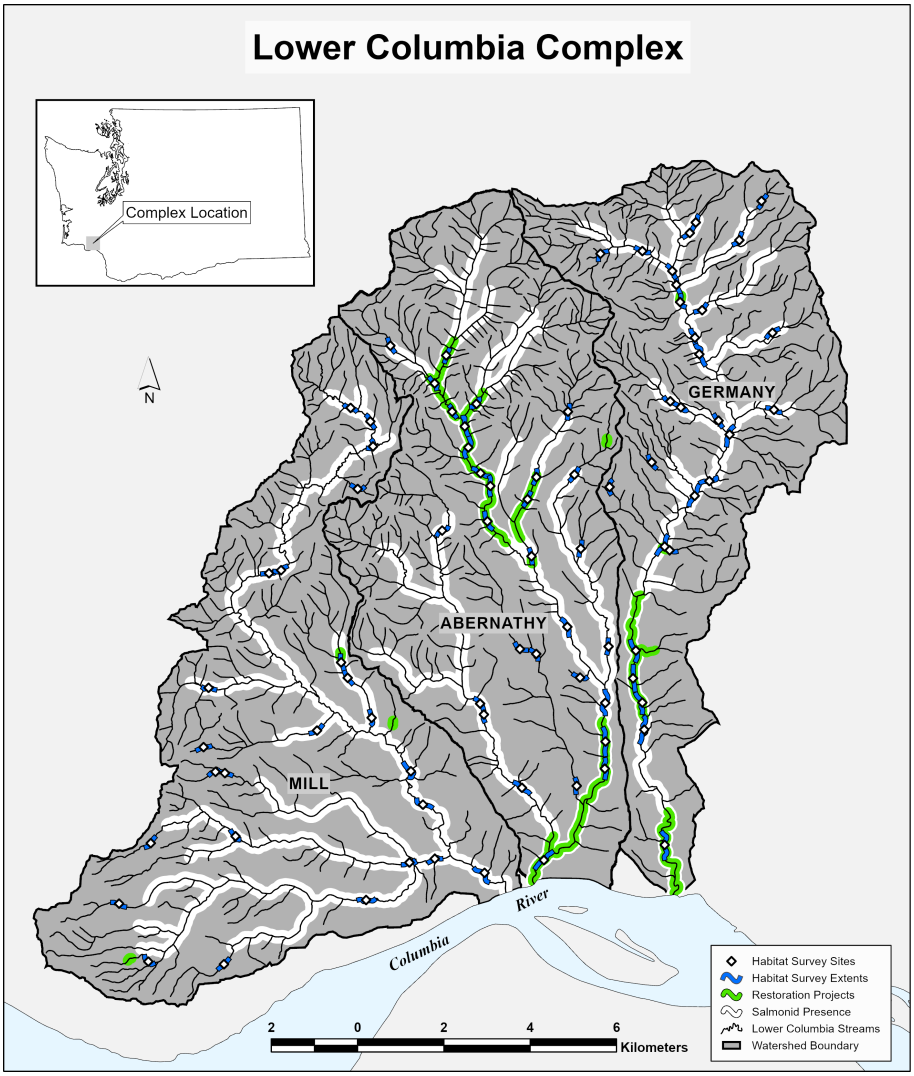


FIGURE 2
Map of the Germany, Abernathy, and Mill creek watersheds showing locations and spatial extents of restored sites (green circles) and reaches (green fill), survey sites (blue fill), and observed presence of Coho salmon and steelhead (white fill) in streams, lakes, and ponds in the Lower Columbia complex.

This paper provides an overview of the habitat monitoring undertaken in these watersheds and describes primary findings relative to the original study design and objectives. We report on 6 common instream habitat measures collected during our long term, spatially extensive, methodologically consistent study. These measures of large instream wood, abundance and depth of pools, abundance of gravel, and bankfull channel geometry are widely used to assess conditions for fish, establish restoration objectives, and gauge restoration effectiveness. We summarize measures at the whole-watershed extent and test for the cumulative effects of multiple projects over a nearly two-decade duration, comparing trends in watersheds with different restoration effort. We anticipated that some trends in treated watersheds would diverge from reference watersheds. In addition, basic properties of these measures are presented at the site scale to illustrate the among-site heterogeneity that was common across watersheds and that affects detection of watershed scale responses.

2 Materials and methods

2.1 Study area

The IMW study has been conducted in ten small watersheds grouped into three complexes (Table 1). The Hood Canal Complex (HC) includes Little Anderson, Big Beef, Seabeck and Stavis (reference) creeks, which drain generally north into the marine waters of western Puget Sound (Figure 1). Surface geology of HC is primarily glacial till and glacial outwash. The Lower Columbia Complex (LC) includes Germany, Abernathy, and Mill (reference) creeks, which drain generally south into the Columbia River between the larger Elochoman and Cowlitz rivers (Figure 2). Surface geology of LC is primarily basalt. The Strait of Juan de Fuca Complex (ST) includes East Twin and West Twin (reference) rivers and Deep Creek, which drain generally north into the marine waters of the western portion of the Olympic peninsula (Figure 3).

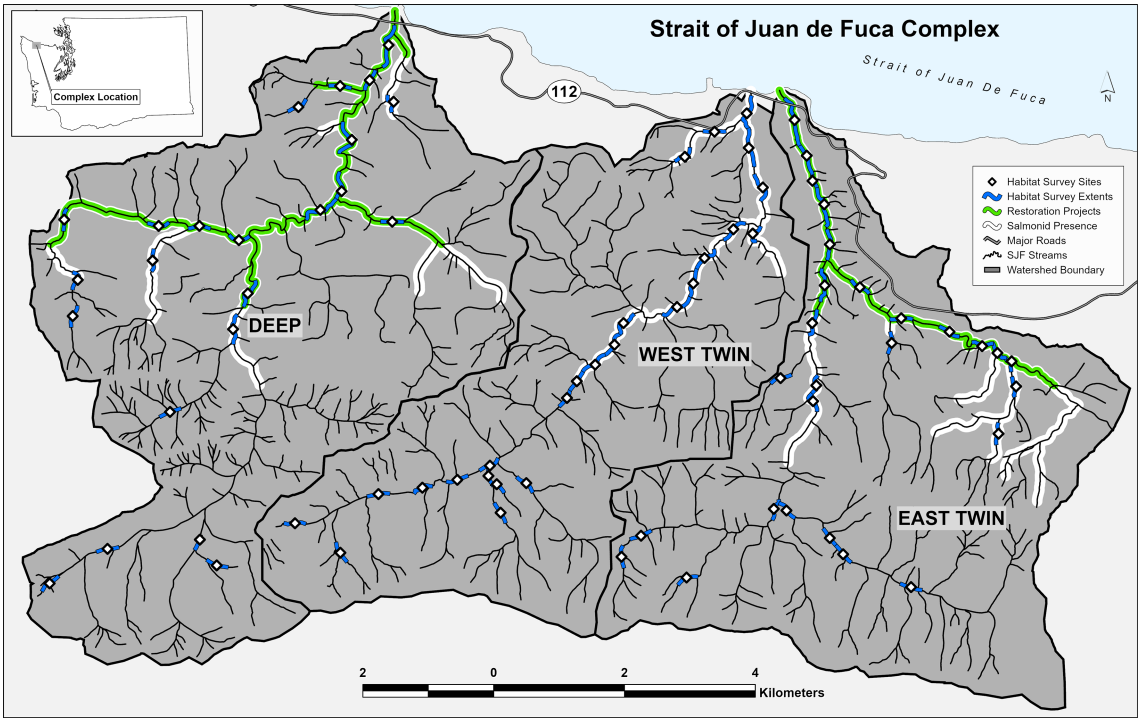


FIGURE 3
Map of the East Twin River, West Twin River, and Deep Creek watersheds showing locations and spatial extents of restored sites (green circles) and reaches (green fill), survey sites (blue fill), and observed presence of Coho salmon and steelhead (white fill) in streams, lakes, and ponds in the Strait of Juan de Fuca complex.

Surface geology of ST is primarily marine sedimentary rock, glacial till, and basalt. These small watersheds are primarily forested and experience a rainfall-driven hydroclimate typical of western Washington, with relatively dry summers and wet winters. Extensive timber harvest in all treatment and reference watersheds began as early as 1870 and continues today. Past logging activities included log drives (prior to 1950) and deliberate removal of instream wood through the 1980s. These activities caused many reaches to become single-thread plane-bed, incised or entrenched channels following Buffington and Montgomery (2013). All reference and treatment watersheds are subject to regulations intended to protect, improve, and allow access to fish habitat (e.g., Washington Forest Practices Rules - Title 222 WAC, Washington Hydraulic Code Rules – WAC 220, Washington Growth Management Act – RCQ36.70A). Ownership is a mosaic of public and private land, and all watersheds, including reference

TABLE 1 Watershed area (ha), Strahler stream order, total stream length (km), maximum elevation (m), total and mean annual number of survey sites, number of survey sites across all years, number of restoration projects, intersections of survey sites and restoration projects, and percent of stream treated where use by anadromous salmon has been observed used in analyses in the Hood Canal, Lower Columbia, and Strait of Juan de Fuca IMW complex watersheds from 2007 through 2019.

	Hood canal				Lower Columbia			Strait of Juan de Fuca		
Measure	LA	BB	SE	ST*	GR	AB	ML*	ET	WT*	DP
Area	12.9	36.6	13.3	17.4	58.6	75	75.8	36.2	33.9	44
Strahler order	3	3	4	4	4	5	5	5	4	4
Reach length	28.4	58	35.1	32.3	204.8	252.4	215.4	89.7	92.8	103.8
Maximum elevation	117	151	113	126	362	285	273	425	340	304
Total surveys	357	398	393	367	343	366	349	291	295	265
Mean annual	25.5	28.2	27.8	26.2	24.4	25.9	25	22.4	22.7	20.4
Sites	27	32	31	28	28	30	25	24	24	20
Projects	6	4	7	2	12	17	3	3	0	7
Intersects	11	10	8	1	19	21	1	22	0	19
% treated	39	21	3	0	15	25	0	41	0	60

Reference watersheds symbolized by asterisks.

streams, are subject to management outside of the IMW study with the potential to affect riverscape processes (e.g., culvert replacement due to road maintenance).

2.2 Study design

At the request of the SRFB the IMW watersheds were selected for this study by IMW scientists to allow comparisons across different restoration effort and physiography. Surface geology, land cover, channel lengths, and channel profiles were generally similar within each complex. Small, low elevation, independent watersheds were chosen with the goal of concentrating restoration and monitoring during the study, and to thereby increase the likelihood of generating detectable habitat and fish population responses. Fish population responses are discussed by Anderson et al. (2019, 2025), Lamperth et al. (2026), and Peters et al., 2026.

We identified habitat survey locations (hereafter sites) using a random, spatially balanced design that was stratified by stream order (Stevens and Olsen, 2004; Larsen et al., 2008). Survey sites were located to provide unbiased estimates of annual watershed-scale habitat conditions. Habitat survey field methods were based on Lazorchak et al. (2000) and Roper et al. (2003) and were very similar to those used by the Oregon Coastal Coho Survey (Anlauf et al., 2009). Since 2004 surveys have been conducted between June and October when rain is rare and stream flows are stable to minimize effects of flow on habitat measures. Following analyses of data collected in 2004 – 2006, in 2007 we adjusted our sampling frame to avoid very small channels where resident and migratory fish were infrequently observed, and we began annually resurveying the same sites in each watershed to increase efficiency (Roper et al., 2003). Surveys were conducted in a different watershed each week and survey order was intentionally irregular to reduce temporal bias.

We analyzed 4,421 habitat surveys completed at 269 sites that were surveyed 5 or more times during the 18-year period from 2007 through 2024. Sites were surveyed a median of 17 years, and 231 sites were resampled in at least 16 years. About 25 sites were surveyed in each watershed in every year (Table 1). The set of sites surveyed differed slightly among some years in some watersheds as sites became inaccessible or were added to increase sample size following the random, spatially-balanced design. The ST Complex was not surveyed in 2017 due to funding constraints.

2.3 Field surveys

From 2007 through 2024, survey data were collected by sixty-six scientific technicians. Typically, one team of two technicians completed all surveys in a complex in a year. Occasionally a team would assist in a different complex to help meet annual sampling goals. Several technicians completed multiple years of surveys. In the LC Complex almost all data collected from 2004 through 2021 were collected by the same lead and two assistant technicians, reducing the likelihood that different observers were primary contributors to interannual variation. Annual training and fieldwork were led by only two biologists throughout the study, the first from 2004 through 2019 and the second from 2019 through 2024. Regardless of experience, all scientific technicians were trained or retrained in the study's survey methods before data collection every year (Krueger et al., 2020).

The centers of survey sites were marked with T-posts and tree tags to aid relocation. Sites were relocated annually using GPS, maps, photographs, and directions to the site from previous surveys. At each site, samples consist of measures and counts made at and between 21 transect cross sections (hereafter transect), positioned equidistantly and perpendicular to flow along a reach length that is the longer of either 40 bankfull widths or 300 m, allowing survey length to increase for larger (wider) reaches. Bankfull width was measured at each transect by locating bankfull indicators across the site. Indicators included abrupt bank slope changes, scour lines, changes in vegetation and vegetation age, and the surface elevation of depositional features such as mid-channel bars. Measurements at each transect included bankfull width (to the nearest 0.1 m), bankfull depth (bankfull height to stream bed to nearest 0.01 m) water depth (≥5 points to the nearest 0.01 m), and tallies of surficial grain size classes. Substrate was classified at approximately 5 points per transect as either smooth bedrock or rough bedrock (> 4000 mm), boulder (250–4000 mm), cobble (64–250 mm), coarse gravel (16–64 mm), fine gravel (2–16 mm), sand (0.06–2 mm), fines (< 2 mm), hardpan, wood, or other. Pieces of wood within the bankfull channel between transects were counted and assigned to length (1.5–5.0, 5.0–15.0, >15.0 m), and diameter (0.1-0.3, 0.3-0.6, 0.6-0.8, >0.8 m) classes. The number of intersections of side channels and backwatered habitats with transects were recorded. When found, dry channels were sampled and all possible measurements were made (e.g., depth was not measured). This protocol enables calculation of various measures commonly used to assess stream fish habitat (e.g., Roper et al., 2010; Al-Chokhachy et al., 2011; Anlauf et al., 2011; Roper et al., 2023). Additionally, a sketch was made depicting the location and size of in-channel and channel-bridging wood, pools, and other stream features relative to each transect, and digital photographs were taken from the center of the survey site following a standardized protocol and where novel conditions were observed. Sketches and georeferenced photographs aided in data entry, quality control, and interpretation of survey results by providing visual references to individual data points. Data sheets and photographs were collected by the biologist every 1 to 3 weeks to allow review and correction prior to additional data collection and data entry. Data entry was performed by a scientific technician who had collected field data. The technician was supervised by the biologist and a data manager. The data manager developed and maintained a database that standardized data entry, limited errors (e.g., allowing for only positive numbers with the correct significant figures to be entered), and ensured data integrity. Summary statistics and figures describing annual results for several habitat measures were calculated and examined annually to identify possible errors and statistical outliers allowing for their investigation and correction. After a preliminary analysis of data collected from 2004 through 2006, we removed habitat measures that appeared difficult to replicate from subsequent surveys (i.e., the data presented here).

2.4 Habitat restoration treatments

Restoration projects are human actions intended to improve fish habitat or access to habitat by altering a channel, floodplain, or

riparian area or the flows of water, sediment, or wood into streams (Bennett et al., 2011). The IMW study design did not control the locations, sequence, or types of restoration performed, relying on local restoration organizations to select and implement projects. Watershed assessments and project design and location were led by local collaborative restoration groups as part of the state government strategy to recover salmon, referred to as the "Washington Way" (Smitch et al., 1999). Some projects were initiated prior to our study, some restoration project locations and designs were aided by IMW scientists, and some were implemented outside the SRFB process. For example, a few barrier culverts were replaced following road maintenance schedules. As a result, restoration projects took many forms, included one or several treatments, and were not necessarily spatially independent. However, the composites of projects, treatment types, and timing allowed assessment of the cumulative effects of stream habitat restoration as it often occurs in practice. We identified and described restoration projects by annually contacting state, county, tribal, and private sources, searching for project proposals, and conducting field surveys. We delineated project extents based on field surveys and restoration project proposals and completion reports. Project treatments included removing and replacing bridges and culverts, channel realignment and repositioning, bank armoring and armor removal, engineered logjam placement, anchored and unanchored LWD placement, side channel and floodplain reconnection, road abandonment, and others. Projects extended several meters to several kilometers, were implemented in one or more years, and were located alone, completely within, or partially within one or more other project footprints. Although benefiting fish was not always the objective of culvert replacements and removals, we considered them as restoration projects because of requirements to meet fish passage criteria (WAC 220-660-200) and the potential to improve fish habitat (Lehrter et al., 2024). We calculated the percent of accessible salmonid (including resident trout) habitat treated by comparing the sum of restoration project extents that intersect the extent of each stream from the most upstream locations where salmonids have been observed to their outlets. Some restoration occurred upstream of mapped upstream extent of salmonids. Several non-salmonid fish (e.g., Longnose dace *Rhinichthys cataractae*, sculpin *Cottus* sp.) are native to IMW watersheds, but their geographic distributions are poorly described and restoration is not specifically intended to benefit them.

2.5 Data analysis

2.5.1 Habitat measures

The IMW scientists assumed that all study watersheds would be recovering from historical forest practices and hypothesized that watersheds with greater restoration effort would have faster increasing trajectories relative to reference watersheds for one or more of six habitat measures. Measures characterized important freshwater habitat conditions for salmonids. First, very large wood debris density (VLWD) was the total count of pieces > 5 m long and > 0.3 m in diameter at each site standardized to pieces per 100 m of stream. Second, VLWD Volume was calculated as the total volume of all pieces of VLWD standardized to volume per 100 m of stream. Very large woody debris was selected because larger woody debris was expected to be less prone to counting errors and less frequently transported than smaller woody debris. Third, proportion gravel (Gravel) was the proportion of samples of surface substrate at each site classified as either fine gravel or coarse gravel, sizes suitable for salmonid spawning. Fourth, pool incidence (Pools) was the proportion of the (usually 21) transects at each site that intersected a pool, defined as a deep, low velocity (unbroken surface) section of stream relative to the reach it is in, with length ≥ wetted width. Pool type (e.g., plunge, lateral scour, etc.) was recorded to promote careful identification of pool occurrence. Fifth, mean pool depth (Pool Depth) was the mean of the maximum depth measured in each transect that intersected a pool at a site. Our definition of pools was expected to identify relatively large and persistent pools that provide important fish habitat. Finally, at each site, we calculated the ratio of bankfull width to bankfull depth (W:D) as the mean of the estimate across all transects. Larger values are generally associated with better fish habitat (e.g., Jones et al., 2014; Roper et al., 2019) especially in the many simplified, single-thread, entrenched reaches in our study watersheds. Generally low W:D in many reaches describes entrenched channels that are disconnected from their floodplains and increasing W:D describes greater connectivity to the floodplain, but this can differ among reaches and alternatively indicate deposition and bank erosion. Improving these fish habitat measures are commonly stated objectives of restoration plans. Each measure was calculated for each site and year when the site was surveyed. Side channel and backwater frequency analyses are not provided because in these watersheds they remain very rare.

2.5.2 Statistics

Means and standard deviations of each measure were calculated at the watershed extent across the study duration to describe differences in habitat conditions between watersheds and watershed complexes (Table 2). A primary concern of the analysis was reducing the risk of failing to detect trends due to the cumulative effects of restoration. Following extensive exploratory analysis, trends in the habitat measures within each watershed were assessed with Mann-Kendall (M-K) tests as a simple and robust non-parametric approach to detect persistent directional change (monotonic increase or decrease) without assuming a specific distribution. To account for the temporal autocorrelation evident in many of the time series of yearly watershed-scale averages, all trend calculations used the modified M-K test in "rtrend::mkTrend" (Kong and Song, 2024), which implements the approach of Hamed and Rao (1998). A significant ($p \leq 0.05$ and 0.10) M-K test statistic indicated that the estimated trend was unlikely due to random variation. We did not correct for multiple testing due to our emphasis on avoiding Type II errors of failing to detect trends where present. We used Sen's slope (Sen, 1968), commonly paired with the M-K test, to estimate the annual rate of change in each habitat measure. Values of Sen's slope describe the magnitude and direction of trend as the median of all possible two-point slopes in the time series. Sen's slope can be interpreted as the characteristic rate of change of a habitat measure per year.

TABLE 2 Mean and *SD* of habitat measures in ten watersheds in three watershed complexes from 2007 through 2024.

	Hood Canal				Lower Columbia			Strait of Juan de Fuca		
Measure	LA	BB	SE	ST*	GR	AB	ML*	ET	WT*	DP
VLWD	8.3	6.8	6.9	11.1	4.2	5.6	5	14.5	10.7	12.5
	3.8	*3.8*	*3.9*	*4.8*	*2.9*	*3.7*	*2.8*	*8.6*	*5.1*	*5.4*
VLWD vol	27.8	23.3	23.4	40.3	18	25.5	19.5	58.2	46.2	53.2
	14.5	*16.4*	*16.5*	*21.2*	*12.2*	*25.5*	*12.7*	*43.8*	*28.5*	*32.9*
% pools	18.7	35.1	16.7	29.6	22.3	23.5	27.9	35.4	32.5	38.4
	10.3	*15.2*	*14.2*	*12.4*	*6.6*	*13.2*	*13.5*	*7.1*	*10.7*	*10.9*
Pool depth	0.18	0.36	0.18	0.31	0.46	0.45	0.35	0.40	0.42	0.40
	0.10	*0.18*	*0.10*	*0.15*	*0.24*	*0.15*	*0.20*	*0.14*	*0.17*	*0.20*
% gravel	62.3	62.7	67.1	63.8	23.4	25.4	27.9	48	45.6	45.7
	10.5	*14.0*	*8.0*	*9.7*	*9.3*	*10.3*	*17.7*	*9.4*	*11.3*	*15.1*
Bankfull W:D	11.7	15.3	12	14.8	13.4	13.9	10.6	14.7	14.5	13.8
	3.5	*5.7*	*3.9*	*3.3*	*4.8*	*4.4*	*3.0*	*4.1*	*4.1*	*4.0*

Reference watersheds symbolized by asterisks.

To further examine change through time relative to restoration, we fit per-complex Bayesian regressions of each annual watershed-scale habitat measure against the stream-year interaction, allowing intercept and slope effects per stream with AR(1) autocorrelation in the year (R version 4.5.1, R Core Team 2025; package `brms` 2.23.0, Bürkner, 2017). Pool incidence and proportion gravel were specified with a beta response family whereas the remaining measures were specified with a lognormal distribution. All models used relatively uninformative priors. Model diagnostics showed good convergence with 4 chains with 3000 iterations each. In addition to examining posterior predictions and coefficient estimates, we compared the distribution of year effect coefficients among each treatment-reference combination using Bhattacharyya coefficients (Guillerme, 2025). This quantified the overlap in the estimates of year effects, thereby assessing consistency or deviation in both the central tendency and variability of the estimated slopes.

Finally, the overall interannual variability of habitat measures within watersheds was described by calculating the range (maximum – minimum) over the study duration at each survey site in each watershed. From the sample distributions across sites of these ranges in habitat measures, the medians, interquartile ranges, and 95% spans enabled a comparison of the spatial variation in temporal variability within and between watersheds.

3 Results

3.1 Change through time in watershed-scale measures

We found relatively weak trends corresponding to small changes in most measures over the eighteen-year study period, with M-K values significant for 21 of 60 watershed-scale measures at $p < 0.10$, and 17 of 60 at $p < 0.05$ (Table 3). Both increases and decreases through time were evident (Table 3; Figure 4). Within complexes, the direction and magnitude of trends in most measures was typically similar among watersheds regardless of restoration effort (Table 3; Figure 4). Only Abernathy Creek had significant increases in VLWD density or VLWD Volume even though large wood placement was a common restoration treatment in all treated watersheds. Pool frequency increased in Little Anderson, Big Beef, Stavis (reference watershed) and Seabeck creeks, and in East Twin River. However, pool depths decreased in Little Anderson, Big Beef, Seabeck and Deep creeks. The proportion of gravel increased in Little Anderson Creek, East Twin River, West Twin River (reference), and Deep Creek. Bankfull W:D increased in Little Anderson Creek, Germany, Deep and Abernathy creeks, and in East Twin River and West Twin River.

Median annual rates of change for habitat measures with significant trends, as described by Sen's slope, were generally small and often similar between treated and reference watersheds (Table 3) despite the extent of restoration projects and their intersection with survey sites (Table 1; Figures 1–3). For example, the relatively large, significant trend for VLWD in Abernathy Creek (Sen = 0.32) equates to roughly one new piece of VLWD per 100 m every three years, or an average total increase in VLWD density of approximately 6 pieces per 100 m over the study duration (Δ = 5.84). The largest change in pool incidence was in Big Beef Creek (Sen = 0.012), followed by the reference Stavis Creek (Sen = 0.009). This relatively large change in pool incidence corresponded to an increase of approximately 1% a year or about 2 of 21 transects newly intersecting a pool per site over 18 years. Seabeck Creek had the largest change in pool depth (Sen = -0.006) where it decreased by about 10%. The largest change in gravel was in Deep Creek (Sen = 0.009) where it increased by about 16%. The largest change in W:D was in East Twin River (Sen = 0.20) where it increased by about 3.5.

Estimates from Bayesian modeling of watershed-scale habitat measures also failed to indicate clear differences among watersheds

TABLE 3 Sen's slope (trends), Mann-Kendall test for trend p-value, and estimated total change due to trends of six stream habitat measures in ten watersheds in three watershed complexes in Washington from 2007 through 2024.

		Hood Canal				Lower Columbia			Strait of Juan de Fuca		
Measure	Statistic	LA	BB	SE	ST*	GR	AB	ML*	ET	WT*	DP
VLWD	Sen	-0.04	-0.06	0	-0.14	0.05	**0.32**	0.05	0	-0.11	-0.07
VLWD	p	0.88	0.4	0.94	0.4	0.6	**0**	0.36	1	0.59	0.42
VLWD	Δ	-0.64	-0.99	0.04	-2.48	0.91	**5.84**	0.96	0.02	-1.9	-1.21
VLWD vol	Sen	0.15	0.14	0.21	0.08	-0.12	**0.99**	-0.25	-0.84	-0.47	-0.94
VLWD vol	p	0.7	0.7	0.54	0.88	0.45	**0.08**	0.5	0.43	0.48	0.54
VLWD vol	Δ	2.76	2.54	3.84	1.38	-2.13	**17.77**	-4.51	-15.14	-8.37	-16.96
% pools	Sen	**0.007**	**0.012**	**0.005**	**0.009**	0.001	0	0	**0.005**	0.004	0.003
% pools	p	**0**	**0.01**	**0.1**	**0**	0.88	0.91	1	**0**	-	0.16
% pools	Δ	**0.13**	**0.22**	**0.1**	**0.16**	0.01	0	0.01	**0.1**	0.07	0.05
Pool depth	Sen	**-0.004**	**-0.003**	**-0.006**	-0.004	0.001	0	-0.001	-0.001	-0.003	**-0.004**
Pool depth	p	**0**	**0.01**	**0.02**	0.23	0.88	0.76	0.5	0.59	0.27	**0.01**
Pool depth	Δ	**-0.068**	**-0.061**	**-0.103**	-0.068	0.016	-0.007	-0.018	-0.02	-0.05	**-0.077**
% gravel	Sen	**0.004**	0.003	-0.001	0.002	0.01	0.006	0.006	**0.008**	**0.008**	**0.009**
% gravel	p	**0.095**	0.2	0.5	0.15	0.35	0.63	0.38	**0.02**	**0.05**	**0.01**
% gravel	Δ	**0.06**	0.05	-0.02	0.04	0.18	0.1	0.1	**0.15**	**0.15**	**0.16**
Bankfull W:D	Sen	**0.18**	0.01	0.09	0.08	**0.18**	**0.12**	0.06	**0.2**	**0.18**	**0.15**
Bankfull W:D	p	**0.02**	0.63	0.4	0.29	**0**	**0.01**	0.16	**0.02**	**0.04**	**0.09**
Bankfull W:D	Δ	**3.26**	0.26	1.58	1.45	**3.23**	**2.1**	1.16	**3.53**	**3.2**	**2.78**

Reference watersheds symbolized by asterisks. Significant ($p \leq 0.10$) trends are bold.

in the magnitude and direction of trends relative to restoration (Figure 4). In most cases, differences among streams within each complex that were apparent in 2007 persisted throughout the study. Among watershed relationships in the median posterior predicted values were usually maintained throughout the study, even as the absolute level of the values changed (i.e., parallel increases and decreases in Figure 4). Directional change in many measures was weakly discernible and quite uncertain, with posterior distributions and both 95% and 50% credible intervals for the per-watershed effects of year centered on 0 and usually overlapping within complexes (Figure 5). Bhattacharyya coefficient values were near one for most habitat measures in most complexes, indicating little disparity in estimated directional change coefficients for comparisons between treated and reference watersheds (Table 4).

Posterior predictions for pool frequency showed modest increases in all the HC watersheds (Figures 4; 5G), but trends were similar among treatment and reference watersheds (Table 4). A modest decrease in pool depth was evident for Little Anderson Creek (Figures 4, 5J), but trends were again similar among all treatment watersheds and their references (Table 4). The proportion gravel showed little evidence of trend in the HC watersheds, but Seabeck Creek had a modest decrease while the others were slightly increasing. Directional change in these measures in the LC and ST watersheds was also largely similar among treatment and reference watersheds (Figures 4, 5; Table 4). Bankfull W:D differed substantially in Little Anderson Creek versus its reference watershed, Stavis Creek, and in Germany Creek relative to its reference watershed, Mill Creek. All watersheds other than Big Beef Creek showed moderate evidence of increasing bankfull W:D (Figures 4, 5P, Q), suggesting that many channels became wider and shallower. We found strong evidence of increased VLWD density and volume in Abernathy Creek that differed substantially from trends in Mill Creek, the reference watershed, with no overlap in 50% credible intervals (Figures 4, 5B) and the lowest Bhattacharyya coefficient values in the analysis (Table 4).

3.2 Interannual variability

All watershed-scale habitat measures exhibited substantial interannual variability, frequently reversing the direction of change from preceding years (Figure 4). However, within watersheds some sites were relatively stable while others fluctuated from year to year in some or all measures throughout the study (Figure 6). The ranges of VLWD density and volume were highest in the ST watersheds, where the median among sites was a range of approximately 25 pieces per 100m. In contrast, the LC watersheds had the narrowest distributions of large wood variation over years, with many sites experiencing a difference of less than 10 pieces per 100m. While some ST sites had ranges <10 pieces per 100m a few LC sites differed by >20 pieces per 100m. Ranges in per-site pool

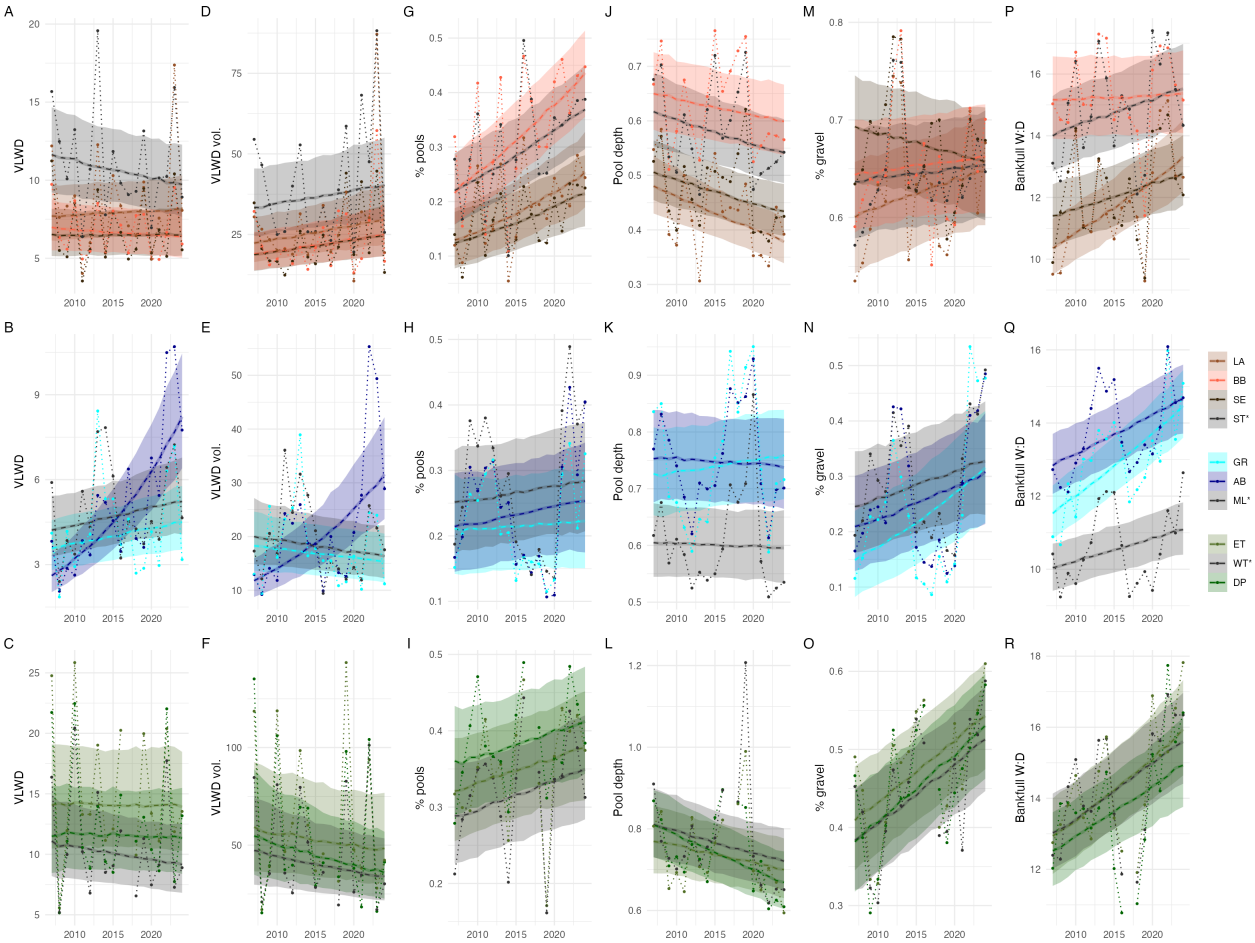


FIGURE 4
Annual whole watershed habitat measures. Panel columns show each measure, and panel rows show each complex. Panel labels **(A–R)** identify each combination of habitat measure and complex in Figures 4 and 5. Observed values per-watershed are shown as dashed lines and points (per-year arithmetic mean across sites), overlaid with posterior predicted values of Bayesian regressions of the measure value against the stream-year interaction per complex (solid line shows median with ribbon of 50% credible interval). Reference watersheds in each complex (ST*, ML*, WT*) are illustrated with light grey; all other colors show treatment streams. Interannual variation is evident in the trajectories of dashed lines of observed measures, and the lack of differences in estimated trends between treatment and reference is shown by the prevalence of parallel fitted solid lines. Large wood measures in Abernathy Creek (dark blue, middle row, left two columns) highlight the strongest detected restoration effect.

prevalence through time spanned differences of less than 30% (most common in Seabeck and Little Anderson creeks) to more than 50% in all watersheds, with many sites in Hood Canal and Mill Creek experiencing differences of more than 70% between the years with the lowest and highest pool frequency. The smallest average range in per-site pool prevalence was more than 30% in Seabeck Creek, with most watersheds approaching 50%. These values meant that a given site might have varied from 5 of 21 transects intersecting a pool in a year to 15 of 21 in another. When pools occurred at a site, the average depths differed between years by 0.25 to 0.35 m, but at least a few sites in most watersheds had average pool depths that differed by nearly a meter over the course of the study. The range of substrate samples at a site that were gravel was greater than 25% in most sites, and averaged close to 50% in the LC and ST streams. Width-to-depth ratios were surprisingly variable at some sites in all watersheds. On average, per-site W:D differed by about 10 during the study. A W:D range of 10 could be due to a site with bankfull width of 6 m decreasing depth from 0.3 m to 0.2 m due to deposition or a site with bankfull depth of 0.5 m increasing bankfull width from 1 m to 6 m. Collectively, the per-site heterogeneity in the ranges of habitat measures over the duration of the study demonstrated the occurrence of relatively stable and highly variable reaches throughout the stream networks of all complexes.

4 Discussion

The Western Washington IMW study assessed the effectiveness of habitat restoration intended to benefit salmon populations (Bilby et al., 2005). We assessed the cumulative effectiveness of intensive, extensive restoration that often included many projects and several treatment types at the scale of whole watersheds – the scale experienced by fish populations that assimilate conditions over multiple reaches and years (Fausch et al., 2002). Watershed assessments and restoration project locations, designs, and implementation were led by local collaborative groups within the context of the "Washington Way" strategy for salmon recovery (Smitch et al., 1999). Most work was funded through the competitive SRFB project review process, though some projects were planned and completed

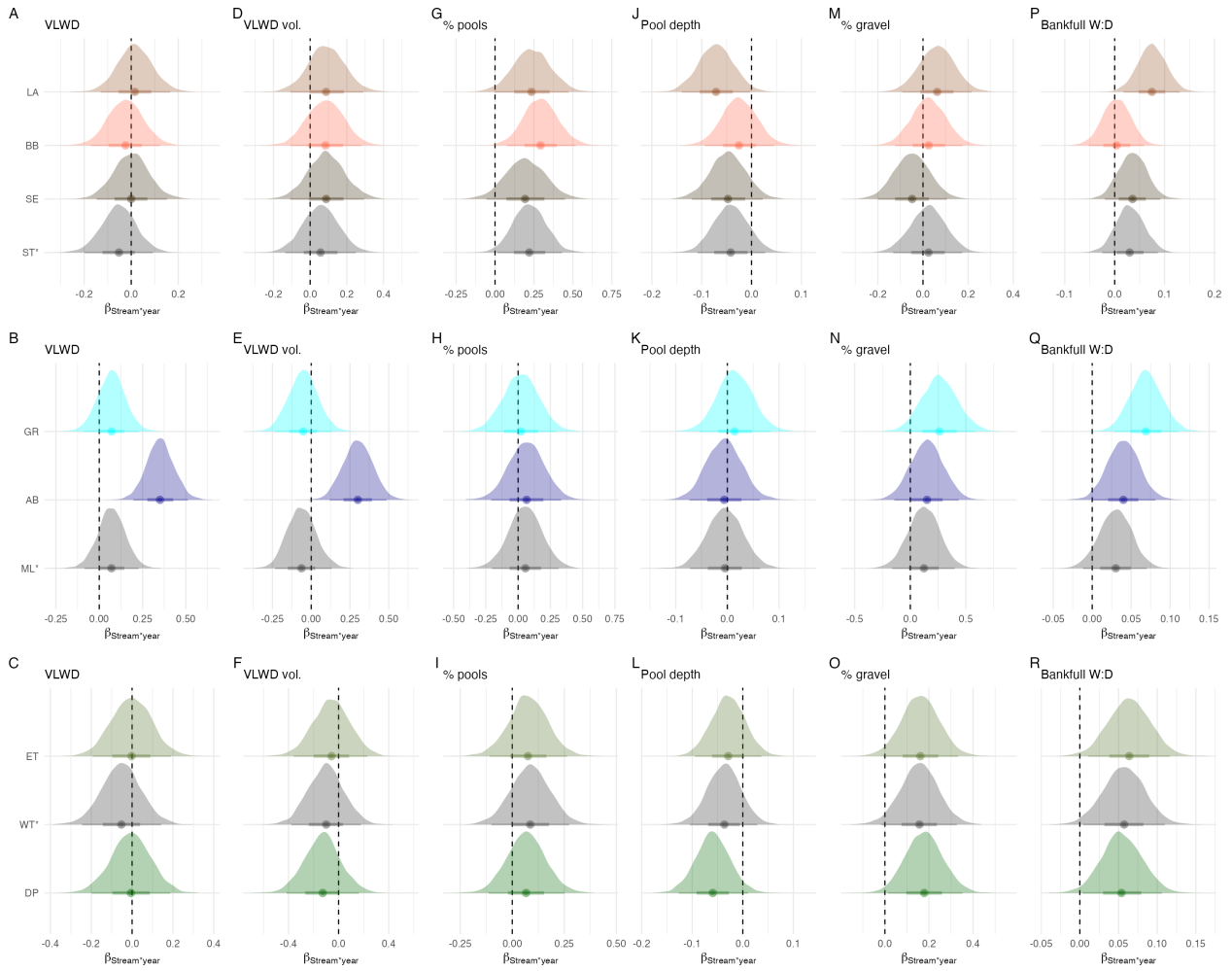


FIGURE 5
Posterior distributions of estimated coefficient values in regressions of measures against a stream-year interaction. Panel columns show each measure, and panel rows show each complex. Panel labels **(A–R)** identify each combination of habitat measure and complex in Figures 4 and 5. Reference watersheds in each complex (ST*, ML*, WT*) are illustrated with light grey; all other colors show treatment streams. Median, 50% and 95% credible intervals are shown as points, bars, and probability distributions respectively. Values overlapping 0 indicate lack of support for consistent directional change, and separation between watersheds within a complex indicates differences in the trajectory of the habitat measure through time.

TABLE 4 **Bhattacharyya distances indicating pairwise distributional overlap of posterior estimates of stream-year effects for each whole-stream habitat measure, comparing treatments versus reference in each complex.**

	Hood Canal			Lower Columbia		Strait of Juan de Fuca	
	LA	BB	SE	GR	AB	ET	DP
VLWD	0.895	0.98	0.936	0.997	**0.212**	0.965	0.969
VLWD vol	0.985	0.989	0.985	0.996	**0.164**	0.985	0.993
% pools	0.991	0.942	0.981	0.988	0.997	0.996	0.992
Pool depth	0.911	0.969	0.994	0.958	0.997	0.988	0.944
% gravel	0.964	0.997	0.9	0.89	0.991	0.997	0.988
Bankfull W:D	**0.737**	0.89	0.993	**0.638**	0.967	0.989	0.996

Values close to 0 support differences of distributions between treated and reference watersheds. Values less than 0.8 are bold, signifying dissimilarity. .

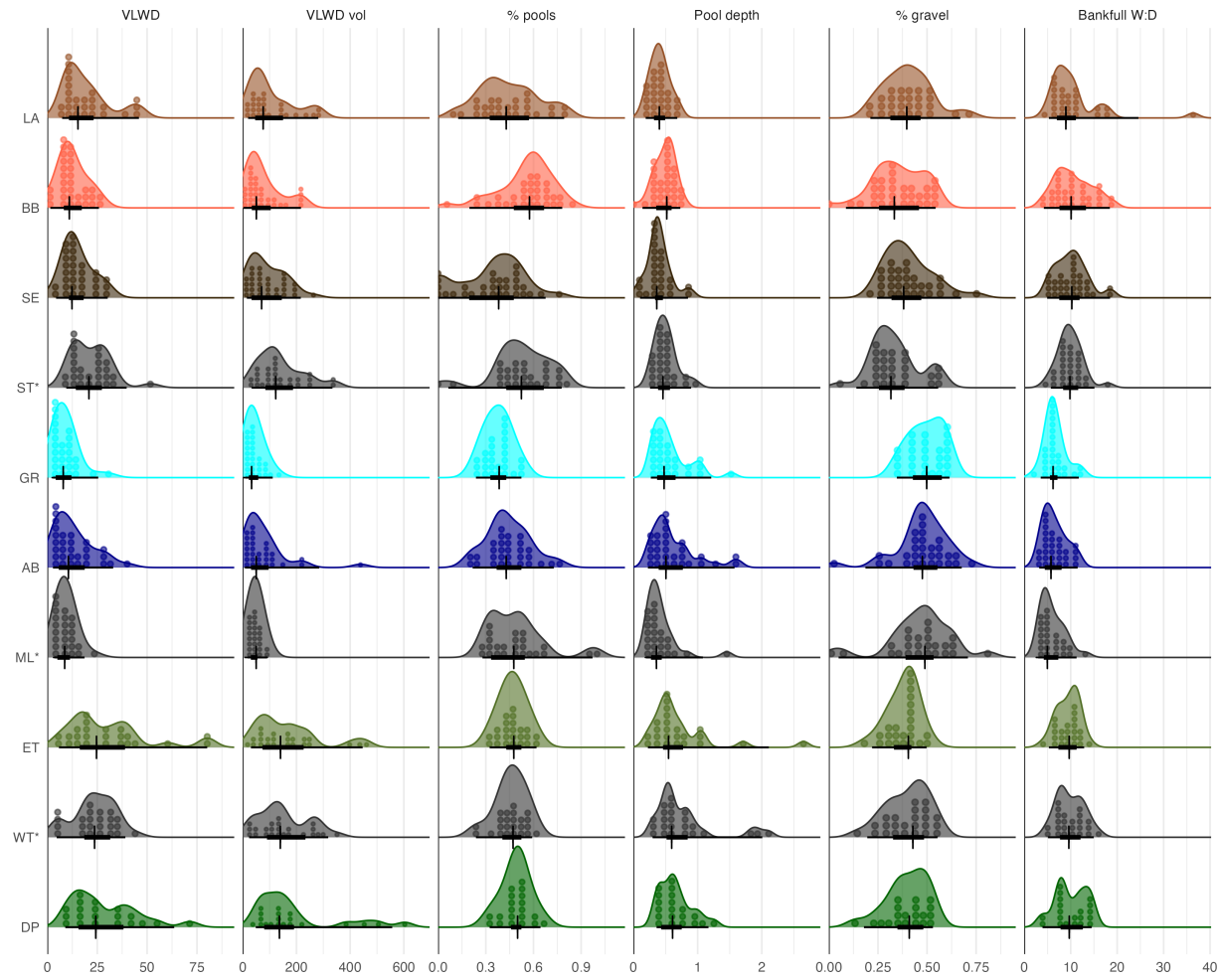


FIGURE 6
Frequencies of the long term interannual ranges (max - min) for six habitat measures (columns) at individual survey sites (points) in ten western Washington IMW watersheds (rows). Lower interval bars show among-site medians and interquartile ranges. Asterisks and gray shading designate reference watersheds. All watersheds display substantial among-site variation in the magnitude of change through time for all measures, including some sites with little to no year-to-year fluctuation.

outside the salmon habitat restoration strategy (see Section 2.4). For example, several barrier culvert replacements that were designed to benefit fish and fish habitat were completed as part of regular road maintenance. Such unsystematic restoration complicated the study design but provided a realistic, perhaps best case, assessment of the cumulative effects of stream habitat restoration as it has often been practiced in the "real world". As such, the long-term, intensive restoration and monitoring efforts in the IMW watersheds are a rare opportunity to describe the cumulative effects of salmon habitat restoration at "riverscape" spatial extents over the multi-decadal periods relevant to population viability.

We anticipated that differences among watersheds in the trajectories of habitat measures would demonstrate the cumulative effects of restoration efforts. We initially expected trends favorable to salmon in most habitat measures due to the shifts in land management policies that have occurred since the 1980s (Roper et al., 2019) in conjunction with the added impact of direct in-stream restoration in the treated watersheds (Anlauf et al., 2011). However, we have not observed many large, favorable trends in fish habitat measures. We detected substantial interannual variability in most habitat measures in all watersheds, with spatial heterogeneity in temporal stability among sites contributing to overall patterns of year-to-year change that was independent of treatment. In the following sections, we consider several factors proposed by Bilby et al. (2024) and Bisson et al. (2024) to potentially limit or delay detection of the effects of restoration on fish populations and habitat, including 1) inadequate monitoring and study duration, 2) insufficient restoration effort, 3) high temporal variability, and 4) ineffective restoration due to poorly matching restoration treatments with location conditions.

4.1 Monitoring

4.1.1 Observer error

The possibility that observer error (low repeatability or precision) was an important source of observed interannual variability and poor detection of trends and restoration effects was a central study concern. Surveyor variability can be high even for simple classification of habitat types (Roper and Scarnecchia, 1995; Roper et al., 2008).

To promote repeatability, we used an established, highly repeatable field protocol (Lazorchak et al., 2000; Roper et al., 2003; Archer et al., 2004; Roper et al., 2010) from which we selected habitat measures that are commonly reported in scientific literature and that minimized subjectivity by employing standardized measurements. Our analytical approaches evaluated observations made by the same technicians in each field season, contrasting among the watersheds within the complex where they worked. We also note that each watershed included sites with ranges that were near zero for year-to-year differences in the value of habitat measures over the course of the study (Figure 6). Moreover, bolstering our direct experience of witnessing dramatic changes in study reaches, the large collection of site photographs and sketches has allowed subsequent inspection and verification of numeric values against field conditions. All field studies are subject to observation uncertainty, but given the measures taken to reduce observer error in field data collection, data entry, and analysis, we think that our results accurately reflect conditions in the study watersheds.

4.1.2 Duration and trends

Our study methods, design, and duration were sufficient to detect the cumulative effects of restoration if they were present and persistent. We detected several small trends in habitat measures that are common aims of restoration. We quantified statistically significant trends in each habitat measure in at least one watershed and in one or more measure in all watersheds except Mill Creek. However, we found little evidence that habitat trends differed between extensively treated and reference watersheds. Larsen et al. (2004) stress the importance of study duration to trend detection and suggest that 10–20 years is often required to detect annual trends of 1 – 2% in habitat measures collected similarly to those in the IMW study. Anlauf et al. (2011) found favorable trends in 4 of 20 similar fish habitat measures across coastal Oregon streams over ten years, and Roper et al. (2023) detected changes in similar habitat measures in nearly a quarter of over 2,000 stream surveys collected across the Pacific Northwest over a similar study duration of 20 years. Additionally, our annual monitoring for almost two decades revealed many 2 to 4-year fluctuations consisting of an increase followed by a decrease of similar duration and magnitude for several habitat measures in most watersheds (Figure 4). While these shorter-phase fluctuations tended to differ among complexes, several appeared to be shared among watersheds, suggesting the influence of a common factor or factors other than restoration.

Additional time might be required for the effects of land management policies and restoration projects to become fully expressed. Regulatory shifts that have occurred over the last several decades, such as increased riparian protection afforded by Washington's Forest Practices Act, Hydraulic Code, and Growth Management Act, may not have produced habitat responses within the time frame of our study, especially for VLWD. It requires nearly a century before riparian stands begin to produce wood of sufficient size to impact channel conditions in Pacific Northwest watersheds (Welty et al., 2002; Gregory et al., 2003). Riparian trees in these historically logged watersheds are only recently reaching sizes (ages) of our VLWD classification (> 0.3 m diameter), so increases in instream VLWD due to natural recruitment has been constrained. Studies attempting to quantify improvements associated with changes in land use regulations are likely to require long assessment periods to detect trends in conditions, as detrimental effects of historical impacts continue to propagate and successional processes lag. Observing similar results across three physiographically distinct complexes suggest such lags in habitat recovery might be common in the Pacific Northwest.

4.2 Restoration effort

As illustrated by the large wood measures in Abernathy Creek, our study methods, duration, and analyses were sufficient to show the effects of restoration on fish habitat measures where actions resulted in large, persistent changes to habitat. Roni (2005); Roni et al. (2010), and Jorgensen et al. (2021) suggested that 20% or more of a watershed must be restored to elicit a detectable response by salmon populations. While quantifying the extent of restoration is complicated by differences in project types and the intensity of restoration (e.g., placing 10 vs. 100 VLWD/100m), by spatial overlap and distance effects (e.g., possible upstream and downstream impacts), and by temporal lags, our experience suggests that Little Anderson, Big Beef, Germany, Abernathy, and Deep creeks, and East Twin River, approached and in some cases far exceeded this 20% threshold for reaches where salmonids have been observed. We did observe small changes in some population metrics for Coho salmon in some watersheds, such as increase in overwinter survival at Deep and Big Beef creek and increased smolt production at Abernathy Creek (Bilby et al., 2022; Anderson et al., 2025; Lamperth et al., 2026). However, we found that the common expectation that even modest amounts of stream restoration can improve habitat measures sufficiently to allow statistical detection of a treatment effect is overly optimistic.

4.3 Interannual variability

Many factors that function at a range of spatiotemporal scales affect the temporal variability of stream habitat (Bisson et al., 2009; Al-Chokhachy et al., 2011; Roper et al., 2019). Drought can reduce pool abundance and suitability for salmon (Vander Vorste et al., 2020). Western Washington experienced several droughts during our study, including in 2015, 2021, 2023, and 2024, but we observed little effect on pool frequency in these rain-dominated watersheds. Preliminary analysis of HC and ST watersheds found interannual differences in summer base flows to differ little among summers over the course of the study (Casey Clishe, Washington Department of Ecology, personal communication).

The watersheds experienced several substantial floods, including in 2007, 2009, and 2021 and we observed changes in stream form in many locations after floods, but much of the interannual variation we observed happened during years without unusually large flow events. We suspect that the effects of historical disturbances (e.g., logging practices and instream wood removal) on stream habitat in IMW watersheds may persist for decades and

contribute to interannual variability of habitat. For example, in Carnation Creek, British Columbia, the effects of landslides due to logging in headwaters have taken several decades to propagate downstream (Tschaplinski et al., 2025). Castro and Jackson (2001) found bankfull flow events, which are largely responsible for transporting bedload and changing instream habitat, had nearly annual recurrence intervals in western Washington rivers. We suspect that in these historically disturbed watersheds such relatively small and frequent flow events are sufficient to fill and scour pools and riffles and transport, bury, and re-expose instream wood in many reaches. Regardless of the causes of observed interannual variability of habitat, such variability should be expected and addressed when planning and implementing restoration.

Interannual variability of habitat measures and failures of restoration treatments to persist or result in sustained changes to habitat measures likely hindered the detection of trends and restoration effects. Assessment of individual restoration projects was outside the scope of this manuscript, but we documented several instances in which restoration treatments did not persist or did not durably alter habitat measures where they did. For example, placed large wood was frequently observed outside of currently active channels due to avulsions and redistribution of wood onto floodplains. At other locations, typically in low gradient, unconfined, depositional reaches (Montgomery, 1999; Buffington and Montgomery, 2013), placed wood was repeatedly buried and re-exposed during the study. Avulsions were infrequent in higher gradient, confined reaches, but placed wood was often transported downstream and sometimes entirely out of the watershed. The persistence of intentional interventions also depended on 'background' processes, such as debris jams leading to complex, multithread channels that were formed by redistribution of naturally recruited and placed wood transported from upstream restoration projects (Flannery et al., 2017; Wohl et al., 2021). Our experience conducting the IMW study clearly indicated that greater attention to reach gradient, confinement, and network position could improve individual and cumulative restoration outcomes.

4.4 Recommendations

Rigorous assessment of stream restoration is uncommon (Bernhardt et al., 2007; Palmer et al., 2007; Jähnig et al., 2011; Palmer et al., 2014; Skinner et al., 2023). This study is unique by describing the cumulative effects of long-term, intensive restoration at watershed extents using long-term, annual monitoring data. Our finding interannual variability of habitat measures often greater than detectable effects of restoration has important implications for restoration project selection and location. Due to historical management, restoration projects might be located in environments exhibiting higher environmental variability than in the past, so previously successful restoration practices (e.g., historical instream wood sizes and abundances) may no longer be sufficient (Greening et al., 2023). Although some trends and treatment effects were detected that followed *a priori* expectations for improving habitat for salmon, the cumulative effects of restoration appeared insufficient to substantially increase salmon productivity (Anderson et al., 2019, 2025). Better accounting for temporal variability of stream habitat and differences in variability among stream reaches might improve restoration outcomes.

When possible, watershed assessments for restoration planning should quantify habitat variability based on long-term monitoring (Miller and Kochel, 2010) and acknowledge likely differences in variability among locations (Schumm, 1985; Castro and Thorne, 2019) so projects can be designed, located, and sequenced to increase the probability of individual and cumulative success (Jones et al., 2014). Watershed assessments often rely on data of insufficient duration to capture temporal variability (Pess et al., 2003). For example, during this study many sites were devoid of pools in some years but were primarily pools in other years. Similarly, VLWD densities in some reaches often differ by more than 25 pieces/100m over time. So, for example, restoration plans to add wood or increase pool frequency to specific reaches might be misguided depending on when the watershed assessment was conducted.

Using historical conditions to guide restoration can be useful (e.g. Pess et al., 2003; Krueger et al., 2017). But benchmarks should be interpreted and applied with appreciation for likely locations and causes of high interannual habitat variability that appears often due to small-scale disturbances (Roper et al., 2023). While long-term monitoring to describe interannual variability is often infeasible, watershed assessments can potentially map reaches that might be expected to respond differently to restoration treatments due to differences in reach stability, possibly based on fundamental controls of channel form such as reach gradient, confinement, and network position to ensure restoration proposals are assessed with consideration of process domains and ongoing river network change (Schumm, 1985; Miller and Kochel, 2010; Jones et al., 2014; Castro and Thorne, 2019). Structuring restoration project review, selection, and funding process to facilitate spatiotemporally coordinated and concentrated interventions coupled with monitoring to adjust actions could increase the efficiency and effectiveness of salmon habitat restoration.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

KK: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Visualization, Writing – original draft, Writing – review & editing. DA: Data curation, Formal analysis, Visualization, Writing – original draft, Writing – review & editing. EW: Formal analysis, Investigation, Writing – review & editing. JA: Funding acquisition, Project administration, Writing – review & editing. RB: Conceptualization, Funding acquisition, Investigation, Writing – review & editing. TQ: Conceptualization, Funding acquisition,

Project administration, Writing – original draft, Writing – review & editing. EP: Data curation, Investigation, Methodology, Project administration, Writing – review & editing. WD: Data curation, Investigation, Methodology, Project administration, Supervision, Writing – review & editing. WE: Conceptualization, Funding acquisition, Project administration, Resources, Writing – review & editing. MM: Funding acquisition, Project administration, Supervision, Writing – review & editing. JL: Funding acquisition, Supervision, Writing – review & editing. ML: Funding acquisition, Supervision, Writing – review & editing.

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Conflict of interest

Author RB was employed by Weyerhaeuser Corporation.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Weyerhaeuser Corporation had no involvement in study design, collection, analysis, interpretation of data, the writing of this article, or the decision to submit it for publication.

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Exhibit List 077

Washington Department of
FISH & WILDLIFE

Abernathy Creek Wildlife Area Unit


Photo by Alan Bauer

The Abernathy Creek Unit is located near the confluence of the Columbia River and Abernathy Creek. Chum salmon spawn in Abernathy Creek, which flows through a portion of this unit into the river. This unit is managed for the protection of riparian and upland forest habitat and to provide fishing access. Access to this site is walk-in only.

The Abernathy Creek Unit is located on Abernathy Creek near the Columbia River, approximately 20 miles west of Longview in Cowlitz County. The unit can be accessed from Abernathy Creek Road off of State Route 4.

The Abernathy Creek Unit is located in the Lower Columbia Basin just upstream of the confluence of Abernathy Creek and the Columbia River across from Crims Island, Oregon.

This unit is part of the Mount Saint Helens Wildlife Area (/places-to-go/wildlife-areas/mount-saint-helens-wildlife-area).

Game Management Unit: 530

Acres: 132



Contact

Zach Breitenstein
Wildlife Area Manager

360-696-6211 (tel:+13606966211)

5525 S 11th St
Ridgefield, WA 98642

Recreation and public access

Recreation and access advisories

- Walk-in access only; this site is gated due to past frequent vandalism.
- Camping and overnight parking is prohibited
- Fires and fireworks are prohibited

A Discover Pass (/licenses/parking) is required on WDFW lands -- including water access areas, wildlife areas, and campgrounds -- unless you already have a Vehicle Access Pass issued with the purchase of an eligible hunting or fishing license. Recreate responsibly on public lands: please know the Public Conduct Rules (/about/wdfw-lands/public-conduct).

Public facility information:

- Parking at pullout by gate
- No restroom

Hunting

This unit may provide hunting opportunities for deer, waterfowl, elk, and small game.

Fishing

This unit offers fishing access to Abernathy Creek.

Wildlife viewing

This unit includes riparian and upland forest habitat, offering opportunities to view a variety of wildlife.

In this reach of the stream, spawning chum salmon may be viewed.

Search for potential birding opportunities on or near a wildlife area unit by using eBird Northwest, a citizen science database portal that provides freely-shared bird lists at 'hotspots' and interactive maps plus other birding information updated daily.

Conservation

Abernathy Creek provides important habitat for endangered fish species.

Special habitats and species

Chum salmon spawn in this reach of the creek.

Conservation goals

- Develop a strategy for riparian/wetland restoration projects to benefit fish and wildlife species
- Maintain and restore riparian and instream habitat for steelhead, chinook, and coho

Land stewardship

The Abernathy Creek Unit was acquired to provide fishing access and protect riparian and forest habitat.

Acquisition history

The parcels making up this area were purchased in 1933.

Funder	Fund
County	Transfer of land
US Fish and Wildlife Service	National Coastal Wetlands Conservation Grant
WA Dept of Fish and Wildlife	WDFW Game Fund (now Wildlife Fund)

Management planning

2019 Mount Saint Helens Wildlife Area Management Plan (https://wdfw.wa.gov/publications/02059)
The Washington Department of Fish and Wildlife completed the new management plan for the Mount St. Helens Wildlife Area, which is comprised of 18 units in Skamania, Clark, Cowlitz, and Wahkiakum counties, and totals 10,002 acres. The Mount St. Helens Wildlife Area is largely managed for elk in the North Fork Toutle River Valley, but the area units are diverse, and provide habitat for multitudes of species, over a broad range of habitats including old growth forest, forested floodplains, riparian areas, ancient lava flows, mineral springs, tidal mudflats, and wetlands. The new management addresses the status of wildlife species and their habitat, ongoing restoration efforts and public recreation opportunities at the wildlife area.

Planning Advisory Committee

Mount Saint Helens Wildlife Area Advisory Committee (https://wdfw.wa.gov/about/advisory/msh-waac)

Additional Materials

- Public Comments and Response Summary (https://wdfw.wa.gov/sites/default/files/2019-08/msh-public-response-summary-2019.pdf)

Plan Updates

- 2023 (/media/15799)

- 2020 (/media/9302)

Exhibit List 081

Exhibit List 082

July 8, 2026

Quiet, please: Hatchery salmon raised amid noise are less likely to return to spawn

By Shawn Vestal, WSU News & Media Relations



Tule Fall Chinook salmon in the Lower Columbia River, such as those shown here, are listed as threatened under the Endangered Species Act. A new study shows that hatchery-raised Tule Fall Chinooks that are raised in noisy environments are less likely to return from the ocean to spawn (photo by Lance Koudele/U.S. Fish & Wildlife Service).

VANCOUVER, Wash. — Fish hatcheries are a critical part of the effort to restore salmon runs in the Pacific Northwest. But hatchery fish are less likely than wild ones to return from the ocean to spawn — and one reason may be hatchery noise.

Exhibit List 083

That's a key finding of new research from Washington State University Vancouver showing that hatchery-raised fall Chinook salmon that started life in noise-protected environments were more likely to complete the journey to the ocean and back than fish raised in noisy ones.

The work indicates that noise in a fish's early life disrupts its ability to survive in the wild, and that the use of sound-dampening techniques in hatcheries could improve return rates.

"The hatchery system is really critical for the nation, ecologically and economically," said Rikeem Sholes, a U.S. Fish and Wildlife fisheries biologist who led the research project as part of his graduate studies at WSU. "We spend millions upon millions of dollars raising these fish for various reasons, so we want to make sure that we're sending them out with all their systems working so they have the best chance of making it back."



As a graduate student at Washington State University, Rikeem Sholes led a project that found that Chinook salmon raised amid hatchery noise were less likely than others to return from the ocean to spawn (photo courtesy of Rikeem Sholes).

Exhibit List 084

The findings were published in the North American Journal of Fisheries Management. Sholes conducted the research while completing his doctorate at WSU, working in the lab of Allison Coffin, who left WSU for a position at Creighton University in 2024. Coffin was a co-author of the new publication, along with Jonah Piovia-Scott, an associate professor of biology at WSU Vancouver, and a group of former undergraduates at WSU Vancouver: Teyline McLean, Alexandra Pederson, Susannah Schloss, and Olivia Molano.

The National Fish Hatchery System, comprised of 71 facilities nationwide, releases 125 million fish each year to help foster economic development, fulfill tribal trust obligations, and bolster endangered fish runs. However, hatchery-raised fish often exhibit lower fitness and survival compared to wild fish, and scientists are exploring hatchery environments for potential explanations.

One of those elements is noise. Hatcheries are noisy operations, with pumps, generators and aerators. They are also sometimes located near other sources of sound, such as roads. Past studies have linked noise exposure to hearing loss in some fish, disrupting their ability to perceive acoustic signals and survive in the wild.

For the recent project, researchers studied Tule Fall Chinook salmon raised at the Spring Creek National Fish Hatchery on the Lower Columbia River — a little more than an hour away from the WSU Vancouver campus. Tule Fall Chinook in the Lower Columbia are listed as threatened under the Endangered Species Act. The hatchery is near a train track and a state highway, so there is a relatively high amount of ambient noise.

> *Fish raised in a quiet environment were slightly more likely to return than those raised in ambient noise, and nearly twice*

Exhibit List 085

> *as likely as those reared with continuous white noise.*

In early 2022, the researchers began evaluating salmon fry raised in three separate environments: one where the noise was dampened with padding and other methods; one where white noise was played continuously; and one with the normal ambient noise of the hatchery.

The team examined the fish during the three months before their release. To their surprise, noise levels were not associated with significant differences in sensory development or swimming behavior, though there were moderate differences in fish size.

However, when they began tracking the return of adult salmon, they saw significant differences. Over the course of two years, fish raised in the quiet environment were slightly more likely to return than those raised in ambient noise, and nearly twice as likely as those reared with continuous white noise.

“That surprised me the most — when they started coming back, we saw differences in the return rates when we had seen very few differences as they were heading out to sea,” Coffin said.

The researchers said that more study is needed to tease out just what it is that causes that difference. It does suggest that noise-dampening techniques, such as padding tanks with felt liners, could improve return rates, but there is a great variety among hatcheries and any such solutions would depend on each individual facility.

Media Contacts

Exhibit List 086

- Allison Coffin, Creighton University , AllisonCoffin@creighton.edu
- Rikeem Sholes, U.S. Fish & Wildlife Service, rikeem_sholes@fws.gov
- Shawn Vestal, WSU News & Media Relations, shawn.vestal@wsu.edu

Categories: Research, Science & Technology

WSU Vancouver

NEXT Story



Washington State Magazine celebrates 25 years with anniversary reception

November 5, 2026

The WSU community is invited to join founding editor Tim Steury, recently retired editor Larry Clark and current staff for a free public gathering Nov. 13 in the Terrell Library Atrium.

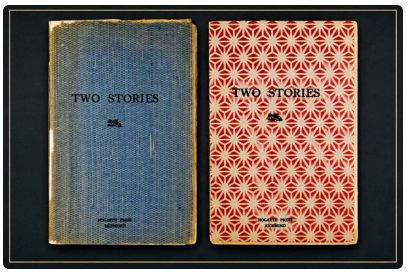
By Adriana Janovich, Washington State Magazine

Recent News

Exhibit List 087

November 5, 2026

WSU librarian explores what makes a book rare



After studying the history of bookmaking at the University of Virginia, Will Gregg is bringing new insights to WSU's collection of more than 50,000 rare books.

By Communications staff, Washington State University

November 4, 2026

Flags being lowered Nov. 6 in honor of Whitman Co. Sheriff Brett Myers



Flags across the state, including on Washington State University campuses, will be lowered to half-staff Friday in honor of former Whitman County Sheriff Brett Myers.

By RJ Wolcott, WSU News & Media Relations

November 4, 2026

Nov. 10: Tax policy expert to speak on navigating Washington state tax policy



Ryan Frost of the Washington Policy Center will discuss the millionaire's tax, capital gains tax and recent changes to state tax policy during the fall Hoops Tax Institute Forum.

By Sue McMurray, Carson College of Business

Exhibit List 088

November 4, 2026

WSU Regent Howard Wright honored for public health work in Guatemala



Later this month, the vice-chair of the WSU Board of Regents will receive an honorary doctorate from the Universidad del Valle de Guatemala and deliver its commencement address to graduating students.

By RJ Wolcott, WSU News & Media Relations

November 4, 2026

Four decades of shaping WSU's visual identity

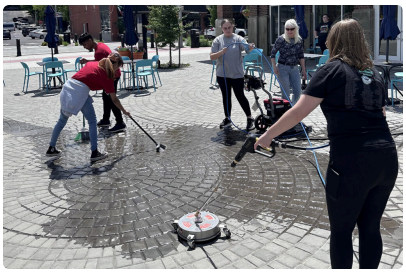


After 42 years capturing everything from Rose Bowl memories to Palouse sunsets, longtime WSU photographer Bob Hubner reflects on his career behind the lens.

By Addy Hatch, WSU Marketing and Communications

November 4, 2026

Center for Civic Engagement recognized for downtown Pullman collaboration



A partnership between WSU's Center for Civic Engagement and the Downtown Pullman Association has earned statewide recognition for connecting hundreds of students with downtown businesses through volunteer projects and community events.

Exhibit List 089

By Steve Nakata, Student Affairs

Exhibit List 090

Marine Pollution Bulletin 174 (2022) 113257

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journal homepage: www.elsevier.com/locate/marpolbul

Behavioural responses of wild Pacific salmon and herring to boat noise

Inge van der Knaap [a], Erin Ashe [b], Dave Hannay [c], Asila Ghoul Bergman [b], Kimberly A. Nielsen [b], Catherine F. Lo [b], Rob Williams [b,*]

[a] Leiden University, Institute of Biology, Sylvius, Sylviusweg 72, 2333 BE Leiden, Netherlands
[b] Oceans Initiative, 117 E Louisa St #135, Seattle, WA 98102, USA
[c] JASCO Applied Sciences, 2305-4464 Markham Street, Victoria, BC V8Z 7X8, Canada

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ABSTRACT

There is growing concern about impacts of ship and small boat noise on marine wildlife. Few studies have quantified impacts of anthropogenic noise on ecologically, economically, and culturally important fish. We conducted open net pen experiments to measure Pacific herring (*Clupea pallasii*) and juvenile salmon (pink, *Oncorhynchus gorbuscha*, and chum, *Oncorhynchus keta*) behavioural response to noise generated by three boats travelling at different speeds. Dose-response curves for herring and salmon estimated 50% probability of eliciting a response at broadband received levels of 123 and 140 dB (re 1 μPa), respectively. Composite responses (yes/no behaviour change) were evaluated. Both genera spent more time exhibiting behaviours consistent with anti-predator response during boat passings. Repeated elicitation of vigilance or anti-predatory responses could result in increased energy expenditure or decreased foraging. These experiments form an important step toward assessing population-level consequences of noise, and its ecological costs and benefits to predators and prey.

1. Introduction

Concerns surrounding the influx of anthropogenic noise, particularly behavioural and physiological impacts on a wide variety of marine taxa, have increased considerably in recent decades (Cox et al., 2018; Duarte et al., 2021; Simpson et al., 2016; Slabbekoorn et al., 2010). Broadly speaking, fish are underrepresented in studies on the ecological effects of anthropogenic noise (Williams et al., 2015a), even though fish are ecologically, culturally, and economically important. In recent years, a number of studies have established how different fish species can respond to anthropogenic noise by moving away from the noise source or changing their behaviour (Popper and Hawkins, 2019). One anthropogenic noise source that is widespread in the marine environment is produced by vessels. Vessel noise can affect fish presence in an area; Atlantic herring (*Clupea harengus*) and Atlantic cod (*Gadus morhua*) have been found to make horizontal and vertical movements away from vessels (Vabø et al., 2002; Handegard et al., 2003). Vessel noise also affects fish behaviour by increasing predation risk (Simpson et al., 2016), reducing the size of a fish's home range (Ivanova et al., 2020), or changing day-night activity patterns (van der Knaap et al., 2021). All fish species are capable of detecting sound via particle motion, but only some species (primarily those with swim bladders, and particularly species with swim bladders in close proximity to the inner ear) can also receive acoustic signals from changes in sound pressure that are then translated to particle motion (Nedwell et al., 2004; Popper and Hawkins, 2019). When particle motion reaches a fish's inner ear, the sensory cells in the inner ear move with the motion, while the far denser otolith structures move at a different amplitude and phase which results in a signal being sent to the brain (Popper et al., 2003). A growing body of research is showing that noise from shipping and other human activities can reduce the acoustic communication space of fishes (Putland et al., 2018), affect the behaviour and physiology of individuals (Hawkins and Popper, 2017; Weilgart, 2018), and could affect survival, reproduction, and population growth (Soudijn et al., 2020; Watson et al., 2020).

In the northeast Pacific Ocean, wild Pacific herring are known to respond to sounds from vessels, killer whales, and sonar (Schwarz and Greer, 1984), but in order to set quantitative targets for allowable noise levels or desirable levels of mitigation, managers need dose-response studies that measure the probability of a response to the same stimulus across a range of intensity (Hawkins et al., 2014; Miller et al., 2014; Southall et al., 2007). Juvenile salmon, including Chinook salmon (*Oncorhynchus tshawytscha*) demonstrate strong avoidance responses to

* Corresponding author.
E-mail addresses: erin@oceansinitiative.org (E. Ashe), david.hannay@jasco.com (D. Hannay), asila@oceansinitiative.org (A.G. Bergman), kimberly@oceansinitiative.org (K.A. Nielsen), catherine@oceansinitiative.org (C.F. Lo), rob@oceansinitiative.org (R. Williams).

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infrasound (Knudsen et al., 1997), but few studies have measured responses of free-ranging fish across a range of received ship noise levels (Hawkins et al., 2014). Survival of juveniles is of conservation concern. In addition to pressures associated with noise pollution and habitat quality, research has indicated that predators may target this life stage at certain times of the year (Lance et al., 2012; Thomas et al., 2016).

In addition to the importance of fish in their own right, maintaining the health of some fish species is essential to the survival and recovery of endangered and legally protected populations of whales. The transboundary waters of the Salish Sea, located between British Columbia (BC), Canada and Washington state, USA, represents an important feeding habitat for critically endangered southern resident killer whales (*Orcinus orca*). One of the main factors affecting the decline of this population is the limitation of Chinook salmon (Ford et al., 2010; Ward et al., 2009; Lacy et al., 2017). Humpback whales (*Megaptera novaeangliae*) in Canada's Pacific region are recovering rapidly from commercial whaling (Ashe et al., 2013), but continued recovery of humpback whales requires healthy stocks of zooplankton and forage fish, including Pacific herring (Fisheries and Oceans Canada, 2013). Vessel noise can inhibit whale foraging through behavioural disruption of feeding activities (Blair et al., 2016; Lusseau et al., 2009; Williams et al., 2006), and possibly through acoustic masking (Clark et al., 2009; Erbe et al., 2016; Williams et al., 2014a).

Shipping and other human activities have already made chronic ocean noise a persistent feature of the Salish Sea (Erbe et al., 2012). Although some parts of Canada's Pacific region are less urbanized than others and may lend themselves to area-based management efforts to maintain acoustic integrity, the Salish Sea experiences high levels of chronic noise from shipping (Erbe et al., 2014; Williams et al., 2015b). Anticipated trends in regional shipping (Kaplan and Solomon, 2016) and multiple proposed fossil fuel-related and port development projects (Gaydos et al., 2015) are poised to increase noise levels in the Salish Sea. Canada's legal framework, under the Oceans Act, Fisheries Act, and Species at Risk Act, requires use of "best available science" in decision making regarding effects of ocean noise on marine habitat and wildlife (Mooers et al., 2010; Williams et al., 2014b). This creates an incentive to assess whether noise affects fish—both for conservation of fish habitat and for recovery of endangered whales—to evaluate whether ocean noise warrants additional consideration in environmental impact assessments, prioritizing research funding, or mitigating effects of industrial development in Canada's Pacific region.

In this study, we measured schooling behaviour of wild juvenile Pacific salmon (pink, *Oncorhynchus gorbuscha*, and chum, *Oncorhynchus keta*) and herring (*Clupea pallasii*) schools in response to boat noise produced by three experimental vessels. Fish were caught from the wild and kept in net pens where their schooling behaviour was observed during experimental trials. Our primary goal was to understand how the schooling behaviour of these three common fish species is affected by boat noise. To accomplish this, we measured responses by identifying changes in typical schooling behaviours (school cohesion, swimming speed, and orientation) and comparing baseline (control) periods to exposure trials when the fish were in the presence of boat noise. Based on the theoretical framework developed by Frid and Dill (2002) in which anthropogenic disturbance can be thought of as a form of predation risk, we expected the fish to respond to vessel noise and disturbance in ways similar to natural predators (De Robertis and Handegard, 2013; Pitcher, 1986; Pitcher et al., 1996). We hypothesized that exposure to boat noise would increase school cohesion, as well as fish swimming speed, and that schools would move down the water column during the exposure period.

2. Materials and methods

2.1. Study site and observation platform

The study site was located in the Broughton Archipelago, a remote fjord system in BC, Canada, between northern Vancouver Island and the BC mainland. All data were collected from the Salmon Coast Field Station (SCFS), a field research station located on Gilford Island, BC (Fig. 1).

Noise exposure trials were conducted during two consecutive field seasons in the summers of 2014 and 2015. One pen contained mixed schools of wild juvenile Pacific salmon (pink, *Oncorhynchus gorbuscha*, and chum, *Oncorhynchus keta*), and a second pen contained Pacific herring (*Clupea pallasii*). A third net pen contained Yellowtail rockfish (*Sebastes flavidus*), however low visibility prevented us from measuring behavioural responses, so this is not discussed further. Net pens were suspended in the water of a floating observation platform, constructed near the research station inside an enclosed, tidal rocky bay similar to the environment of the fish catch sites (vertical tidal difference of 2–4 m, max depth 8 m). This construction was part of the research equipment available at SCFS and specifically designed to house fish. The location was chosen for its proximity to the SCFS and for its relative isolation from the typical travel routes of recreational boaters. The observation platform was constructed to optimize observations of swimming fish schools in the presence and absence of vessel noise from local vessel traffic.

The observation platform allowed for temporary containment of the three fish species collected for the experiment. Captured fish were contained inside mesh-lined, open net pens hung from the platform (Fig. 2). Anti-predator nets covered the top of the net pens to mitigate predation from piscivorous birds. Salmon (pink, *Oncorhynchus gorbuscha*, and chum, *Oncorhynchus keta*) and herring (*Clupea pallasii*) schools were separated and given a minimum of 24 h to acclimate to the enclosures before trials were initiated. The captured fish were retained inside the net pens for no longer than eight consecutive days, after which they were released back into the wild. No supplementary food was provided as the fish foraged freely from prey moving through the pens.

2.2. Fish collection and containment methods

Live fish collection was carried out by experienced local fisherman under the supervision of SCFS staff. All fish used in the study were caught within 8 nautical miles (13 km) of the experimental site to limit transportation time and distance, and to minimise stress to the fish. Fish were housed in square containers (approximately 1.0 m, 1.0 m, 0.5 m) filled with water from the catch site which was oxygenated during transport. Water temperatures in the containers were the same as local water temperatures. Depending on the distance of the catch site from the net pens, the time between catch and release varied between 15 and 60 min. Catch methods were genera-specific and were designed to cause as little damage to the fish as possible. Juvenile salmon are known to shoal close to the shoreline. In both years, mixed species schools of juvenile pink and chum salmon were captured using a beach seine (Table 1). Herring "bait balls" were targeted and the herring were captured using a fine mesh dip net. This approach maximised the number of herring captured while minimising handling (Table 1). One school of each fish type (one herring and one salmon) were caught in both years of the study for a total of four schools that were repeatedly exposed to boat noise.

2.3. Acoustic recording and analysis methods

A hydrophone (Reson TC4032; Teledyne RESON Inc., Daytona Beach, Florida, USA) was installed inside the net pen at 1 m depth (approximately mid-net depth) to measure the received level from the experimental vessel inside the net pens and to record any fish vocalisations. The hydrophone was connected to a recorder (Sound Device 722; Sound Devices, LLC, Reedsburg, Wisconsin, USA) as well as an amplifier, which allowed real-time monitoring of sounds. The sampling rate was set at 48 kHz with 24-bit samples and recordings were stored on 32 GB compact flash cards and backed up onto a 1 TB hard drive daily. Acoustic system calibration was carried out using a GRAS pistonphone

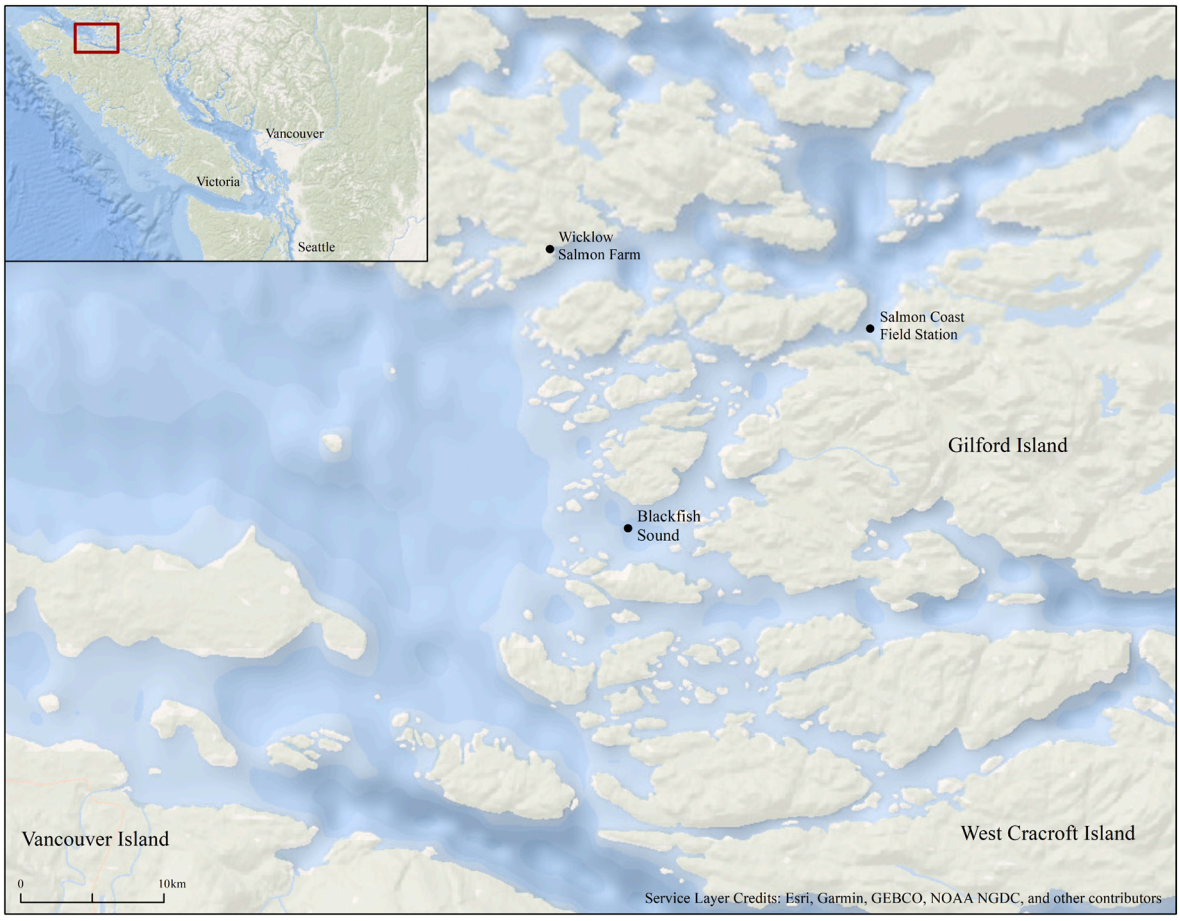


Fig. 1. Map of study and catch locations in the Broughton Archipelago, British Columbia, Canada.
Salmon Coast Field Station (50.7459° N, 126.4983° W) and associated open-net fish pens were located on Gilford Island.

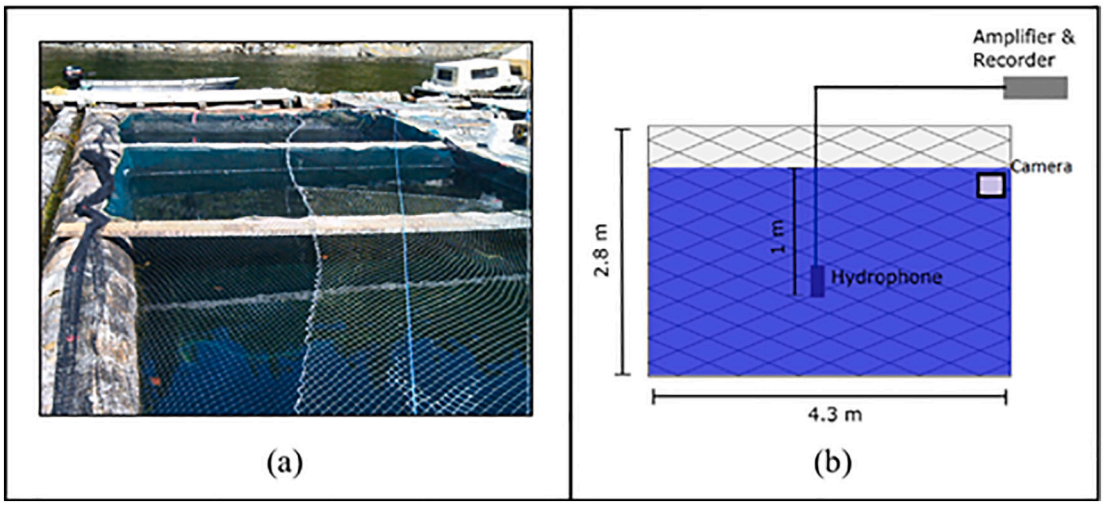


Fig. 2. (a) Two net pens suspended from the floating platform covered with anti-predator nets.
The docking station of the tender vessel, used to create the boat noise, is located at the far back next to the net pens. (b) Experimental setup; net size 4.3 m × 3.5 m × 2.8 m.

(Type 42) (GRAS Sound & Vibration, Holte, Denmark) before the start and at the end of each field season and accounted for frequency dependent hydrophone sensitivity (JASCO Applied Sciences in Victoria, BC, Canada). The raw recordings were processed using PAMlab (JASCO Applied Sciences, Canada) to calculate sound pressure level (SPL) each second in decidecade (1/3-octave base 10) frequency bands (10 Hz to 20 kHz) from the averaged pairs of spectra computed from 50% overlapped Hanning-windowed one second FFTs (fast Fourier transformation). The octave-band SPL was calculated by summing three adjacent decidecade bands. The weighted broadband (per genera) SPL

Table 1
The number of trials, catch site, and associated fish composition of each noise-fish exposure trial. Total lengths of the juvenile salmon and herring are estimations based on a sample of 10 individuals.

Number of trials	Species group	Fish number	Fish length (cm)	Catch method	Catch date	Catch site
24	Pacific Pink salmon (*O. gorbuscha*) and Chum salmon (*O. keta*)	>200	12–17	Beach seine	07/30/2014	Rocky shore close to Wicklow Salmon Farm
24	Pacific herring (*C. pallasii*)	>250	15–20	Dip net	08/05/2014	Water surface close to SCFS
24	Pacific Pink salmon (*O. gorbuscha*) and Chum salmon (*O. keta*)	49	15–18	Beach seine	08/20/2015	Rocky shore close to Wicklow Salmon Farm
13	Pacific herring (*C. pallasii*)	>200	19–25	Dip net	09/01/2015	Black fish sound

was calculated by subtracting a weighting value, representing fish audiogram values (Hawkins and Johnstone, 1978; Nedwell et al., 2004), in dB from each octave-band level before summing to obtain broadband measurements. Broadband weighted and unweighted SPLs were time-averaged for each exposure and control trial period for further analysis. Descriptive statistics (average ± standard deviation (SD)) were calculated for the unweighted broadband received level of ambient noise and vessel treatments.

Vessel noise experiments used one of the three vessels of varying length and engine horsepower (Fig. 3). A noise exposure trial was conducted by monitoring the fish behaviour in the absence of any boats within the bay for a minimum of 15 min (control period), then operating the treatment vessel past the fish nets at randomly varying speeds and distances (~5–40 m from the hydrophone), and monitoring fish behaviour during a 3-minute noise treatment session. After 3 min, the engine was shut down and fish were allowed to recover for at least 1 h before another trail was initiated.

Fish school behaviour was recorded continuously (i.e., before, during, and after boat transit) using three underwater cameras (GoPro Hero 4+ silver, GoPro Hero 4 silver, and a GoPro Hero silver) mounted on a pole at 23 cm depth in the corner of each net pen (Fig. 2). Schooling behaviour was assessed simultaneously from playbacks of video recordings for each separate trial since the fish school was generally only visible on one of the cameras. All video processing was completed in Windows Media Player (2013 Microsoft).

2.4. Behavioural data

Behavioural categories and their descriptions were defined using an ethogram developed a priori (Table 2). Video recordings were analysed without sound to avoid observer bias. Three schooling behavioural categories were identified, each divided into two response options (Table 2) that were all given a unique key code used to connect the behaviour to a certain time in the video using a simple PC behavioural analysis program called JWatcher (version 1.0, 2000–2006 (Blumstein et al., 2006)).

During each trial, there were times (of varying duration) when the fish were out of camera view. An "out of sight" code, mutually exclusive to all other behaviours (i.e., none of the other behaviours could co-occur when the fish were "out of sight"), was created in JWatcher to account for the proportion of time the fish were not captured on video.

Behavioural rates were standardized to the proportion of time the fish were in view of the cameras. Overall changes in schooling behaviour of the fish were used to describe the response(s) of the fish from the control period to the noise treatment during boat passage and to the received SPL changes throughout the trials. The decision to conduct an experimental treatment was governed by the availability of boats and drivers, while they were conducting other research projects in the area. Although the treatments were not applied in a random fashion, neither were they applied in an "ordered" way in which fish could be sensitized to increasing noise levels over time. Instead, the use of the small, medium, and large vessels was staggered throughout the field seasons.

2.5. Dose-response curve

The response variable of interest was not the behaviour (e.g., swimming speed or orientation) itself, but rather the change in behaviour between the experimental control and the treatment period.

Each of the three behavioural metrics (school cohesion, swimming speed, and school orientation) was defined such that it could either change or not change during the vessel exposure period. If no change occurred in any of the three behavioural metrics from before to during exposure, then the trial resulted in a score of 0. If the fish schooling behaviour changed for more than 20% of the time for one, two or all three behaviours, then the trial resulted in a score of 1, 2 or 3. Although the sum of behavioural changes can be used to assess severity of behavioural responses (e.g., Miller et al., 2012; Southall et al., 2007), modelling severity of ordered, categorical responses results in a suite of dose-response curves that require policy-makers to decide what constitutes a response large enough to warrant concern. Similarly, we could have used a different threshold for the duration of a behavioural change required to constitute a response (e.g., from 20% to 50% of the observation period). We chose a 20% threshold because it was long enough to convince us that it represented a true change in behaviour, rather than



Fig. 3. Photographs of each of the "treatment", or sound exposure vessels used: (a) *Tenderoni*, 4.5 m aluminium skiff with 8 hp. outboard Mercury; (b) *Broughton*, 5.5 m fiberglass runabout with outboard 115 hp. Evinrude E-tec engine; (c) *Wishart*, 9.4 m Sargo with a 370 hp. Volvo Penta diesel inboard engine.

Table 2
Ethogram describing the behaviour exhibited by the Pacific herring and juvenile salmon schools. Each behaviour has a response value, which indicates the severity of the response; 0 for no response, 1 for response (defined as ≥50% of the school responding).

Category	Response value	Behaviour	Description
School cohesion	0	Loose school	Individuals form a loose group; swimming in all directions at different swim speeds
	1	Polarised school	Individuals form a tight group; oriented in the same direction and swimming at approximately the same speed
Swimming speed	0	Slow swimming	Normal swim behaviour, no increase observed
	1	Fast movement/burst swimming	Increase of swim speeds of short duration
School orientation	0	Horizontal	Swimming at constant depth
	1	Vertical	Movement directed toward the water surface or net bottom (upward or downward)

variability, without being so high a threshold that it could not be triggered by the modest noise sources (small boats) we were testing. Ultimately, policy-makers may set thresholds that are linked to biologically significant effects. In the absence of any policy guidance, we followed previous recommendations that reduce multivariate behavioural data into a binary (response/no-response) outcome for each trial, depending on: a change in one or some combination of behaviours according to expert opinion (Miller et al., 2014); exceeding some modest threshold (Williams et al., 2014c); or change in a biologically significant behaviour such as feeding (Moretti et al., 2014). Binning involved some loss of information, but facilitated the primary objective of the study, which was to be able to inform managers of the point at which 50% of fish were likely to respond to a given received noise level. In this case, a score of 0 or 1 (i.e. a change in none or one of the three behavioural metrics) was considered a non-response, and a score of 2 or 3 (i.e. a change in two or three of the three behavioural metrics) was considered a response. This allowed the data to be modelled as a generalized linear model (GLM) (R stats version 3.6.2) (Faraway, 2005) with a binomial outcome.

The probability of a behavioural change was modelled as a function of fish group, trial number, vessel used, audiogram-weighted broadband received level (dB SPL re: 1 μPa), unweighted broadband received level, or the change in received level between the control and treatment stages of each trial. All statistical analyses were conducted in R (version 3.2.3 (R Core Team, 2015)). We used AICc to select the model that had the most support from the data. Additional models were tested with narrower frequency bands, but several models failed to converge because they had nearly as many parameters as data.

3. Results

A total of 79 noise exposure trials were performed on herring and juvenile salmon schools (Table 1). On average, ambient noise (i.e. no vessels) was 105.2 dB and small, medium, and large vessel treatments increased ambient noise by 12.4 dB, 18.0 dB, and 41.4 dB, respectively (Table 3, Fig. 4). On average, fish were within sight of the camera for 61% of the time (SD 28%). During five trials, fish remained out of camera sight for the entire trial and these were removed from further analysis. The top two models (binomial GLMs with a probit link function) included the broadband (unweighted) received sound level with both genera combined, or with a genera interaction term (Table 4). The AIC values for the two models (77.21 and 78.17, respectively) were effectively tied ($\Delta < 2$). The model with the genera interaction term was ultimately chosen, because it explained slightly more of the residual deviance when the genera interaction was included (0.23 vs 0.21, R package 'modEvA' version 2.0; Barbosa et al., 2013). The selected model was used to predict the dose-response relationship, including 95% confidence intervals, of both herring and salmon to the received sound pressure levels (dB re: 1 μPa) of boat noise across the range of received levels recorded in the study (Fig. 5). Results showed that 50% of the herring or salmon schools responded when sound levels reached above 123 dB or 140 dB, respectively, but that there is considerable variability around this relationship (Fig. 5). The binomial GLM with a probit link function allows the two genera to exhibit similar sigmoidal shapes, but allows differences in the scale parameter that governs steepness. As a result, the herring curve shows a characteristic sigmoidal shape, whereas the salmon curve is shallower—resulting in a 17 dB difference between the noise level most likely to trigger a response by 50% of the fish.

Recall that the binary response (yes/no) variable is a composite variable that contains information on school cohesion, orientation, and swimming speed (Table 2). The analysis was not conducted on the raw data, but rather on the response or lack of response of the school in each experimental trial. A typical response to boat noise involved increasing swimming speeds, forming tight schools, and diving, which are all consistent with predator avoidance.

Table 3
Mean ± standard deviation of received level (RL) (dB re: 1 μPa) and the change in RL between control and vessel treatments.

Vessel	Treatment	RL (dB re: 1 μPa)	SD	Δ RL (dB re: 1 μPa)
Small	Control	106.1	6.6	12.4
Small	Small	118.5	3.7	
Medium	Control	107.2	6.7	18.0
Medium	Medium	125.2	6.3	
Large	Control	102.4	8.5	41.4
Large	Large	143.7	13.4	

4. Discussion

When exposed to boat noise, wild Pacific herring and juvenile pink and chum salmon schools showed stereotyped responses that are consistent with classic vigilance behaviours associated with anti-predator tactics (Magurran, 1990). During exposure trials (in the presence of boat noise) both fish groups spent more time in behaviours considered to be a response to predators. These composite response findings suggest that salmon and herring respond to boat noise as a non-lethal predator (Beale and Monaghan, 2004; Frid and Dill, 2002). Flight responses to predators, including perceived predators, are adaptive. Once a predator is detected, schooling behaviour decreases any one individual's probability of being eaten (Pitcher, 1986). But repeated responses to predation risk can carry costs. If fish are repeatedly replacing foraging activities with vigilance and anti-predator behaviour, this can reduce their energetic intake and fitness. Simply living in a "landscape of fear" of predation risk can carry population-level consequences, even in the absence of actual predation (Lima and Dill, 1990).

In fact, fish exposed to boat noise are responding to perceived and actual predation risk. In addition to disrupting normal behaviour in response to anthropogenic disturbance, juvenile salmon and herring in the Salish Sea face a gauntlet of predators (Chasco et al., 2017).

Although both marine mammals and fish are capable of producing and detecting sounds, marine mammal predators and their prey have co-evolved in what has been termed an acoustic arms race (Tyack and Clark, 2000). If whales are better equipped to detect fish in a noisy environment than fish are at detecting predators, then the fishes' anti-

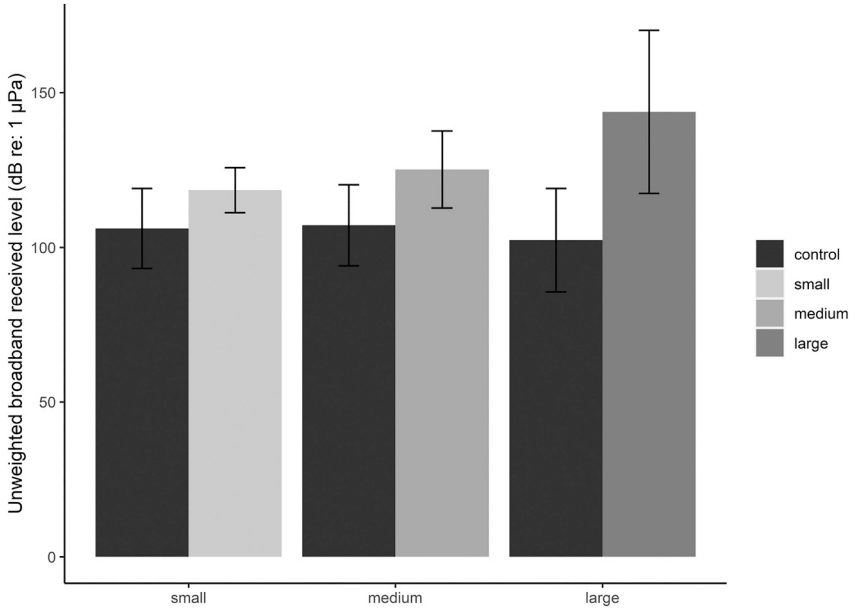


Fig. 4. Grouped bar plot of unweighted broadband received level of control (no vessels) and small, medium, and large vessel treatments. Lines are 95% confidence intervals.

Table 4
Model summaries. GLMs have a binary response with probit link functions. Model selection was performed by balancing minimised AICc score and maximised deviance explained. The final model is indicated in bold.

Model	Formula	K	AICc	deltaAIC	Akaike weights	Cumulative Akaike weights	Log-likelihood	Deviance explained
glm.all2	Response ~ received level + genera	3	77.2109	0.0000	0.5875	0.5875	−35.4340	0.21
glm.all3	**Response ~ received level * genera**	**4**	**78.1706**	**0.9597**	**0.3636**	**1.000**	**−34.7954**	**0.23**
glm.all	Response ~ received level	2	82.1854	4.9745	0.0488	1.000	−39.0082	0.13

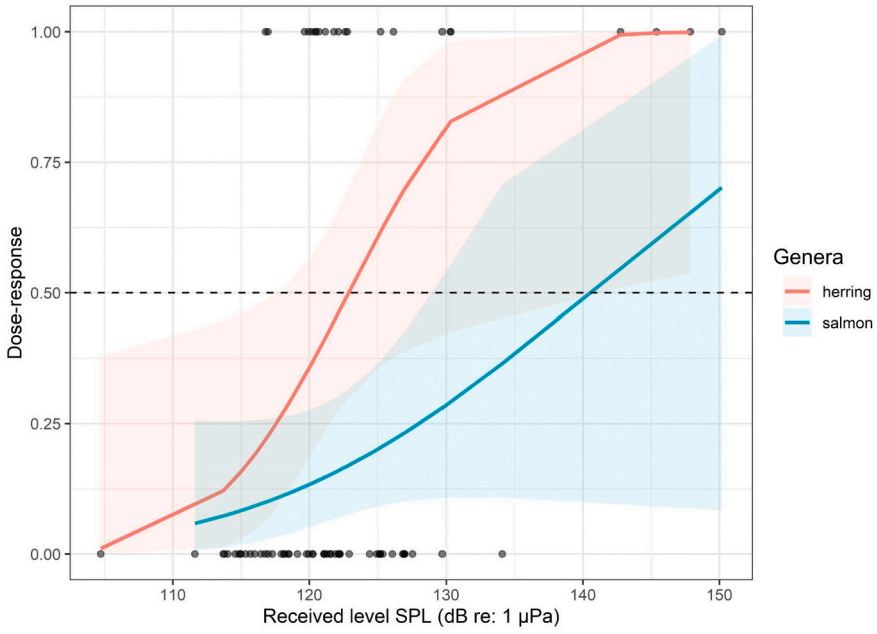


Fig. 5. Predicted dose-response curves for herring (red line) and juvenile salmon (blue line). The lighter red and blue polygons represent the 95% confidence interval on the dose-response relationship for herring and salmon, respectively. The observed response values for both genera are shown as black points. The dotted line indicates the 50% response probability that occurs at a received sound pressure level (SPL dB re: 1 µPa). For herring, this unweighted received level is 123 dB, and for salmon, this level is 140 dB. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

predatory behaviour may prove to be maladaptive. That is to say, evasive tactics that were adaptive over evolutionary time may now be disadvantageous to fish when compared to pre-industrial acoustic conditions (i.e., providing whales with higher foraging success, or ability to capture larger schools of fish). This reliance on evolutionary responses that are maladaptive today is a hallmark of Ehrenfeld's hypothetical "most endangered animal" (Ehrenfeld, 1970).

It is always a challenge to extrapolate from captive or semi-captive controlled experiments to wild scenarios, but several questions remain. Were fish responding to sound pressure level, particle motion,

wake or current produced by passing boats, bubbles generated by propeller cavitation, or shadows caused by the boat? This does not alter the conclusions of the study, but it does affect whether a manager could look up a ship track on an automatic identification system (AIS) and ship source characteristics (Veirs et al., 2016) to predict a zone of influence along the ship's path (Erbe, 2002). How often do we think fish could be exposed to received levels of 123–140 dB in the Salish Sea? With large ships passing through Haro Strait, the channel connecting the Strait of Juan de Fuca with the Strait of Georgia, every 20 min or so (Erbe et al., 2012), it is reasonable to think that fish may be exposed to noise levels high enough to cause disturbance throughout much of their time in the region. As a non-exhaustive example, we use available data on source characteristics of ships in the local fleet (Veirs et al., 2016; Wladichuk et al., 2019) to illustrate scenarios that could result in received levels of 123 dB and 140 dB (Table 5). Empirical noise measurements off Lime Kiln, San Juan Island in 2019 suggest that noise levels in Haro Strait exceeded a 123 dB threshold for herring 46% of the time, but rarely (<1%) exceed the 140 dB threshold needed to elicit behavioural responses of salmon (see Fig. 24 in JASCO Applied Sciences and SMRU Consulting, 2020).

Initially, our aim was to include a broader range of fish species in our experiment. In addition to the herring and juvenile salmon species, we captured adult pink salmon and yellowtail, quillback and copper rockfish. Unfortunately, adult salmon sustained heavy injuries during catching. These injuries were too severe for the animals to be used in the experiments and they were therefore excluded from further analysis. Rockfish are a demersal species, which meant that we had to be very careful in bringing the animals up to the water's surface after hooking them. Both quillback and copper rockfish could not withstand the pressure difference and died shortly after capture. Yellowtail turned out to be more resilient and sustained no observable injuries. However, as soon as the animals were set inside the net pen they disappeared between the folds and stayed on the bottom of the net, making it impossible to follow their behaviour by camera. Even the Pacific herring and juvenile salmon schools were captured on film only 30–88% and 34–86% of the time, respectively, over the trial durations. The length of time the fish were out of view did not allow for individual focal follows and subsequent behavioural analyses at the scale of the individual were not tenable given the schooling behaviour of these species at the juvenile stage. Future studies on rockfish would benefit from higher-quality video cameras now available, and the use of passive acoustic monitoring to detect changes in vocal behaviour. Conducting the study during a season with improved visibility or using acoustic telemetry would allow for observations of demersal fish.

The shallower dose-response curve of salmon relative to herring has some interesting implications. Either juvenile salmon appear more tolerant than herring to noise, or salmon respond only when noise levels reach some threshold (e.g., the received level of a dolphin or killer whale echolocation click). The distinct curve shapes predicted for the two genera can also be explained by the significant differences seen between salmonid and clupeid auditory anatomy and sensitivity. Salmonids are considered "hearing generalists" as the swim bladder is not believed to be involved in sound detection (Popper and Hawkins, 2019). They are therefore most sensitive to particle motion and have a much more restricted frequency range of hearing and higher sensitivity thresholds (Hawkins and Johnstone, 1978; Popper and Hawkins, 2019) when compared to "hearing specialists" such as clupeids. Herring and other clupeids are considered specialists because they possess anatomical structures joining the swim bladder to the ear (Popper and Fay, 1999), leading to an expanded hearing range (both in frequency and relative sensitivity) aided by sound pressure detection capabilities (Enger, 1967; Popper et al., 2003). Therefore, our results showing a 50% response probability for received levels of 123 dB for herring and 140 dB for juvenile salmon are consistent with hearing data available for these fishes (Nedwell et al., 2004; Matsuda, 2021). Herring use sound to communicate (Wilson et al., 2004), and their reliance on acoustic cues could mean they are more sensitive to anthropogenic noise than salmon.

Received level is an important predictor describing the probability that an animal will respond to noise, in part because this quantitative framework lends itself to implementation through establishing safety zones around noise-generating activities (Barlow and Gisiner, 2006). However, received level is not the only factor determining an animal's responsiveness to sound. Behavioural context (Clark et al., 2009; Ellison et al., 2012; Williams et al., 2006) may be a far more important determinant than received level alone. A previous study showed startle responses of Pacific herring to qualitatively different sounds ranging from 98 to 120 dB (Schwarz and Greer, 1984). Nevertheless, simple experiments like these offer a valuable starting point to gauge, however roughly, the level of noise that fish may tolerate.

This study showed that ecologically, economically, and culturally important schooling fish species exhibited changes in behaviours consistent with an anti predator response such as increased swimming speed, polarisation of schools, and diving, in response to relatively modest levels of boat noise. As we move from net pens to more ecologically relevant settings, we intend to assess whether ocean noise may be disrupting predator-prey pathways. Ecologically, noise could make herring and salmon more vulnerable to predators such as killer whales, humpback whales, seals, and Pacific white-sided dolphins. Rising ocean noise levels are likely to be picking evolutionary winners and losers in the acoustic arms race between marine predators and their prey. Larger-scale experiments will be needed to assess whether the anti-predatory behaviour of fishes seen in this study are successful in the face of real-world predation risk.

Table 5
Illustrative examples of vessel traffic scenarios that could result in a received level of 123 dB and 140 dB using published ship source characteristics, speeds, and transmission loss data from the Salish Sea. Mean broadband source levels (dB re: 1 μPa) are shown for container, tanker, tug, and fishing vessels (Veirs et al., 2016) and pleasure craft vessels (Wladichuk et al., 2019).

Vessel type	Mean source level (dB)	Mean speed (knots)	Range (m) resulting in 123 dB received level	Range (m) resulting in 140 dB received level
Container	178	19	905	110
Tanker	174	14	552	67
Tug	170	8	336	41
Fishing	164	9	160	20
Pleasure craft	166	11	205	25

CRediT authorship contribution statement

Inge van der Knaap: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization, Project administration. **Erin Ashe:** Conceptualization, Methodology, Validation, Investigation, Resources, Writing – original draft, Writing – review & editing, Supervision, Project administration, Funding acquisition. **Dave Hannay:** Conceptualization, Methodology, Software, Validation, Resources, Data curation, Writing – original draft, Writing – review & editing, Supervision, Project administration, Funding acquisition. **Asila Ghoul Bergman:** Writing – original draft. **Kimberly A. Nielsen:** Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Visualization. **Catherine F. Lo:** Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Visualization. **Rob Williams:** Conceptualization, Methodology, Validation, Investigation, Resources, Writing – original draft, Writing – review & editing, Supervision, Project administration, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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The Effects of Temperature on Steelhead Trout, Coho Salmon, and Chinook Salmon Biology and Function by Life Stage

Implications for Klamath Basin TMDLs

Katharine Carter
Environmental Scientist
California Regional Water Quality Control Board
North Coast Region

August 2005

Exhibit List 100

Introduction and Purpose

Temperature is one of the most important environmental influences on salmonid biology. Most aquatic organisms, including salmon and steelhead, are poikilotherms, meaning their temperature and metabolism is determined by the ambient temperature of water. Temperature therefore influences growth and feeding rates, metabolism, development of embryos and alevins, timing of life history events such as upstream migration, spawning, freshwater rearing, and seaward migration, and the availability of food. Temperature changes can also cause stress and lethality (Ligon et al. 1999). Temperatures at sub-lethal levels can effectively block migration, lead to reduced growth, stress fish, affect reproduction, inhibit smoltification, create disease problems, and alter competitive dominance (Elliott 1981, USEPA 1999). Further, the stressful impacts of water temperatures on salmonids are cumulative and positively correlated to the duration and severity of exposure. The longer the salmonid is exposed to thermal stress, the less chance it has for long-term survival (Ligon et al. 1999).

A literature review was performed to evaluate temperature needs for the various life stages of steelhead trout (*Oncorhynchus mykiss*), coho salmon (*Oncorhynchus kisutch*), and Chinook salmon (*Oncorhynchus tschawytscha)*. The purpose of this review was to identify temperature thresholds that are protective of salmonids by life stage, as a basis for evaluating Klamath River basin stream temperatures.

This review included USEPA temperature guidance, Oregons' and Washingtons' temperature standards reviews, reports that compiled and summarized existing scientific information, and laboratory and field studies. When possible, species-specific needs were summarized by the following life stages: migrating adults, spawning and incubation/emergence, and freshwater rearing and growth. Additionally, the effects of temperature on disease and lethality are also discussed. Some of the references reviewed covered salmonids as a general class of fish, while others were species specific. Information for fall run coho salmon, spring/summer, fall, and winter steelhead, and spring and fall run Chinook salmon are compiled by life stage in Table 1 through Table 12.

Temperature Metrics

In considering the effect of temperature on salmonids, it is useful to have a measure of chronic (i.e. sub-lethal) and acute (i.e. lethal) temperature exposures. A common measure of chronic exposure is the maximum weekly average temperature (MWAT). The MWAT is the maximum seasonal or yearly value of the mathematical mean of multiple, equally spaced, daily temperatures over a running seven-day consecutive period (Brungs and Jones 1977, p.10). In other words, it is the highest single value of the seven-day moving average temperature. A common measure of acute effects is the instantaneous maximum. A third metric, the maximum weekly maximum temperature (MWMT), can be used as a measure of both chronic and acute effects. The MWMT (also known as the seven-day average of the daily maximum temperatures (7-DADM)) is the maximum seasonal or yearly-value of the daily maximum temperatures over a running seven-day consecutive period. The MWMT is useful because it describes the maximum temperatures in a stream, but is not overly influenced by the maximum temperature of a single day.

Much of the information reported in the literature characterizes temperature needs with terms such as "preferred" or "optimum". Preferred stream temperatures are those that fish most frequently inhabit when allowed to freely select temperatures in a thermal gradient (USEPA 1999). An optimum range provides suitable temperatures for feeding activity, normal physiological response, and normal behavior (without symptoms of thermal stress) (USEPA 1999). Optimal temperatures have also been described as those temperatures at which growth rates, expressed as weight gain per unit of time, are maximal for the life stage (Armour 1991).

Salmonid stocks do not tend to vary much in their life history thermal needs, regardless of their geographic location. The USEPA (2001) in their *Summary of Technical Literature Examining the Physiological Effects of Temperature on Salmonids* makes the case that there is not enough

significant genetic variation among stocks or among species of salmonids to warrant geographically specific water temperature standards.

> Climate conditions vary substantially among regions of the State and the entire Pacific Northwest. …Such [varying climatic] conditions could potentially have led to evolutionary adaptations, resulting in development of subspecies differences in thermal tolerance. …[However,] the literature on genetic variation in thermal effects indicates occasionally significant but very small differences among stocks and increasing differences among subspecies, species, and families of fishes. Many differences that had been attributed in the literature to stock differences are now considered to be statistical problems in analysis, fish behavioral responses under test conditions, or allowing insufficient time for fish to shift from field conditions to test conditions (Mathur & Silver 1980, Konecki et al. 1993, both as cited in USEPA 2001).

Additionally:

> There are many possible explanations why salmonids have not made a significant adaptation to high temperature in streams of the Pacific Northwest. Temperature tolerance is probably controlled by multiple genes, and consequently would be a core characteristic of the species not easily modified through evolutionary change without a radical shift in associated physiological systems. Also, the majority of the life cycle of salmon and steelhead is spent in the ocean rearing phase, where the smolt, subadults, and adults seek waters with temperatures less than 59°F (15°C) (Welch et al, 1995, as cited in USEPA 2001).

As a result, literature on the temperature needs of coho and Chinook salmon and steelhead trout stemming from data collected in streams outside Northern California are cited in this document and are considered relevant to characterizing the thermal needs of salmonids which use Northern California rivers and streams.

Adult Migration and Holding

All of the adult migration and holding temperature needs referenced in this section can be found in Table 1 through Table 3. Salmon and trout respond to temperatures during their upstream migration (Bjornn and Reiser 1991). Delays in migration have been observed in response to temperatures that were either too cold or too warm. Most salmonids have evolved with the temperature regime they historically used for migration and spawning, and deviations from the normal pattern can affect survival (Spence et al. 1996).

The USEPA document *EPA Region 10 Guidance for Pacific Northwest State and Tribal Water Quality Standards* (2003) recommends that the seven-day average of the daily maximum temperatures (7-DADM) should not exceed 18°C in waters where both adult salmonid migration and "non-core" juvenile rearing occur during the period of summer maximum temperatures. The document does not define what constitutes the "summer" period. Non-core juvenile rearing is defined as moderate to low density salmon and trout rearing usually occurring in the mid or lower part of the basin, as opposed to areas of high density rearing which are termed "core" rearing areas. This criterion is derived from analysis and synthesis of past laboratory and field research. The USEPA believes that this temperature recommendation will protect against lethal conditions, prevent migration blockage, provide optimal or near optimal juvenile growth conditions, and prevent high disease risk by minimizing the exposure time to temperatures which can lead to elevated disease rates.

A 7-DADM temperature of 20°C is recommended by the USEPA (2003) for waterbodies that are used almost exclusively for migration during the period of summer maximum temperatures.

> "EPA believes that a 20°C criterion would protect migrating juveniles and adults from lethal temperatures and would prevent migration blockage conditions. However, EPA is concerned that rivers with significant hydrologic alterations (e.g., rivers with dams and reservoirs, water withdrawals, and /or significant river channelization) may experience a

> loss of temperature diversity in the river, such that maximum temperatures occur for an extended period of time and there is little cold water refugia available for fish to escape maximum temperatures. In this case, even if the river meets a 20°C criterion for maximum temperatures, the duration of exposure to 20°C temperatures may cause adverse effects in the form of increased disease and decreased swimming performance in adults, and increased disease, impaired smoltification, reduced growth, and increased predation for late emigrating juveniles…."

Therefore, the USEPA recommends a narrative provision to protect and, if possible, restore the natural thermal regime accompany the 7-DADM 20°C criterion for rivers with significant hydrologic alterations.

In an exhaustive study of both laboratory and field studies of temperature effects on salmonids and related species, USEPA (1999, 2001) concluded that temperatures of approximately 22-24°C limit salmonid distribution, i.e., they totally eliminate salmonids from a location. USEPA (1999) also notes that changes in competitive interactions between fish species can lead to a transition in dominance from salmonids to other species at temperatures 2-4°C lower than the range of total elimination.

Steelhead Trout Migration

In a review of numerous studies, WDOE (2002) concluded that daily average temperatures of 21-24°C are associated with avoidance behavior and migration blockage in steelhead trout. WDOE suggests that the MWMT should not exceed 17-18°C, and daily maximum temperatures should not exceed 21-22°C to be fully protective of adult steelhead migration.

Table 1: Effects of Temperature in Considering Adult Steelhead and Migration

<table>
<tr><th>C</th><th colspan="3">Migration</th></tr>
<tr><td>24</td><td rowspan="3">21-24 Average daily temperature associated with avoidance and migration blockage (2)</td><td colspan="2" rowspan="2">22-24 Temperature range which eliminates salmonids from an area (3,4)</td></tr>
<tr><td>23</td></tr>
<tr><td>22</td><td rowspan="2">21-22 Daily maximum temperature should not exceed this to be fully protective (2)</td><td rowspan="4">18-22 Temperature range at which transition in dominance from salmonids to other species occurs (4)</td></tr>
<tr><td>21</td></tr>
<tr><td>20</td><td colspan="2">20 MWMT should not exceed this in waterbodies used almost exclusively for migration. Should be used in conjunction with a narrative provision about protecting/restoring the natural thermal regime for rivers with significant hydrologic alterations (1)</td></tr>
<tr><td>19</td><td colspan="2"></td></tr>
<tr><td>18</td><td rowspan="2">17-18 MWMT should not exceed this to be fully protective (2)</td><td>18 MWMT should not exceed this where migration and non-core rearing occur (1)</td></tr>
<tr><td>17</td><td colspan="2"></td></tr>
</table>

References

1 USEPA 2003 (reviewed many literature sources to make assessments of temperature needs)
2 WDOE 2002 (reviewed many literature sources to make assessments of temperature needs)
3 USEPA 2001 (reviewed many literature sources to make assessments of temperature needs)
4 USEPA 1999 (reviewed many literature sources to make assessments of temperature needs)

Chinook Salmon Migration and Holding

USEPA (2001) cited various literature sources that identified thermal blockages to Chinook salmon migration at temperatures ranging from 19-23.9°C, with the majority of references citing migration barriers at temperatures around 21°C.

Table 2: Effects of Temperature in Considering Adult Chinook and Migration and Holding

<table>
<tr><th>°C</th><th colspan="5">Migration</th></tr>
<tr><td>24</td><td colspan="2"></td><td colspan="2" rowspan="5">19-23.9 Range of temperatures causing thermal blockage to migration (3)</td><td rowspan="2"></td></tr>
<tr><td>23</td><td colspan="2">23 Klamath Basin fall Chinook begin migration upstream at temperatures as high as 23C if temperatures are rapidly falling (6)</td><td colspan="2" rowspan="2">22-24 Temperature range which eliminates salmonids from an area (3,5)</td></tr>
<tr><td>22</td><td colspan="2">22 Klamath Basin fall Chinook will not migrate upstream when mean daily temperatures are 22C or greater (6)</td><td rowspan="4">18-22 Temperature range at which transition in dominance from salmonids to other species occurs (5)</td></tr>
<tr><td>21</td><td colspan="2" rowspan="2">21-22 Daily maximum temperature should not exceed this range to be protective of migration (2)</td><td colspan="2">21 Most references cite as thermal block to migration (3)</td></tr>
<tr><td colspan="2">21 Klamath Basin fall Chinook will not migrate upstream if temperatures are 21C or above and rising (6)</td></tr>
<tr><td>20</td><td colspan="4">20 MWMT should not exceed this in waterbodies used almost exclusively for migration. Should be used in conjunction with a narrative provision about protecting/restoring the natural thermal regime for rivers with significant hydrologic alterations (1)</td></tr>
<tr><td>19</td><td colspan="2"></td><td rowspan="11">10.6-19.6 Temperature range where adult fall Chinook migrate (4)</td><td></td></tr>
<tr><td>18</td><td colspan="2" rowspan="2"></td><td></td><td>18 MWMT should not exceed this where migration and non-core rearing occur (1)</td></tr>
<tr><td>17</td><td colspan="2" rowspan="3">16-17 MWMT should be below this where Chinook are holding (2)</td><td></td></tr>
<tr><td>16</td><td></td></tr>
<tr><td>15</td><td colspan="2"></td><td></td></tr>
<tr><td>14</td><td colspan="2" rowspan="6">7.2-14.5 Preferred temperatures for Chinook (4)</td><td>13-14 Average daily temperature should be below this where spring Chinook are holding (2)</td></tr>
<tr><td>13</td><td rowspan="6">3.3-13.3 Temperature range where adult spring Chinook migrate (4)</td></tr>
<tr><td>12</td></tr>
<tr><td>11</td></tr>
<tr><td>10</td></tr>
<tr><td>9</td></tr>
<tr><td>8</td><td colspan="2"></td></tr>
<tr><td>7</td><td colspan="2"></td></tr>
<tr><td>6</td><td></td><td></td><td></td></tr>
<tr><td>5</td><td></td><td></td><td></td><td></td></tr>
<tr><td>4</td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td></td><td></td><td></td><td></td></tr>
</table>

References

1 USEPA 2003 (reviewed many literature sources to make assessments of temperature needs)
2 WDOE 2002 (reviewed many literature sources to make assessments of temperature needs)
3 USEPA 2001 (reviewed many literature sources to make assessments of temperature needs)
4 Bell 1986 (reviewed many literature sources to make assessments of temperature needs)
5 USEPA 1999 (reviewed many literature sources to make assessments of temperature needs)
6 Strange (personal communication 2005)

A radio tracking study on spring Chinook revealed that when maximum temperatures of 21.1°C were reached, a thermal barrier to migration was established (Bumgarner et al. 1997, as cited by USEPA 1999). Bell (1986) reviewed various studies and notes spring Chinook migrate at water temperatures ranging from 3.3-13.3°C, while fall Chinook migrate at temperatures of 10.6-19.6°C. Preferred temperatures for Chinook range from 7.2-14.5°C (Bell 1986). Based on a technical literature review, WDOE (2002) concluded that daily maximum temperatures should not exceed 21-22°C during Chinook migration.

Utilizing radio telemetry to track the movements and monitor the internal body temperatures of adult fall Chinook salmon during their upriver spawning migration in the Klamath basin, Strange (personal communication 2005) found that fall Chinook will not migrate upstream when mean daily temperatures are ≥22°C. Strange (personal communication 2005) also noted that adult fall Chinook in the Klamath basin will not migrate upstream if temperatures are 21°C or above and rising, but will migrate at temperatures as high as 23°C if temperatures are rapidly falling.

Spring Chinook begin entering freshwater streams during a relatively cool-water season but must hold throughout the warm summer period, awaiting cooler spawning temperatures (ODEQ 1995). The cumulative effects of management practices such as elevated water temperatures, reduced cover from large woody debris, and reduced resting pool area due to pool filling increase the susceptibility of holding adult fish to mortality from thermal effects (ODEQ 1995). WDOE (2002) states that where spring Chinook are holding over for the summer prior to spawning the average daily water temperature should be below 13-14°C and the MWMT should be below 16-17°C.

Coho Salmon Migration

Migration for coho is delayed when water temperatures reach 21.1°C (Bell 1986). Bell (1986) also notes that the preferred water temperatures for coho range from 11.7-14.5°C. In California coho salmon typically migrate upstream when water temperatures range from 4-14°C (Briggs, 1953 and Shapovalov and Taft, 1954, as cited by Hassler, 1987). WDOE (2002) reviewed various studies and concluded that to be protective of adult coho migration, MWMTs should not exceed 16.5°C.

Reutter and Herdendorf (1974) conducted laboratory experiments and found that the preferred temperature, that is the temperature where fish will ultimately congregate given an infinite gradient of temperatures to choose from (Fry 1947, as cited by Reutter and Herdendorf 1974), for coho salmon was 11.4°C.

Table 3: Effects of Temperature in Considering Adult Coho and Migration

<table>
<tr><th>°C</th><th colspan="3">Migration</th></tr>
<tr><td>24</td><td rowspan="3">22-24 Temperature range which eliminates salmonids from an area (3,6)</td><td></td></tr>
<tr><td>23</td><td></td></tr>
<tr><td>22</td><td rowspan="5">18-22 Temperature range at which transition in dominance from salmonids to other species occurs (6)</td></tr>
<tr><td>21</td><td>21.1 Migration is delayed when temperatures reach this value (4)</td></tr>
<tr><td>20</td><td>20 MWMT should not exceed this in waterbodies used almost exclusively for migration. Should be used in conjunction with a narrative provision about protecting/restoring the natural thermal regime for rivers with significant hydrologic alterations (1)</td></tr>
<tr><td>19</td><td></td></tr>
<tr><td>18</td><td colspan="2">18 MWMT should not exceed this where migration and non-core rearing occur (1)</td></tr>
<tr><td>17</td><td colspan="3"></td></tr>
<tr><td>16</td><td colspan="3">16.5 MWMT should not exceed this value to be fully protective (2)</td></tr>
<tr><td>15</td><td colspan="3"></td></tr>
<tr><td>14</td><td rowspan="4">11.7-14.5 Preferred temperature range (4)</td><td rowspan="5" colspan="2">4-14 Temperature range at which migration typically occurs (5)</td></tr>
<tr><td>13</td></tr>
<tr><td>12</td></tr>
<tr><td>11</td></tr>
<tr><td></td><td>11.4 Preferred temperature (7)</td></tr>
</table>

References

1 USEPA 2003 (reviewed many literature sources to make assessments of temperature needs)
2 WDOE 2002 (reviewed many literature sources to make assessments of temperature needs)
3 USEPA 2001 (reviewed many literature sources to make assessments of temperature needs)
4 Bell 1986 (reviewed many literature sources to make assessments of temperature needs)
5 Briggs 1953, and Shapovalov and Taft (1954, as cited by Hassler 1987)
6 USEPA 1999 (reviewed many literature sources to make assessments of temperature needs)
7 Reutter and Herdendorf 1974 (laboratory study)

Spawning, Incubation, and Emergence

All of the spawning, incubation, and emergence temperature needs referenced in this section can be found in Table 4 through Table 7. Many sources have stated that temperature affects the time of migration in adults and thus the time of spawning, which influences the incubation temperature regime, which in turn influences survival rates, development rates, and growth of embryos and alevins (Murray and McPhail 1988). USEPA Region 10 (2003) recommends that the 7-DADM temperatures should not exceed 13°C for salmonid spawning, egg incubation, and fry emergence. Optimum temperatures for salmonid egg survival ranges from 6-10°C (USEPA 2001).

Steelhead Spawning, Incubation, and Emergence

In a discussion paper and literature summary evaluating temperature criteria for fish species including salmonids and trout, WDOE (2002) cites studies showing that steelhead were observed spawning in temperatures ranging from 3.9-21.1°C, and that the preferred temperatures for steelhead spawning range from 4.4-12.8°C. In a review of various studies, Bell (1986) concludes that steelhead spawning occurs at water temperatures ranging from 3.9-9.4°C.

Steelhead and rainbow trout eggs had the highest survival rates between 5-10°C according to Myrick and Cech (2001) and while they can tolerate temperatures as low as 2°C or as high as 15°C, mortality is increased at these temperatures. WDOE (2002) reviewed literature on the survival of steelhead and rainbow trout embryos and alevins at various temperatures and concluded that the average water temperature should not exceed 7-10°C throughout development, and the maximum daily average temperature should be below 11-12°C at the time of hatching.

Table 4: Effects of Temperature in Considering Steelhead Incubation and Emergence

<table>
<tr><th>°C</th><th colspan="3">Incubation and Emergence</th></tr>
<tr><td>15</td><td colspan="3">15 Steelhead and rainbow trout eggs can survive at temperatures as high as this but mortality is high compared to lower temperatures (3)</td></tr>
<tr><td>14</td><td colspan="3"></td></tr>
<tr><td>13</td><td colspan="3">13 MWMT should not exceed this value to be protective of spawning, egg incubation, and fry emergence (1)</td></tr>
<tr><td>12</td><td colspan="3" rowspan="2">11-12 Maximum daily average temperature should be below this range at the time of hatching (2)</td></tr>
<tr><td>11</td></tr>
<tr><td>10</td><td rowspan="5">5-10 Steelhead and rainbow trout eggs had the highest survival within this range (3)</td><td rowspan="3">6-10 Optimum temperature for salmonid eggs survival to hatching (4)</td><td rowspan="2">7-10 Average daily temperature should not exceed this range throughout embryo development (2)</td></tr>
<tr><td>9</td></tr>
<tr><td>8</td></tr>
<tr><td>7</td><td rowspan="2">7-10 Average daily temperature should not exceed this range throughout embryo development (2)</td></tr>
<tr><td>6</td></tr>
<tr><td>5</td><td colspan="2"></td></tr>
<tr><td>4</td><td colspan="3"></td></tr>
<tr><td>3</td><td colspan="3"></td></tr>
<tr><td>2</td><td colspan="3">2 Steelhead and rainbow trout eggs can survive at temperatures as low as this but mortality is high compared to higher temperatures (3)</td></tr>
</table>

References

1 USEPA 2003 (reviewed many literature sources to make assessments of temperature needs)
2 WDOE 2002 (reviewed many literature sources to make assessments of temperature needs)
3 Myrick and Cech 2001 (reviewed many literature sources to make assessments of temperature needs)
4 USEPA 2001 (reviewed many literature sources to make assessments of temperature needs)

Chinook Spawning, Incubation, and Emergence

The Oregon Department of Environmental Quality (ODEQ 1995) reviewed numerous studies and recommended a temperature range of 5.6-12.8°C for spawning Chinook. A discussion paper and literature summary by WDOE (2002) found that the literature reviewed noted a wide range of temperatures associated with Chinook spawning (5.6-17.7°C), although the majority of these temperature observations cite daily maximum temperatures below 14.5°C. Reiser and Bjornn (1979, as cited by Armour et al. 1991) cites recommended spawning temperature ranges for spring, summer and fall Chinook salmon populations in the Pacific Northwest of 5.6-13.9°C. When ripe adult spring Chinook females experience temperatures above 13-15.5°C, pre-spawning adult mortality becomes pronounced (ODEQ 1995). Additionally, there is decreased survival of eggs to the eyed stage and alevin development is inhibited due to the exposure of the ripe female to warm temperatures, even if the stream temperatures during the egg and alevin development are appropriate (ODEQ 1995).

WDOE (2002) reviewed numerous references on the effects of various temperatures on Chinook incubation and development and used these studies to derive the temperatures that are protective of Chinook salmon from fertilization through fry development. References reviewed by WDOE (2002) include laboratory studies assessing Chinook embryo survival at various constant temperatures, studies attempting to mimic naturally fluctuating temperatures experienced by incubating eggs, studies which have made stepwise reductions in the incubation temperatures as incubation progressed to evaluate survival of eggs, and studies on the effects of transferring eggs to optimal constant incubation temperatures after they had been exposed to higher temperatures for various periods. As a result of this review, WDOE (2002) recommends that average daily temperatures remain below 11-12.8°C at the initiation of incubation, and that the seasonal average should not exceed 8-9°C in order to provide full protection from fertilization through initial fry development. The highest single day maximum temperature should not exceed 17.5-20°C to protect eggs and embryos from acute lethal conditions.

Table 5: Effects of Temperature in Considering Chinook Incubation and Emergence

<table>
<tr><th>°C</th><th colspan="5">Incubation and Emergence</th></tr>
<tr><td>20</td><td colspan="5" rowspan="3">17.5-20 The highest single day maximum temperature should not exceed this range to protect eggs and embryos from acute lethal conditions (2)</td></tr>
<tr><td>19</td></tr>
<tr><td>18</td></tr>
<tr><td>17</td><td colspan="4"></td><td rowspan="15">1.7-16.7 Eggs can survive these temps. but mortality is greatly increased at the extremes (3)</td></tr>
<tr><td>16</td><td colspan="4"></td></tr>
<tr><td>15</td><td colspan="4"></td></tr>
<tr><td>14</td><td rowspan="12">5-14.4 Recom-mended temp. range for incubation (4)</td><td rowspan="2">13.5-14.5 Daily maximum temperatures should not exceed this from fertilization through initial fry development (5)</td><td colspan="2">14 Moderate embryo survival (6)</td><td rowspan="13">2-14 Range of temps. for normal embryo develop-ment (6)</td></tr>
<tr><td>13</td><td colspan="2">13 MWMT should not exceed this value to be protective of spawning, egg incubation, and fry emergence (1)</td></tr>
<tr><td>12</td><td></td><td rowspan="10">4-12 Lowest levels of egg mortality at these temps. (3)</td><td>11-12.8 Average daily temperatures should be below this range at beginning of incubation (2)</td></tr>
<tr><td>11</td><td>11 High embryo survival (6)</td><td></td></tr>
<tr><td>10</td><td>9-10 Optimal temp. should be below this range (5)</td><td rowspan="4">6-10 Optimum temperature for salmonid eggs survival to hatching (5)</td></tr>
<tr><td>9</td><td rowspan="2">8-9 Seasonal ave. temps. should not exceed this range from fertilization through initial fry development (2)</td></tr>
<tr><td>8</td></tr>
<tr><td></td><td>8 High embryo survival (6)</td></tr>
<tr><td>7</td><td></td><td></td></tr>
<tr><td>6</td><td></td><td></td></tr>
<tr><td>5</td><td>5 High embryo survival (6)</td><td></td></tr>
<tr><td>4</td><td></td><td></td><td></td></tr>
<tr><td>3</td><td colspan="3"></td></tr>
<tr><td>2</td><td colspan="3">2 Poor embryo survival (6)</td></tr>
<tr><td>1</td><td colspan="4"></td></tr>
</table>

References

1 USEPA 2003 (reviewed many literature sources to make assessments of temperature needs)
2 WDOE 2002 (reviewed many literature sources to make assessments of temperature needs)
3 Myrick and Cech 2001 (reviewed many literature sources to make assessments of temperature needs)
4 Reiser and Bjornn (1979, as cited by Armour et al. 1991)
5 USEPA 2001 (reviewed many literature sources to make assessments of temperature needs)
6 Murray and McPhail 1988 (laboratory study)

USEPA (2001) reviewed multiple literature sources and concluded that optimal protection from fertilization through initial fry development requires that temperatures be maintained below 9-10°C, and that daily maximum temperatures should not exceed 13.5-14.5°C. Reiser and Bjornn (1979, as cited by Armour et al. 1991) list recommended temperature ranges of 5.0-14.4°C for spring, summer and fall Chinook salmon incubation in the Pacific Northwest. Myrick and Cech (2001) reviewed studies on the Sacramento-San Joaquin R. and concluded that the lowest levels of Chinook egg mortality occurred at temperatures between 4-12°C, and while eggs can survive at temperatures from 1.7-16.7°C, mortality is greatly increased at the temperature extremes.

Embryo survival was studied in a laboratory experiment conducted by Murray and McPhail (1988). They incubated five species of Pacific salmon, including Chinook, at five incubation temperatures (2, 5, 8, 11, 14°C). Chinook embryo survival was high at 5, 8, and 11°C, but survival was moderate at 14°C and poor at 2°C. As a result of their study, Murray and McPhail (1988) concluded that the range of temperatures for normal embryo development is > 2°C and <14°C.

Coho Spawning, Incubation, and Emergence

WDOE (2002) found that several studies and literature reviews state that spawning activity in coho may typically occur in the range of 4.4-13.3ºC. According to a review by Bell (1986), preferred spawning temperatures range from 4.5-9.4ºC. Brungs and Jones (1977) used existing data on the optimum and range of temperatures for coho spawning and embryo survival to create criteria using protocols from the National Academy of Sciences and National Academy of Engineering. The resultant criteria were that the MWAT should not exceed 10ºC and the daily maximum temperature should not exceed 13ºC to be protective of coho (Brungs and Jones 1977, p.16).

Table 6: Effects of Temperature in Considering Coho Incubation and Emergence

<table>
<tr><th>°C</th><th colspan="4">Incubation and Emergence</th></tr>
<tr><td>14</td><td colspan="4">14 Upper limit for normal embryo development (5)</td></tr>
<tr><td>13</td><td colspan="2">13 MWMT should not exceed this value to be protective of spawning, egg incubation, and fry emergence (1)</td><td>13 Daily maximum temperature should not exceed this value to be protective (6)</td><td rowspan="11">4.5-13.3 Preferred emergence temperature range (3)</td></tr>
<tr><td>12</td><td colspan="2"></td><td rowspan="2">9-12 MWMT should not exceed this range to be fully protective (4)</td><td></td></tr>
<tr><td>11</td><td colspan="2"></td><td></td></tr>
<tr><td>10</td><td rowspan="5">6-10 Optimum temperature for salmonid eggs survival to hatching (4)</td><td rowspan="3">8-10 Ave. daily temp. during incubation should be at or below this to be supportive (2)</td><td>10 MWAT should not exceed this to be protective (6)</td></tr>
<tr><td>9</td><td></td><td></td></tr>
<tr><td>8</td><td></td><td></td><td></td></tr>
<tr><td>7</td><td colspan="3"></td></tr>
<tr><td>6</td><td colspan="3"></td></tr>
<tr><td>5</td><td></td><td colspan="3"></td></tr>
<tr><td>4</td><td></td><td colspan="3"></td></tr>
</table>

References

1 USEPA 2003 (reviewed many literature sources to make assessments of temperature needs)
2 WDOE 2002 (reviewed many literature sources to make assessments of temperature needs)
3 Bell 1986 (reviewed many literature sources to make assessments of temperature needs)
4 USEPA 2001 (reviewed many literature sources to make assessments of temperature needs)
5 Murray and McPhail 1988 (laboratory study)
6 Brungs and Jones 1977 (used existing data on the optimum range of temperatures for spawning and embryo survival to create criteria using protocols from the National Academy of Engineering (1973)).

In a discussion paper and literature summary WDOE (2002) reviewed studies that assessed the survival of embryos and alevin at various temperatures. Based on the findings of these studies WDOE (2002) has determined that the average daily temperature during the incubation period should be at or below 8-10ºC to fully support this coho salmon life stage. According to a review of various literature sources by Bell (1986), the preferred emergence temperatures for coho range from 4.5-13.3ºC. USEPA (2001) concluded that to fully support pre-emergent stages of coho development MWMTs should not exceed 9-12°C.

Murray and McPhail (1988) incubated five species of Pacific salmon, including coho, at five temperatures (2, 5, 8, 11, 14°C) to determine embryo survival at various temperatures. Coho embryos suffered increased mortality above 11°C although survival was still high. They concluded that the upper limit for normal coho embryo development is 14°C (Murray and McPhail 1988).

Table 7: Effects of Temperature in Considering Steelhead, Chinook, and Coho Spawning

<table>
<tr><th>°C</th><th colspan="3">Steelhead</th><th colspan="3">Chinook</th><th colspan="2">Coho</th><th>All Salmonids</th></tr>
<tr><td>21</td><td rowspan="20">3.9-21.2 Steelhead observed spawning in this temp. range (2)</td><td colspan="2"></td><td colspan="3"></td><td colspan="2"></td><td></td></tr>
<tr><td>20</td><td colspan="2"></td><td colspan="3"></td><td colspan="2"></td><td></td></tr>
<tr><td>19</td><td colspan="2"></td><td colspan="3"></td><td colspan="2"></td><td></td></tr>
<tr><td>18</td><td colspan="2"></td><td colspan="3"></td><td colspan="2"></td><td></td></tr>
<tr><td>17</td><td colspan="2"></td><td></td><td></td><td rowspan="13">5.6-17.7 Range of temps. associated with spawning from references reviewed (2)</td><td colspan="2"></td><td></td></tr>
<tr><td>16</td><td colspan="2"></td><td></td><td></td><td colspan="2"></td><td></td></tr>
<tr><td>15</td><td colspan="2"></td><td rowspan="3">13-15.5 Temp. range at which pre-spawning mortality becomes pronounced in ripe spring Chinook (4)</td><td></td><td colspan="2"></td><td></td></tr>
<tr><td>14</td><td colspan="2"></td><td rowspan="2">14.5 Majority of refs. cite daily max temps. associated with spawning below this level (2)</td><td colspan="2"></td><td></td></tr>
<tr><td>13</td><td></td><td rowspan="8">4.4-12.8 Preferred temp. range for spawning (2)</td><td rowspan="7">5.6-13.9 Recommended temperature range for spawning (5)</td><td>13 Daily maximum temp. not to exceed this value to be protective (6)</td><td rowspan="8">4.4-13.3 Typical temps. during which spawning occurs (2)</td><td>13 MWMT not exceed this value during spawning, egg incubation, and fry emergence (1)</td></tr>
<tr><td>12</td><td></td><td rowspan="7">5.6-12.8 Recom-mended temperature range for spawning (4)</td><td></td><td></td></tr>
<tr><td>11</td><td></td><td></td><td></td></tr>
<tr><td>10</td><td></td><td>10 MWAT not exceed this value to be protective (6)</td><td></td></tr>
<tr><td>9</td><td rowspan="9">3.9-9.4 Temp. range where spawning occurs (3)</td><td rowspan="6">4.5-9.4 Preferred spawning temperature range (3)</td><td></td></tr>
<tr><td>8</td><td></td></tr>
<tr><td>7</td><td></td></tr>
<tr><td>6</td><td></td></tr>
<tr><td>5</td><td></td></tr>
<tr><td>4</td><td colspan="2"></td><td></td></tr>
<tr><td>3</td><td></td><td colspan="3"></td><td colspan="2"></td><td></td></tr>
</table>

References

1 USEPA 2003 (reviewed many literature sources to make assessments of temperature needs)
2 WDOE 2002 (reviewed many literature sources to make assessments of temperature needs)
3 Bell 1986 (reviewed many literature sources to make assessments of temperature needs)
4 ODEQ 1995 (reviewed many literature sources to make assessments of temperature needs)
5 Reiser and Bjornn (1979, as cited by Armour et al. 1991)
6 Brungs and Jones 1977 (used existing data on the optimum range of temperatures for spawning and embryo survival to create criteria using protocols from the National Academy of Engineering (1973))

Freshwater Rearing and Growth

All of the freshwater rearing and growth temperature needs referenced in this section can be found in Table 8 through Table 10. Temperature affects metabolism, behavior, and survival of both juvenile fish as well as other aquatic organisms that may be food sources. In streams of the Northern California Coast, including the Klamath River, young Chinook, coho and steelhead may rear in freshwater from one to four years before migrating to the ocean.

In an exhaustive study of both laboratory and field studies of temperature effects on salmonids and related species, USEPA (1999) concluded that temperatures of approximately 22-24°C limit salmonid distribution, i.e., they totally eliminate salmonids from a location. USEPA (1999) also notes that changes in competitive interactions between fish species can lead to a transition in dominance from salmonids to other species at temperatures 2-4°C lower than the range of total elimination.

To protect salmon and trout during summer juvenile rearing the USEPA (2003) for Region 10 provided a single guidance metric designating 16°C as the 7-DADM temperature that should not be exceeded in areas designated as "core" rearing locations. Core rearing areas are defined as areas with moderate to high densities of summertime salmonid juvenile rearing generally found in the mid- to upper portions of river basins. This criterion will protect juvenile salmonids from lethal temperatures, provide optimal to upper optimal conditions for juvenile growth depending on the time of year, avoid temperatures where salmonids are at a competitive disadvantage with other fish species, protect against increased disease rates caused by elevated temperatures, and provide temperatures which salmonids prefer according to scientific studies.

Steelhead Freshwater Rearing and Growth

Nielsen et al. (1994) studied thermally stratified pools and their use by juvenile steelhead in three California North Coast rivers including the Middle Fork Eel River, Redwood Creek at Redwood National Park, and Rancheria Creek, located in the Navarro River watershed. In detailed observations of juvenile steelhead behavior in and near thermally stratified pools in Rancheria Creek, Nielsen et al. (1994) noted behavioral changes including decreased foraging and increased aggressive behavior as pool temperature reached approximately 22°C. As pool temperature increased above 22°C, juveniles left the observation pools and moved into stratified pools where temperatures were lower.

Wurtsbaugh and Davis (1977, as cited by USEPA 2001) found that steelhead trout growth could be enhanced by temperature increases up to 16.5°C. Using a risk assessment approach which took into account "realistic food estimates", Sullivan et al. (2000) report temperatures of 13-17.0°C (MWAT), 14.5-21°C (MWMT), and 15.5-21°C (annual maximum) will ensure no more than a 10% reduction from maximum growth for steelhead. Reduction from maximum growth will be $\leq$20% for temperatures ranging from 10-19.0°C (MWAT), 10-24°C (MWMT), and 10.5-26°C (annual maximum).

Table 8: Effects of Temperature in Considering Juvenile Steelhead Rearing and Growth

<table>
<tr><th>°C</th><th colspan="5">Rearing and Growth</th></tr>
<tr><td>26</td><td colspan="4"></td><td rowspan="2">21-26 Annual maximum temp. which will ensure no more than 20% reduction from max. growth (4)</td></tr>
<tr><td>25</td><td colspan="4"></td></tr>
<tr><td>24</td><td>22-24 Temperature range which totally eliminates salmonids from area, limiting their distribution (6)</td><td colspan="3"></td><td rowspan="3">21-24 MWMT which will ensure no more than 20% reduction from max growth (4)</td></tr>
<tr><td>23</td><td></td><td colspan="3">>22 Juveniles left observation pools and moved to pools with lower temperatures (2)</td></tr>
<tr><td>22</td><td></td><td colspan="2">22 Decreased foraging, increased aggressive behavior (2)</td><td rowspan="4">18-22 Temperature range at which transition in dominance from salmonids to other species occurs (6)</td></tr>
<tr><td>21</td><td></td><td colspan="2"></td><td rowspan="5">14.5-21 MWMT which will ensure no more than 10% reduction from maximum growth (4)</td><td rowspan="6">15.5-21 Annual maximum temperature which will ensure no more than 10% reduction from maximum growth (4)</td></tr>
<tr><td>20</td><td></td><td colspan="2"></td></tr>
<tr><td>19</td><td></td><td rowspan="2">17-19 MWAT will ensure no more than 20% reduction from max. growth (4)</td><td rowspan="2">17.2-19 Growth may be maximized at temperatures as high as this under satiated feeding conditions, lab studies at constant temperature (5)</td></tr>
<tr><td>18</td><td></td></tr>
<tr><td>17</td><td></td><td rowspan="5">13-17 MWAT range which will ensure no more than 10% reduction from maximum growth (4)</td><td rowspan="4">15.5-18 Average daily temperatures at which maximum growth occurs under satiated feeding, lab studies at varying temps (5)</td></tr>
<tr><td>16</td><td>16.5 Growth enhanced by temp. increases up to this temp. (3)
16.2 Mean temp. at which max. growth occurred during the summer, lab studies using natural feeding conditions and varying temps. (5)</td><td>16 MWMT should not exceed this value to be protective of core rearing locations (1)</td></tr>
<tr><td>15</td><td>15.2 Mean temp. at which max. growth occurred during the fall, lab studies using natural feeding conditions and varying temps. (5)</td><td></td><td rowspan="2">10.5-15.5 Annual maximum temperature which will ensure no more than 20% reduction from maximum growth (4)</td></tr>
<tr><td>14</td><td></td><td colspan="2"></td><td rowspan="5">10-14.5 MWMT which will ensure no more than 20% reduction from maximum growth (4)</td></tr>
<tr><td>13</td><td>13.3 Mean temp. at which max. growth occurred during the spring, lab studies using natural feeding conditions and varying temps. (5)</td><td rowspan="4">10-13 MWAT will ensure no more than 20% reduction from maximum growth (4)</td><td colspan="2"></td></tr>
<tr><td>12</td><td></td><td colspan="2"></td></tr>
<tr><td>11</td><td></td><td colspan="2"></td></tr>
<tr><td>10</td><td></td><td colspan="2"></td></tr>
</table>

References

1 USEPA 2003 (reviewed many literature sources to make assessments of temperature needs)
2 Nielsen et al. 1994. (field study)
3 Wurtsbaugh and Davis (1977, as cited by USEPA 2001)
4 Sullivan et al. 2000 (developed method for estimating effects of temperature and food consumption on gain/ loss of weight, using previously collected data)
5 WDOE 2002 (reviewed many literature sources to make assessments of temperature needs)
6 USEPA (1999)

A literature review was conducted by WDOE (2002) in which studies to determine the water temperature that would allow for maximum growth of steelhead trout were analyzed. These included laboratory studies conducted at constant and fluctuating temperatures. One of the studies was conducted using feeding rates comparable to those observed in natural creeks, although most of the laboratory studies were conducted under satiated feeding conditions. As a result of this review of laboratory studies conducted at constant temperatures, WDOE (2002) concludes that under satiated rations growth may be maximized at temperatures as high as 17.2-19°C. Results from laboratory studies using variable temperatures show maximum growth occurs at average daily temperatures between 15.5-18°C, and that under feeding rates similar to natural conditions at various times of the year maximum growth rates occurred at mean temperatures of 13.3°C (spring season), 15.2°C (fall season) and 16.2°C (summer season).

Chinook Freshwater Rearing and Growth

In a laboratory study, Brett (1952) demonstrated that juvenile Chinook salmon, acclimated to a temperature of 20°C, selectively aggregated in areas where the temperature was in the region of 12-13°C.

ODEQ (1995), reviewed numerous studies and concluded for juvenile spring Chinook salmon rearing, positive growth takes place at temperatures between 4.5-19°C, and that optimum rearing production is between 10.0-15.6°C. However, as the extremes of this temperature range are reached growth reaches zero. Above and below these thresholds growth becomes negative as feeding ceases and respiration rates increase and/or decrease rapidly.

After synthesizing data from several sources USEPA (2001), came up with the same recommended optimum temperature zone for all Chinook salmon as ODEQ (1995) of 10.0-15.6°C. While there is research suggesting that some Chinook stocks exhibit adequate rearing capabilities above 15.6°C, USEPA (2001) conclude that anything over this threshold significantly increases the risk of mortality from warm-water diseases.

In a laboratory study Marine and Cech (2004) studied the incremental effects of chronic exposure to three temperature regimes (13-16 °C, 17-20 °C, and 21-24 °C) on Chinook juveniles during rearing and smoltification. Their findings reflected that Chinook juveniles reared at the 17-20 ºC and 21-24 ºC temperature ranges experienced significantly decreased growth rates, impaired smoltification indices, and increased predation vulnerability compared with juveniles reared at 13-16 ºC.

In a field study Chinook grew faster in a stream where temperatures peaked at 16°C compared to a stream where temperatures peaked at 20°C (ODFW 1992, as cited by WDOE 2002). WDOE (2002) reviewed literature on Chinook growth including laboratory studies conducted at a constant temperature, laboratory studies conducted at fluctuating temperatures, and field studies to evaluate the water temperature that would be protective of Chinook and allow for maximum growth. Most of the laboratory studies were conducted under satiated feeding conditions, although one of the studies was conducted using feeding rates more comparable to those observed in natural creeks. As a result of this review of laboratory studies conducted at constant temperatures, WDOE (2002) concludes that maximum growth is expected to occur with exposure to constant temperatures from 15.6-19°C. However, increased growth at temperatures above 15.6°C was inconsistently greater, and under natural rations the temperatures at which maximum growth occurs may decline by as much as 4.2°C. Recommendations based on the review of two laboratory studies conducted at fluctuating temperatures are that "…average temperatures below 19°C are necessary to support maximum growth rates in Chinook salmon, and that the average temperature that produces maximum growth rates likely lies between 15-18°C (median 16.5°C)".

Table 9: Effects of Temperature in Considering Juvenile Chinook Rearing and Growth

<table>
<tr><th>°C</th><th colspan="5">Rearing and Growth</th></tr>
<tr><td>24</td><td rowspan="3" colspan="2">22-24 Temperature range which totally eliminates salmonids from area, limiting their distribution (7)</td><td></td><td rowspan="3" colspan="2">21-24 Decreased growth, impaired smoltification, increased predation compared to juveniles reared at 13-16 (6)</td></tr>
<tr><td>23</td><td></td></tr>
<tr><td>22</td><td rowspan="2">18-22 Temperature range at which transition in dominance from salmonids to other species occurs (7)</td></tr>
<tr><td>21</td><td colspan="2"></td><td rowspan="3" colspan="2">17-20 Decreased growth, impaired smoltification, increased predation compared to juveniles reared at 13-16 (6)</td></tr>
<tr><td>20</td><td colspan="2"></td><td></td></tr>
<tr><td>19</td><td>19 Temperatures above this do not support maximum growth, lab studies at varying temperatures (3)</td><td rowspan="5">15.6-19 Maximum growth expected according to lab studies conducted at constant temperature and satiated rations. Under natural feeding conditions maximum growth may occur at temperatures as much as 4.2C lower (3)</td><td rowspan="2">4.5-19 Temperature range at which positive growth takes place (5)</td></tr>
<tr><td>18</td><td rowspan="3">15-18 Average temperature where maximum growth occurs, lab studies conducted at varying temperatures (3)</td><td></td></tr>
<tr><td>17</td><td></td><td rowspan="3">13-16 Increased growth, unimpaired smoltification, lower predation compared to juveniles reared at 21-24, or 17-20 (6)</td></tr>
<tr><td>16</td><td>16 Chinook grew faster in a stream where temperatures peaked at 16 than when they peaked at 19C (3)
16 MWMT should not exceed this value to be protective of core rearing locations (2)</td><td rowspan="5">10-15.6 Optimal temperature range for rearing (5)</td></tr>
<tr><td>15</td><td rowspan="5">10-15.6 Temperature range for optimal growth. Anything over this threshold increases the risk of mortality from warm water disease (1)</td><td rowspan="4"></td></tr>
<tr><td>14</td><td rowspan="3">12-13 Juvenile Chinook acclimated to 20 selectively aggregate to these water temperatures (4)</td></tr>
<tr><td>13</td><td rowspan="2"></td></tr>
<tr><td>12</td><td rowspan="2"></td></tr>
<tr><td>11</td><td></td><td></td></tr>
<tr><td>10</td><td></td><td></td><td></td><td></td></tr>
<tr><td>9</td><td colspan="5"></td></tr>
<tr><td>8</td><td colspan="5"></td></tr>
<tr><td>7</td><td colspan="5"></td></tr>
<tr><td>6</td><td colspan="5"></td></tr>
<tr><td>5</td><td colspan="5"></td></tr>
<tr><td>4</td><td colspan="5"></td></tr>
</table>

References

1 USEPA 2001 (reviewed many literature sources to make assessments of temperature needs)
2 USEPA 2003 (reviewed many literature sources to make assessments of temperature needs)
3 WDOE 2002 (reviewed many literature sources to make assessments of temperature needs)
4 Brett 1952 (laboratory study)
5 ODEQ 1995 (reviewed many literature sources to make assessments of temperature needs)
6 Marine and Cech 2004 (laboratory study)
7 USEPA (1999)

Coho Freshwater Rearing and Growth

In a study of juvenile coho presence and absence in the Mattole watershed, Welsh et al. (2001) used logistic regression to determine that an MWAT greater than 16.8°C or a MWMT greater than 18.1°C may preclude the presence of juvenile coho salmon in the stream. The criterion correctly determined the presence or absence of juvenile coho in 18 of 21 streams. Welsh et al. (2001) also reported that juvenile coho were found in all streams with an MWAT less than 14.5°C, or a MWMT less than 16.3°C.

Sullivan et al. (2000) reviewed sub-lethal and acute temperature thresholds from a wide range of studies, incorporating information from laboratory-based research, field observations, and risk assessment approaches. Using a risk assessment approach based on "realistic food estimates" Sullivan et al (2000) suggest that MWATs ranging from 12.5-14.5°C for coho will result in no more than a 10% reduction from maximum growth, and that a range for the MWAT of 9-18.5°C will reduce growth no more than 20% from maximum. Sullivan et al. (2000) also calculated temperature ranges for MWMT (13-16.5°C) and the annual maximum temperature (13-17.5°C) that will result in no more than a 10% reduction in maximum growth. They further calculated ranges for MWMT (9-22.5°C) and the annual maximum temperature (9.5-23°C) that will result in no more than a 20% growth loss.

In an attempt to determine the water temperature that will allow for maximum growth of coho salmon, WDOE (2002) reviewed literature on laboratory studies conducted at a constant temperature and fluctuating temperatures, and field studies. The two laboratory studies reviewed were conducted under satiated feeding conditions. Shelbourn (1980, as cited by WDOE 2002) found that maximum growth occurred at a constant temperature of 17°C, while Everson (1973, as cited by WDOE 2002) tested fish at different temperatures and determined that coho had the greatest growth at the temperature test regime from 12.1-20.8°C (median 16.5°C). While the various field studies reviewed did not provide an estimate of the temperature best for maximum growth they did allow for WDOE (2002) to conclude that weekly average temperatures of 14-15°C were more beneficial to growth than lower temperature regimes, and daily maximum temperatures of 21-26°C were detrimental to growth.

Brett (1952) acclimated five different species of salmon to various temperatures ranging from 5-24°C and found that coho salmon showed the greatest preference for temperatures between 12-14°C. It was also determined that coho showed a general avoidance of temperatures above 15°C even in fish who were acclimated to temperatures as high as 24°C.

Konecki et al. (1995a) raised two groups of juvenile coho salmon under identical regimes to test the hypothesis that the group from a stream with lower and less variable temperature would have a lower and less variable preferred temperature than the group from a stream with warmer and more variable temperatures. Results reflected that the two groups tended to differ in their preferred temperature range as predicted above, but the differences were slight. Konecki et al. (1995a) concluded that the temperature preference of juvenile coho salmon in their study was 10-12°C.

Exhibit List 115

Table 10: Effects of Temperature in Considering Juvenile Coho Rearing and Growth

<table>
<tr><th>°C</th><th colspan="5">Rearing and Growth</th></tr>
<tr><td>26</td><td colspan="2" rowspan="4">21-26 Daily maximum temperatures in this range are detrimental to growth, according to field studies (3)</td><td colspan="3"></td></tr>
<tr><td>25</td><td colspan="3"></td></tr>
<tr><td>24</td><td colspan="2" rowspan="2">22-24 Temperature range which totally eliminates salmonids from an area, limiting their distribution (9)</td><td></td></tr>
<tr><td>23</td><td rowspan="5">17.5-23 Annual maximum temperature will ensure no more than 20% reduction from maximum growth (2)</td></tr>
<tr><td>22</td><td rowspan="4">16.5-22.5 MWMT will ensure no more than 20% reduction from maximum growth (2)</td><td rowspan="3">18-22 Temperature range at which transition in dominance from salmonids to other species occurs (9)</td></tr>
<tr><td>21</td><td rowspan="3">12.1-20.8 Greatest growth occurs in this temperature range under satiated conditions, lab study (7)</td></tr>
<tr><td>20</td><td></td></tr>
<tr><td>19</td><td></td><td></td><td></td></tr>
<tr><td>18</td><td>18.1 MWMT above this may preclude the presence of juvenile coho in steams (5)</td><td></td><td></td><td></td></tr>
<tr><td>17</td><td rowspan="5">14.5-18.5 MWAT will ensure no more than 20% reduction from maximum growth (2)</td><td></td><td>17 Maximum growth at this constant temperature, at satiated rations in a lab study (6)</td><td rowspan="7">13.5 17.5 Annual maximum temperature will ensure no more than 10% reduction from maximum growth (2)</td></tr>
<tr><td>16</td><td rowspan="6">13-16.5 MWMT will ensure no more than 10% reduction from maximum growth (2)</td><td>16.8 MWAT above this may preclude the presence of juvenile coho in streams (5)</td></tr>
<tr><td></td><td>16.3 Juveniles found in all streams with MWMT less than this value (5)</td></tr>
<tr><td></td><td>16 MWMT not exceed this value to be protective of core rearing locations (1)</td></tr>
<tr><td>15</td><td>>15 Juveniles show avoidance, even those acclimated to 24C (4)</td></tr>
<tr><td></td><td>14-15 Weekly average temperatures in this range are more beneficial than lower temperatures (3)</td></tr>
<tr><td>14</td><td>14.5 Juvenile coho found in all streams with MWAT less than this value (5)</td><td rowspan="3">12-14 Preferred temperature range (4)</td></tr>
<tr><td>13</td><td rowspan="2">12.5-14.5 MWAT will ensure no more than 10% reduction from maximum growth (2)</td><td rowspan="3">9-13 MWMT will ensure no more than 20% reduction from maximum growth (2)</td><td rowspan="3">9.5-13.5 Annual maximum temperature will ensure no more than 20% reduction from max. growth (2)</td></tr>
<tr><td>12</td></tr>
<tr><td>11</td><td rowspan="3">9-12.5 MWAT will ensure no more than 20% reduction from maximum growth (2)</td><td rowspan="3">10-12 Preferred temperature range (8)</td></tr>
<tr><td>10</td><td></td></tr>
<tr><td>9</td><td></td><td></td><td></td></tr>
</table>

References

1 USEPA 2003 (reviewed many literature sources to make assessments of temperature needs)
2 Sullivan et al. 2000 (developed method for estimating effects of temperature and food consumption on gain/ loss of weight, using previously collected data)
3 WDOE 2002 (reviewed many literature sources to make assessments of temperature needs)
4 Brett 1952 (laboratory study)
5 Welsh et al. 2001 (study on coho presence and absence in the Mattole watershed, using logistic regression to determine temperature needs)
6 Shelbourn (1980, as cited by WDOE 2002) (laboratory study)
7 Everson (1973, as cited by WDOE 2002) (laboratory study)
8 Konecki et al. 1995a (laboratory study)
9 USEPA (1999)

Exhibit List 116

Lethality

All of the lethal temperatures referenced in this section can be found in Table 11. WDOE (2002) reviewed literature on three types of studies (constant exposure temperature studies, fluctuating temperature lethality studies, and field studies) and used this information to calculate the MWMT that, if exceeded, may result in adult and juvenile salmonid mortality. The resultant MWMTs for these various types of studies are as follows: constant exposure studies 22.64°C, fluctuating lethality studies 23.05°C , and field studies 22.18°C.

Table 11: Effects of Temperature in Considering Lethality and Salmonids

°C	Steelhead	Chinook	Coho	All Salmonids
28			28 LT50[1] for age 0-fish acclimated to a 10-13C cycle (6)	
27				
26			26 LT50[1] for presmolts (age 2-fish) acclimated to a 10-13C cycle (6)	
25		25.1 Upper lethal temp. at which 50% of the population would die after infinite exposure, juvenile Chinook acclimated to temperatures from 5-24C (4)	25.6 Upper lethal threshold (3)	
		25 Upper lethal threshold (3)	25 Upper lethal temp. at which 50% of the population would die after infinite exposure, juvenile coho acclimated to temps. from 5-24C (4)	
		25 Chronic (exposure >7 days) upper lethal limit for juvenile Chinook (5).		
24		24-24.5 Survival becomes less than 100% for juvenile Chinook acclimated to temperatures from 5-24C (4)		
23	23.9 Upper lethal threshold for steelhead (3)			23.05 do not exceed this value to prevent adult and juvenile mortality, data from fluctuating temp. studies (1)
22				22.64 do not exceed this value to prevent adult and juvenile mortality, data from constant exposure studies (1)
				22.18 do not exceed this value to prevent adult and juvenile mortality, data from field studies (1)
21	21.1 Temperature lethal to adults (7)			
	21 Lethal threshold for steelhead acclimated to 19C (2)			

[1] Maximum temperature in the cycle at which 50% mortality occurred

References

1 WDOE 2002 (reviewed many literature sources to make assessments of temperature needs)
2 Coutant (1970, as cited by USEPA 1999)
3 Bell 1986 (reviewed many literature sources to make assessments of temperature needs)
4 Brett 1952 (laboratory study)
5 Myrick and Cech 2001 (reviewed many literature sources to make assessments of temperature needs)
6 Thomas et al. 1986 (laboratory study)
7 CDFG 2001 (reviewed literature sources to make assessments)

Steelhead Lethality
Coutant (1970, as cited by USEPA 1999) found that Columbia River steelhead, which were acclimated to a river temperature of 19°C, had a lethal threshold of 21°C. Bell (1986) reviewed various studies and states that the lethal threshold for steelhead is 23.9°C. According to the California Department of Fish and Game (2001, p.419), temperatures of 21.1°C have been reported as being lethal to adults.

Chinook Lethality
In a laboratory study Brett (1952) acclimated five different species of juvenile salmon to various temperatures ranging from 5-24°C. At temperatures of 24°C and below there was 100% survival of fish during the one-week duration of the experiment. Brett (1952) concluded that the lethal temperature (temperature where survival becomes less than 100%) was between 24.0 and 24.5°C, and the ultimate upper lethal temperature was 25.1°C (temperature at which 50% of the population is dead after infinite exposure). A review of numerous studies led Bell (1986) to conclude that the upper lethal temperature for Chinook is 25°C. Myrick and Cech (2001) reviewed literature on studies from the Central Valley and found data to suggest that the chronic (exposure >7 days) upper lethal limit for juvenile Chinook is approximately 25°C.

Coho Lethality
In a review of various literature sources, Bell (1986) found that the upper lethal temperature for coho is 25.6°C. Brett (1952) concluded that the ultimate upper lethal temperature of juvenile coho salmon was 25.0°C (temperature at which 50% of the population is dead after infinite exposure). Thomas et al. (1986) conducted a study to determine the mortality of coho subjected to fluctuating temperatures. It was determined that the LT50 (the temperature at which 50% of the population will die) for fish acclimated to a 10-13°C cycle was 26°C for presmolts (age-2 fish), and 28°C for age-0 fish.

Disease
All of the effects of temperatures on disease risk in salmonids referenced in this section can be found in Table 12. WDOE (2002) reviewed studies of disease outbreak in salmonids and estimates that an MWMT of 14.38°C will virtually prevent warm water disease effects. To avoid serious rates of infection and mortality the MWMT should not exceed 17.38°C, and that severe infections and catastrophic outbreaks become a serious concern when the MWMTs exceed 20.88°C.

In a summary of temperature considerations, USEPA (2003) states that disease risks for juvenile rearing and adult migration are minimized at temperatures from 12-13°C, elevated from 14-17°C, and high at temperatures from 18-20°C.

Acknowledging that there are many diseases that affect salmonids, the following discussion will focus on three which are common in the Klamath Basin: Ichthyophthiriasis (Ich), Ceratomyxosis, and Columnaris. *Ichthyophthirius multifiliis* is a protozoan parasite that causes the disease known as Ichthyophthiriasis (Ich). The disease ceratomyxosis is caused by a parasite, *Ceratomyxa shasta* (*C. shasta*). Columnaris disease is a bacterial infection caused by *Flavobacterium columnare* (synomyms*: Bacillus columnaris, Chondrococcus columnaris, Cytophaga columnaris, Flexibacter columnaris*).

Ichthyophthiriasis (Ich)
Nigrelli et al. (1976, as cited by Dickerson et al. 1995) proposed that there are physiological races of Ich, which are related to the temperature tolerance of the host fishes. Thus, there are races of Ich that infect cold-water (7.2-10.6°C) fishes such as salmon, and others that infect warm-water (12.8-16.1°C) tropical fishes. Bell (1986) discusses Ich and states that at water temperatures

above 15.6°C, this disease often breaks out in salmon fingerlings, especially Chinook. CDWR (1988) states that serious outbreaks of Ich occur at temperatures from 18.3-21.2°C.

Numerous studies and reviews have been conducted on the optimal temperature for Ich. Piper et al. (1982, p.316.) wrote that optimal temperatures range from 21-23.9°C. CDWR (1988) stated the optimum temperature for Ich is in the range of 25 to 26.7°C, while Bell (1986) states optimum temperatures are noted from 21.2-26.7°C.

Temperature is an important factor in the persistence of Ich infections in salmonids. The growth period varies from 1 week at 20 °C to 20 days at 7 °C (Nigrelli et al. 1976, as cited by Dickerson et al. 1995). Piper et al. (1982, p.316) state that at optimal temperatures of 21-23.9°C, the life cycle may take as few as 3-4 days. The cycle requires 2 weeks at 15.5°C, and more than 5 weeks at 10°C (Piper et al. 1982, p.316). Durborow et al. (1998) note that to complete its lifecycle, Ich requires from less than 4 days at temperatures higher than 24°C, to more than 5 weeks at temperatures lower than 7°C. Although studies report varying lengths of time for Ich to complete its lifecycle at similar temperatures, it is clear that the speed at which Ich develops increases as temperatures increase.

Ceratomyxosis

In reviewing the literature on Ceratomyxosis it is clear that the intensity of the disease increases, and the incubation period decreases, as water temperatures increase (CDWR 1988, Letritz and Lewis, Udey et al. 1975). At water temperatures greater than 10°C steelhead will show evidence of Ceratomyxosis in approximately 38 days (Leitritz and Lewis 1976, p.154). In a study of juvenile coho salmon by Udey et al. (1975), time from exposure to death was more than 90% temperature dependent, and increased from 12.5 days at 23.3°C to 146 days at 9.4°C indicating the accelerating effect of higher temperatures on the progress of the disease. The time from exposure to death of juvenile rainbow trout was nearly 97% temperature dependent, increasing from 14 days at 23.3°C to 155 days at 6.7°C (Udey et al. 1975).

C. shasta appears to become infective at temperatures around 10-11°C (CDWR 1988). According to Leitritz and Lewis (1976, p.154), steelhead from the Klamath River are quite susceptible to *C. shasta* infections and suffer severe losses when exposed.

Udey et al. (1975) conducted a study to determine the relation of water temperature to Ceratomyxosis in juvenile rainbow trout and coho salmon. Rainbow trout from the Roaring River Hatchery, and coho from Fall Creek Salmon Hatchery (both in Oregon) were used in this experiment. Groups of 25 fish exposed to *C. shasta* were transferred to 12.2°C water, and then were tempered to one of eight experimental temperatures from 3.9 to 23.3°C (2.8°C increments).

In the juvenile coho salmon experiment Udey et al. (1975) found that percent mortality increased progressively from 2% at 9.4°C to 22% at 15.0°C and 84% at 20.5°C. No deaths occurred in coho salmon maintained at 3.9 and 6.7°C, indicating that ceratomyxosis in coho can be suppressed by water temperatures of 6.7°C or below (Udey et al. 1975).

Tests conducted by Udey et al. (1975) on rainbow trout juveniles indicate that once infection is initiated, juvenile rainbow trout have little or no ability to overcome *C. shasta* infections at water temperatures between 6.7 and 23.3°C. Fatal infections varied from 75-86% at temperatures ranging from 6.7 to 15.0°C (Udey et al. 1975). Mortality in trout held at 20.5 and 23.3°C were lower (72% and 52% respectively) due to losses from *Flexibacter columnaris,* which occurred well before the onset of deaths caused by *C. shasta,* in spite of efforts to control it with terramycin (Udey et al. 1975). The results from Udey et al. (1975) also reflected no deaths occurred in juvenile trout held at 3.9°C.

Table 12: Effects of Temperature in Considering Disease and Salmonids

Exhibit List 119

°C	Ich		Ceratomyxosis		Columnaris	Disease (general)	
26		21-26.7 Optimum temp. range for Ich, compilation of temps. from three references (3,4,5)					
25							
24	>24 Lifecycle takes less than 4 days (5)						
23	21-23.9 Life cycle takes as few as 3-4 days (5)		23.3 Juvenile coho salmon and rainbow trout time from exposure to death is 12.5 and 14 days respectively (9)	6.7-23.3 Juvenile rainbow trout have little or no ability to overcome infection, and mortality varied from 75-86% (9)	23.3 Juvenile spring Chinook mortality was 92%, and time from exposure to death was 2.3 days (13)		
22					22.2 Mortality is 100% in juvenile sockeye exposed to *C. columnaris* (10)		
21					>21.1 Temperatures at this level are associated with a 28-74% infection rate in Chinook (11)		
20	18.3-21.2 Serious outbreaks of Ich occur (4)	20 Lifecycle takes 1 week (6)	20.5 Mortality is 84% in juvenile coho exposed to *C. shasta* (9).		20.5 Mortality in juvenile steelhead and coho from Columnaris was 100%, and 70% in juvenile spring Chinook (13)	>20.88 MWMTs over this value can result in severe infections and catastrophic outbreaks (1)	18-20 Temperature range which is associated with a high risk of disease in rearing juveniles and migrating adults (2)
					20.5 In juvenile steelhead and coho time from exposure to death was 1.6-1.7 days (13)		
					20 Average water temperature at which low virulence strains show signs of outbreak (3, 12)		
19							
18							
17					17.8 Mortality rates were 52, 92, and 99% for juvenile spring Chinook, steelhead and coho respectively (13)	17.38 MWMT should not be exceeded to avoid serious rates of infection and mortality (1)	14-17 Temperature range which is associated with an elevated risk of disease in rearing juveniles and migrating adults (2)
16					16.1 Mortality is 30% in juvenile sockeye exposed to *C. columnaris* (10)		
15	>15.6 Associated with outbreaks in salmonid fingerlings, especially Chinook (3)		15 Mortality is 22% in juvenile coho exposed to *C. shasta* (9).		15.6 Average water temperature at which low virulence strains show signs of outbreak (3)		
	15.5 Lifecycle of Ich takes 2 weeks (5)				15 Mortality was 31, 56, and 51% for juvenile spring Chinook, steelhead, and coho respectively (13)		
14						14.38 MWMT will virtually prevent all warm water disease (1)	

Table 12 (continued):Effects of Temperature in Considering Disease and Salmonids

°C	Exhibit List 120 Ich	Ceratomyxosis		Columnaris	Disease (general)
13			6.7-23.3 Juvenile rainbow trout have little or no ability to overcome infection, and mortality varied from 75-86% (9)		12-13 Temperature range which minimizes the risk of disease in rearing juveniles and migrating adults (2)
12				12.8 After 7 days of infection mortality is 60-100% (majority of tests 100%) (12)	
				12.2 Mortality was 4-20% in juvenile spring Chinook, steelhead, and coho respectively. Time from exposure to death ranged from 7.6-12.2 days (13).	
11		10-11 *C. shasta* appears to be come infective (4)			
10	10 Lifecycle takes more than 5 weeks (5)				
		<10 Steelhead show evidence of *C. shasta* in ~38 days (8)			
9		9.4 Juvenile coho time from exposure to death is 146 days, mortality is 2% (9)		3.9-9.4 No mortality in spring Chinook, steelhead, or coho from Columnaris (13)	
8					
7	7 Lifecycle takes 20 days (6)				
	<7 Lifecycle takes more than 5 weeks (7)				
6			6.7 Juvenile rainbow trout time from exposure to death is 155 days (9)		
			3.9-6.7 No mortality in Juvenile coho exposed to *C. shasta* (9)		
5					
4					
3					

References

1 WDOE 2002 (reviewed many literature sources to make assessments of temperature needs)
2 USEPA 2003 (reviewed many literature sources to make assessments of temperature needs)
3 Bell 1986 (reviewed many literature sources to make assessments of temperature needs)
4 CDWR (1988)
5 Piper et al. (1982)
6 Nigrelli et al. (1976, as cited by Dickerson et al. 1995)
7 Durborow et al. (1998)
8 Leitritz and Lewis (1976)
9 Udey et al. (1975)
10 Ordal and Rucker (1944, as cited by Pacha et al. 1970)
11 USEPA 1999 (reviewed many literature sources to make assessments of temperature needs)
12 Pacha et al. (1970)
13 Holt et al. (1975)

Columnaris

The importance of temperature on infections of Columnaris has been demonstrated in numerous laboratory studies. Ordal and Rucker (1944, as cited by Pacha et al. 1970) exposed juvenile sockeye salmon to *C. columnaris* and studied the effect of temperature on the disease. In these studies, the overall mortality ranged from 30% in fish held at 16.1°C to 100% in those held at 22.2°C (Ordal and Rucker 1944, as cited by Pacha et al. 1970). USEPA (1999) cites studies that conducted surveys of Columnaris infection frequency on Chinook in the Snake River in July and early August of 1955-1957, which revealed 28-75% of fish infected when water temperature was >21.1°C.

Low virulence strains of Columnaris show signs of outbreak when average water temperatures are over 20°C (Bell 1986, Pacha et al. 1970). Bell (1986) states that outbreaks of high virulence strains occur when average water temperatures reach 15.6°C, and Pacha et al. (1970) found mortalities of 60-100% (majority of tests 100%) occur at temperatures of 12.8°C after 7 days of infection. With regard to strains of higher virulence, while these strains are capable of beginning infection and producing disease at water temperatures as low as 12.8°C, the disease process becomes progressively slower as the water temperature is lowered (Pacha et al. 1970).

Holt et al. (1975) performed a study on the relation of water temperature to Columnaris in juvenile steelhead trout and juvenile coho and spring Chinook salmon. Tests were performed on groups of 25-35 fish at eight temperatures ranging from 3.9°C to 23.3°C (2.8°C increments). At 20.5°C mortality was 100% in juvenile steelhead trout and coho salmon, 70% in juvenile spring Chinook salmon, and at temperatures 23.3°C juvenile spring Chinook mortality was 92% (Holt et al. 1975). Mortality rates were 52, 92, and 99% at 17.8°C for juvenile spring Chinook, steelhead trout, and coho salmon respectively, and mortality dropped to 31, 56, and 51% at 15.0°C (Holt et al. 1975). At 12.2°C mortality varied from 4 to 20% among juveniles of the three species, and at temperatures of 9.4°C and below, no deaths due to the experimental infection with *F. columnaris* occurred (Holt et al. 1975). Holt et al. (1975) state that these results indicate that under the conditions of these experiments Columnaris disease was completely suppressed by water temperatures of 9.4°C or below.

In general, data from laboratory studies indicates that as water temperatures increase, the time to death decreases (Pacha et al. 1970). With juvenile steelhead trout and juvenile coho and spring Chinook salmon as the temperature increased above 12.2°C, the disease process was progressively accelerated, resulting in a minimum time to death at 20.5 or 23.3°C and a maximum at 12.2°C (Holt et al. 1975). In these juvenile salmonids Holt et al. (1975) found the mean time to death decreased from 7.6-12.2 days at 12.2°C to 1.6-1.7 days at 20.5°C for juvenile coho and steelhead, and 2.3 days at 23.3°C for juvenile spring Chinook (Holt et al. 1975).

Selection of TMDL Temperature Thresholds

As a result of this literature review, Regional Water Board staff has selected chronic and acute temperature thresholds for evaluation of Klamath River basin stream temperatures. Chronic temperature thresholds (MWMTs) were selected from the USEPA document *EPA Region 10 Guidance For Pacific Northwest State and Tribal Temperature Water Quality Standards* (2003), and are presented in Table 13. The Region 10 guidance is the product of a three-year interagency effort, and has been reviewed by both independent science review panels and the public. Acute lethal temperature thresholds were selected based upon best professional judgment of the literature, and are presented in Table 14.

Table 13: Temperature Thresholds-from USEPA 2003

Life Stage	MWMT (°C)
Adult Migration	**20**
Adult Migration plus Non-Core[1] Juvenile Rearing	**18**
Core[2] Juvenile Rearing	**16**
Spawning, Egg Incubation, and Fry Emergence	**13**

[1] Non-Core is defined as moderate to low density salmon and trout rearing usually occurring in the mid or lower part of the basin (moderate and low not defined).
[2] Core is defines as areas of high density rearing (high is not specifically defined).

Table 14: Lethal Temperature Thresholds

Lethal Threshold (°C)			
Life Stage	**Steelhead**	**Chinook**	**Coho**
Adult Migration and Holding	**24**	**25**	**25**
Juvenile Growth and Rearing	**24**	**25**	**25**
Spawning, Egg Incubation, and Fry Emergence	**20**	**20**	**20**

In some cases it may be necessary to calculate MWATs for a given waterbody, and compare these to MWAT thresholds. USEPA (2003) states that for many rivers in the Pacific Northwest the MWMT is about 3°C higher than the MWAT (USEPA 2003, as cited by Dunham et al. 2001and Chapman 2002). Rather than list MWAT thresholds in this document using the 3°C difference suggested above, the Regional Water Board will consider stream temperatures within an individual watershed. Thus the Regional Water Board will calculate both MWMTs and MWATs for a given waterbody, and characterize the actual difference between these temperature metrics for the watershed using an approach similar to that used in Sullivan et al. (2000). Once this relationship is understood, MWAT thresholds for each life stage can be identified for a specific watershed, and compared to the watershed MWATs.

The freshwater temperature thresholds presented in this section are applicable during the season or time of year when the life stage of each species is present. Periodicity information is not discussed in this document and will be presented in the watershed-specific TMDLs. Where life history, timing, and/or species needs overlap, the lowest of each temperature metric applies.

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Exhibit List 126

Lower Columbia Estuary Partnership

BATWATER STATION FLOODPLAIN RESTORATION PROJECT

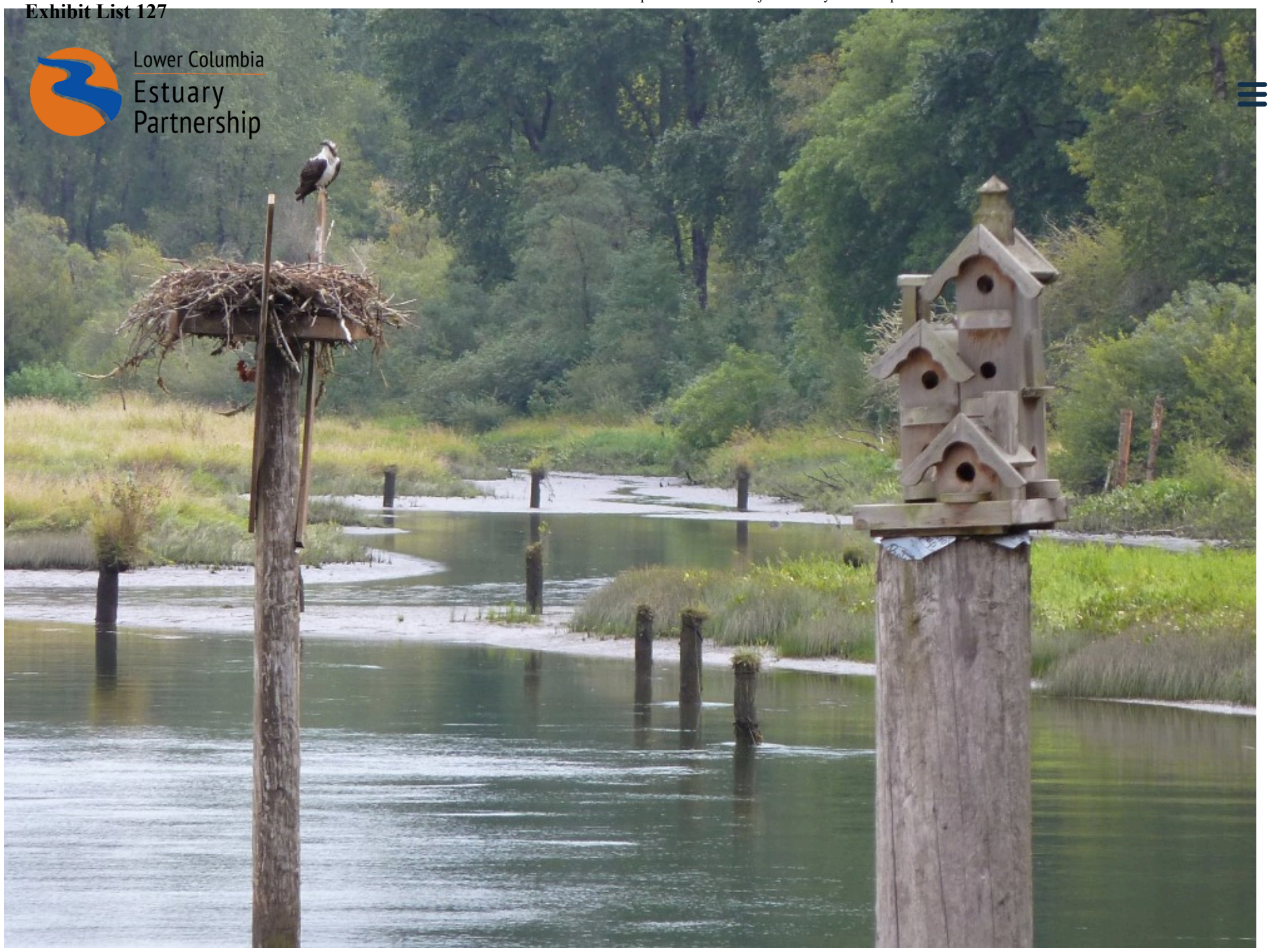
In 2011, a private landowner reached out to her local Soil & Water Conservation District to begin a conversation. Her property is directly on the Columbia River, and she wanted to return it to a more natural state to support fish and wildlife. They were happy to start the conversation about how to make that happen.



The levee along Batwater Station before the project

Completed in 2015, the Batwater Station Floodplain Restoration Project reconnected a 26-acre tidal wetland to the lower Columbia River. The project benefits threatened and endangered species of salmon and steelhead and other native species. Located on private land near Clatskanie, Oregon, the site lies at the confluence of Bradbury Slough and the Columbia River near the head of Crims Island. Historically, habitat at this site was a tidally-influenced scrub-shrub wetland habitat, but over time levees, tide gates, creek realignments, and land clearing impacted the site and reduced its habitat potential.

Exhibit List 127



The landowner has a deep care for wildlife and provides a variety of nesting habitat for birds. She also manages the other half of her property for Columbian White-tailed Deer.

Collaboration between the private landowner, who is committed to natural resource conservation, and local restoration partners Lower Columbia River Watershed Council and Columbia Soil and Water Conservation District made this project a special success. The landowner recognized the opportunity to balance agricultural and habitat priorities on their property and worked with partners to design a project that benefits native fish, turtles, frogs, deer and beaver, all found at the site. The landowner enjoys watching these wildlife species thrive in their newly created habitat.



Exhibit List 128



Painted turtles and red-legged frogs are some of the amphibians that live at Batwater Station.

The project included breaching the levee and constructing a starter tidal channel into the historic wetland to provide fish access to the off-channel habitat. Large wood structures and beaver dam analogs were installed in the channel to create habitat complexity, cover for juvenile fish, basking structures for turtles, and to encourage beaver activity. Crews revegetated 11 acres of the site with native wetland trees, shrubs, and emergent vegetation to initiate natural ecological processes, hydraulic diversity, control sediment, moderate water temperatures, and provide fish and wildlife habitat.

Exhibit List 129



Removing the tide gate at Batwater Station

Exhibit List 130



Wood habitat structures in the starter tidal channel

The year following construction, 4th and 6th graders from Clatskanie got to visit the site with our educators. It was an excellent opportunity for students to see a newly completed habitat restoration project near their home, and to contribute to the project by planting new trees. They also got to paddle our Big Canoes around Bradbury Slough and into the newly created channels of Batwater Station.

Exhibit List 131



We continue to monitor the area as the site approaches five years post-construction. Estuary Partnership staff monitor using photo points and gauges for physical characteristics such as water surface elevation, sediment accretion and temperature to observe the hydrologic connectivity to the Columbia River, habitat quality, and changes in the floodplain over time.

Exhibit List 132

Lower Columbia Estuary Partnership



Aerial drone image of the restoration at Batwater Station

Reach C

Start Year 2011

End Year 2017

Total Acres 26

Type ..... Habitat

Project

Habitat Restoration

Project Partners

Columbia Soil and Water Conservation District

Lower Columbia River Watershed Council

Private Landowner

Funders

Bonneville Power Administration

Exhibit List 133

Restoration Activities

Flow Barrier (Dam) Removal/Modification

Levee Breach

Off/Side Channel Creation/Enhancement

Re-vegetation

Lower Columbia Estuary Partnership

Estuary Partnership

Protecting the Columbia River in partnership with its communities.

503-226-1565
info@estuarypartnership.org
Lower Columbia Estuary Partnership
400 NE 11th Avenue, Portland, OR 97232

Sign up for our newsletter

Exhibit List 134

The Wayback Machine - https://web.archive.org/web/20261007124630/https://swap.oregon.gov/sgcn/northern-red-legged-...



Northern red-legged frogs are primarily diurnal. They are a medium-sized frog that can be found in a variety of aquatic habitat types and in terrestrial habitats. They have a prominent ridges (dorsolateral folds) from the eyes down either side of the back, and the under half of the hind legs are a bright red. They have long legs, smooth skin, and are a greenish-gray to reddish-brown color overall with dark flecks on the back, sides, and legs. Distinctive markings are a dark mask, a horizontal stripe from eye to shoulder, and cream and dark gray marble patterns on the throat and chest. Older frogs have red coloring on their sides, while juveniles have yellow under the legs and belly instead of red. The tadpoles are brown with small black flecks on the upper body and small light flecks on the lower body. Northern red-legged frogs are relatively large: males grow up to 2.7 inches, and adult females can grow up to 5 inches in length.

OVERVIEW

Species Common Name
Northern Red-legged Frog

Species Scientific Name
Rana aurora

Federal Listing Status
Species of Concern

State Listing Status
Sensitive

ECOREGIONS

Exhibit List 135



Coast Range

(https://web.archive.org/web/20261007124630/https://swap.oregon.gov/ecoregion/coast-range/)



Klamath Mountains

(https://web.archive.org/web/20261007124630/https://swap.oregon.gov/ecoregion/klamath-mountains/)



West Cascades

(https://web.archive.org/web/20261007124630/https://swap.oregon.gov/ecoregion/west-cascades/)



Willamette Valley

(https://web.archive.org/web/20261007124630/https://swap.oregon.gov/ecoregion/willamette-valley/)

SPECIAL NEEDS

Northern red-legged frogs spend a greater portion of their life cycle in terrestrial habitats compared to other ranid species. Upland deciduous or coniferous forested areas with complex structure, a closed canopy, woody debris, small mammal burrows, and leaf litter provide important habitat year-round, and particularly during the non-breeding and overwintering periods. Northern red-legged frogs typically require ponds and wetlands with shallow areas and emergent plants. For breeding, they need access to forested wetland and upland habitats with sunny, exposed, still-water breeding sites with emergent vegetation. Breeding habitat can be seasonal or permanent, but water must be present for at least 5 months in duration. Thick submerged branches and stems are often used to deposit egg masses. Both adults and juveniles use moist riparian and upland forests.

LIMITING FACTORS

An important threat to Oregon populations of northern red-legged frog is the loss of wetlands, especially in the Willamette Valley. Loss of egg-laying habitat is a key limiting factor for this species. Hydrologic modifications to riparian and floodplain area, fragmentation and direct mortality associated with roads, suburban development, and other land use changes are likely to have direct effects on populations. Land management actions that affect canopy cover can reduce habitat quality for this species. Predation and

Exhibit List 136

competition by nonnative invasive fish and bullfrogs present further major threats. Warming and drying trends associated with climate change may exacerbate risks to populations from drought, wildfire, and altered hydrologic regimes.

DATA GAPS

• Increase knowledge of basic life history, including terrestrial habitat use, movement and dispersal, phenology, and relationships to hydrology.
• Estimate abundance and population size.
• Clarify impacts of climate change, pollutants, invasive plant and animal species, diseases (such as chytrid fungus) and parasites on this species.
• Identify seasonally important habitat components and overwintering areas.
• Conduct baseline monitoring to better understand threats, trends, and habitat associations.
• Assess how this species responds to forest management practices including timber harvest, fuels reduction, and restoration activities and how riparian buffer widths affect population parameters.
• Assess the effect that agricultural and urban toxins (including fertilizer run-off and sewerage) have on the species.
• Assess habitat carrying capacity for the species.
• Identify overwintering habitat associations.
• Assess vulnerability to climate change

CONSERVATION ACTIONS

• Restore habitat.
• Revise wetland hydroperiod requirements for mitigation and other created wetlands in occupied areas to reduce ‘population sinks’.
• Create upland buffer and aquatic habitat retention requirements for housing developments to minimize local extirpations in the Willamette Valley.
• Identify regionally important sites to the species and work with partners to secure protections for these sites, and to improve or restore connectivity between them.
•Maintain wetland habitat with emergent plants and adjacent forest.
• Address barriers and/or culverts at key road crossings to reduce mortality of lowland (Willamette Valley and Coast Range) frogs, and monitor outcomes to improve mitigation effectiveness.
• Control bullfrogs and invasive fish at priority sites.
• Monitor priority populations.
• Maintain connectivity between wetland and upland sites to allow for life cycle movements.
• Establish priorities for disease monitoring and implement treatment or prevention programs as needed.
• Conduct outreach and education to support conservation.
• Identify and prioritize protection and management of habitats with high climate resiliency.

Exhibit List 137

KEY REFERENCE OR PLAN

Environment and Climate Change Canada. 2017. Management Plan for the Northern Red-legged Frog (Rana aurora) in Canada. Species at Risk Act Management Plan Series. Environment and Climate Change Canada, Ottawa. 2 parts, 4 pp.+ 51 pp. **Read here (https://web.archive.org/web/20261007124630/https://www.registrelep-sararegistry.gc.ca/virtual_sara/files/plans/mp_northern_red_legged_frog_e_final.pdf)**

LIFE HISTORY TRAITS

Exhibit List 138



Exhibit List 139

Exhibit List 140

My name is Jonathan J. Rhodes. My education includes Ph.D. study in forest hydrology from the University of Washington (1989), an M.S. in hydrology and hydrogeology from the University of Nevada-Reno, and a B.S. in hydrology and water resources from the University of Arizona.

I have more than 35 years of professional experience. I have been an independent consulting hydrologist since 2002, working for an array of clients, including county governments, on a variety of issues. Most of my work has focused on the impacts of various land and water management on water quality, streams, and fisheries. I have published numerous reports and peer-reviewed scientific journal papers on these topics.

The assessment that follows is based on my experience, education, and an onsite review of the area, conducted on July 28, 2017, along with conversations with local blueberry farmers.

Summary

I provide these comments to explain how industrial development within the five general categories proposed to occur within 837 acres at Point Westward (hereafter: "Project") is incompatible with nearby local agriculture and fish populations due to water quality impacts. Due to the sensitivity of the surrounding uses and their physical setting, it is unlikely that the Project could be made compatible with existing agricultural uses and fisheries.

If implemented, this Project would vastly increase stormwater runoff. Due to the area's hydrology and the amount of rainfall it receives, it would be impossible to entirely contain the stormwater onsite. Stormwater runoff from industrial areas contains high levels of sediment and a variety of chemical contaminants, which would pollute adjacent water bodies, including those used for irrigation of agriculture and by imperiled fish. Due to the Project's nature, the pollution from stormwater runoff will be ongoing, resulting in permanent, and, in some cases, progressive,

impairment of beneficial uses by agriculture and fish populations. The Project's pollution impacts on these beneficial uses would be unavoidable, due to the affected area's climate, hydrology, and physical setting.

Discussion

Existing conditions

The land generally slopes southwesterly from the existing Port Westward site towards sloughs and surrounding areas (Map 1). The flow of water follows the land surface slope, primarily in a southwesterly direction (Map 1). The McLean Slough drains southwesterly from the proposed Project to the Beaver Slough, which generally flows westerly in a meandering fashion (Map 1). Much of the area southwesterly from the existing Port Westward site is below sea level and lower in elevation than surrounding lands (Map 1). These lowlands are surrounded by dikes that separate surface water flow from the Columbia and Clatskanie Rivers to sloughs and farms in the lowlands. These dikes also serve to contain much of the surface waters within the agricultural lowlands. The farms in the diked lowlands produce mint, blueberries, and other agricultural products.

The Hopville farm, located in the agricultural lowlands, uses water from the Beaver Slough to irrigate blueberries during the summer. Clean water is critical to producing marketable blueberries, particularly for international markets, which require relatively stringent testing of food products. Currently, Hopville farm filters algae from withdrawn water for irrigation, as well as testing it for various potential components.

Due to the low elevation, high levels of precipitation, and adjacent rivers, the water table in these agricultural lowlands is shallow. Currently, the irrigation district pumps water out of sloughs used for irrigation to lower the water table seasonally for agriculture during parts of the

year, depending on water table conditions. It is likely that shallow groundwater flow follows the slope of the land in the area as well, with some draining into the sloughs that drain to the south and west that provide irrigation water. During winter, the water table often is at or above the land surface with standing water for considerable periods of the time. For these foregoing reasons, shallow groundwater and surface water in these lowlands is mixed and interconnected.

Due to the high water table, wetlands occur in parts of the lowlands, as confirmed in the rezoning proposal. It is worth noting that some of the areas occupied by dense poplar plantations located within the rezoning area would likely have wetlands, if the trees are harvested. This is because poplars consume large amounts of water and dense plantations can lower water table elevations locally. Once the plantations are harvested, it is extremely likely that the local water table elevation will rise in these harvested areas.

The nearby Columbia River provides passage and rearing habitat for numerous populations of steelhead and several species of salmon, including Chinook and coho, many of which are listed under the Endangered Species Act (ESA). Several of the nearby sloughs and streams also provide important habitats for coho and fall Chinook, which are listed under the ESA. The Clatskanie River also provides passage habitat for steelhead, which are listed under the ESA, and cutthroat trout, which are considered "potentially at risk" (ODFW, 2005).

Project Impacts

Although the rezoning proposal provides no detail on the physical alterations of the landscape that would have to occur to accommodate the operations under the five categories of uses, it is safe to assume that these operations would require:

- copious amounts of fill material over a large area to raise elevation of the operating surfaces by a minimum of several feet over existing land surface

elevation, so that the operation surface area is well above the high water table and standing water during the winter;

- creation of highly compacted and paved areas and other impervious surfaces, such as roofed structures, over a large area.

The fill will significantly increase the land surface slopes towards the farmlands to the south and west of the proposed Project area in a permanent manner, so that surface water and groundwater will continue to flow from the Project area to the agricultural lowlands, albeit in a more pronounced manner.

The Project's impervious surfaces and/or compacted soils will vastly increase stormwater runoff to adjacent waters and lands. The major increases in stormwater runoff from impervious surfaces and compacted soils have been documented by large body of scientific information (National Research Council, 2008). Increased stormwater runoff volumes generated by impervious surfaces for the proposed uses will be both large and frequent due to the high levels of frequent precipitation in the area, particularly during the wet winter season. Importantly, impervious surfaces permanently increase stormwater runoff.

Stormwater runoff from impervious surfaces in industrial areas is significantly polluted, typically carrying significantly elevated levels of nutrients, metals, hydrocarbons, including petroleum-related compounds, and sediment (National Research Council, 2008; NOAA Fisheries, 2016),. These have several adverse impacts on beneficial uses by agriculture and fisheries, as described in greater detail later in these comments.

The frequency and volume of stormwater discharge will make it extremely difficult or impossible to control appreciably onsite. Due to high precipitation, the sheer volume of stormwater discharge generated by compacted and impervious areas will be too large to tractably

retain onsite. High water tables preclude infiltrating stormwater, especially during the winter, when soils are usually saturated or occupied by standing water. Precipitation amounts are greater than evaporation and infiltration rates, so any retention ponds would capture more water from precipitation than would be lost by infiltration and evaporation, particularly during winter months, making complete onsite retention impossible. For these reasons, the proposed Project would deliver large amounts of stormwater runoff to adjacent lands and water bodies with considerable frequency.

These same factors make it impossible to prevent stormwater discharge from the Project area to adjacent land and waters. Stormwater runoff delivered to the south of the Project area during periods when the lowlands are inundated will be mixed with the standing surface water that is ultimately used for irrigation. The high water tables preclude any appreciable infiltration of stormwater offsite, especially during the winter, when soils are commonly saturated or covered by standing water. However, even during drier periods, the any infiltrating stormwater will pollute shallow groundwater, which in the area, is mixed with surface waters that are used for irrigation, as previously discussed.

Stormwater discharged to the north of the proposed Project area would also affect shallow groundwater. Some of this groundwater likely drains southwesterly where it would mix with surface water that is ultimately used for irrigation in the agricultural lowlands south and west of the Project site.

Attempts to discharge the Project's stormwater runoff to the Columbia River is likely to be extremely problematic due to the numerous ESA-listed populations of salmon and steelhead that that use the lower Columbia for passage and rearing. The pollutants in stormwater discharge are known to harm salmon and steelhead. Thus, there is no simple tractable solution for avoiding

pollution of adjacent waterways from the large volume stormwater runoff that will be generated permanently if the proposed Project is implemented.

The pollutants typically found in stormwater runoff harm beneficial water uses in several ways. Elevated nutrients contribute to increases in algae in affected waters. Increases in algae typically increase filtration and treatment costs for irrigation. Increases in algae can also contribute to increases in harmful bacteria, which can increase irrigation water treatment costs, as well as posing a threat to human health.

The elevated levels of metals that typically occur in stormwater runoff pose major problems for agriculture and fish. The metals (typically copper, nickel, lead, and zinc) can accumulate in soils exposed to polluted stormwater discharge. These metals can be taken up by plants, reducing their desirability or marketability, due to human health concerns. Metals in stormwater discharge, particularly copper, are known to have a number of adverse impacts on salmonids (NOAA Fisheries, 2016).

Hydrocarbons, including those from petroleum products, in stormwater runoff also impair beneficial uses by agriculture. Even trace amounts of hydrocarbon pollutants in fruit can reduce its marketability and value. These pollutants also have a number of negative impacts on salmon and steelhead (NOAA Fisheries, 2016).

Elevated levels of sediment can increase dredging costs in affected waterways used for irrigation water storage. It can also increase filtration costs for irrigation withdrawals. Elevated levels of sediment have numerous adverse impacts on salmon, steelhead, and trout. Construction of infrastructure creates particularly large increases in sediment in stormwater runoff, during the construction period (National Research Council, 2008)

For these combined reasons, the Project, if implemented, will permanently impair and conflict with existing beneficial uses of water by agriculture and fish. Due to the setting, it will not be possible to eliminate or reverse these adverse impacts if the Project is implemented.



JONATHAN J. RHODES

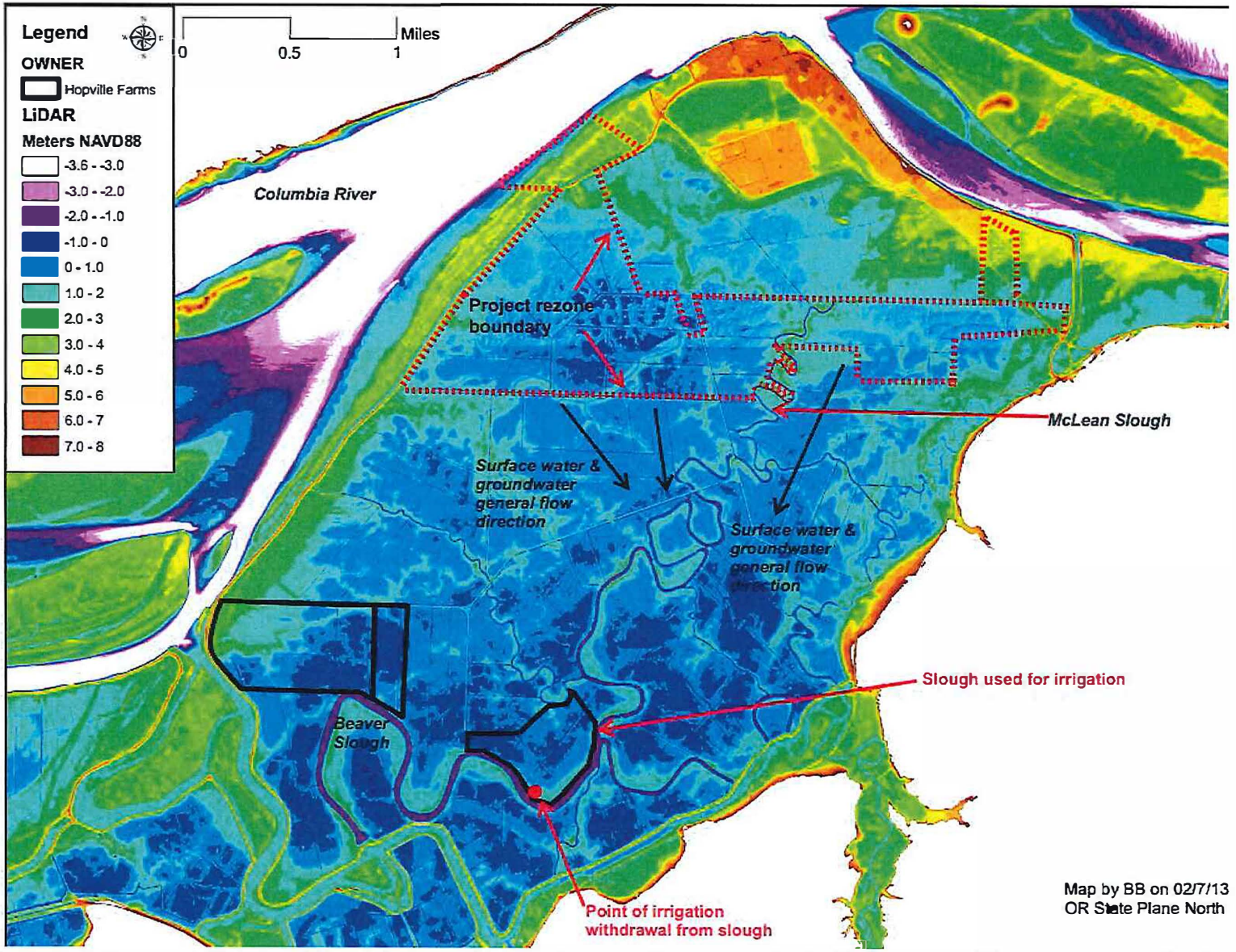
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Exhibit List 147



Map 1. Lidar map showing existing elevations in the Project area and surroundings, annotated to display some of the existing uses, sloughs, general flow direction of surface water and groundwater, and the general area proposed for industrial uses. Most annotations are illustrative and not geographically exact.

Exhibit List 148

HALVERSON | NORTHWEST LAW GROUP

Raymond G. Alexander
Alan D. Campbell++
J. Jay Carroll
Paul C. Dempsey**
James S. Elliott
Robert N. Faber
F. Joe Falk, Jr.+
Mark E. Fickes
Carter L. Fjeld+
Lawrence E. Martin*
Terry C. Schmalz+
Linda A. Sellers
Michael F. Shinn
Stephen R. Winfree+

*Also OR Bar Member
**Also State Bar of CA Member
+Of Counsel
++Retired

September 24, 2021

VIA EMAIL <Dan.Cary@state.or.us> AND REGULAR U.S. MAIL

Oregon Department of State Lands
ATTN: Mr. Dan Cary, DSL Coordinator
775 Summer Street NE, Suite 100
Salem, OR 97301-1279

RE: *Permit Application 0063077 Rev. (NEXT Renewable Fuels Oregon)*
Public Comment – Beaver Drainage Improvement Company

Dear Mr. Cary:

This firm represents Beaver Drainage Improvement Company, a nonprofit corporation organized under ORS Chapter 544, which provides drainage, flood control, and irrigation services to approximately 5,717 acres within Columbia County, Oregon (the "Drainage Company"). We are writing to express concerns regarding the above-referenced joint permit application and, specifically, to applicant NEXT Renewable Fuels Oregon, LLC's ("NEXT Fuels") application to the Department of State Lands ("DSL") to remove and fill in wetland areas (the "Application"), in connection with the construction and operation of a renewable fuel facility at Port Westward, near Clatskanie (the "Facility"). The Application proposes a Compensatory Wetland Mitigation Plan ("Mitigation Plan"), to mitigate Facility impacts. In fact, the Mitigation Plan will adversely impact water resources by fundamentally altering drainage facilities and operations on adjacent, Primary Agriculture-zoned lands that lie entirely within the Drainage Company's service area. As more fully described below, the Mitigation Plan is inconsistent with the Drainage Company's jurisdictional authority, as well as with the fundamental, agricultural character of affected lands. Moreover, by its design, the Mitigation Plan is intended to convert productive irrigation lands into wetlands, which will have potentially catastrophic regulatory implications for the Drainage company and its landowner members under both federal and state water quality laws.

Finally, we also write to voice concerns about the *process* by which DSL is evaluating the Mitigation Plan. In light of the size and scope of proposed land use changes under the Application – including acknowledged data gaps concerning the underlying hydrology at the proposed "Mitigation Site," as described below – the Application cannot and should not be approved until the Mitigation Plan is complete. As discussed below, this will require, among other things, a thorough, third-party review of all fundamental geotechnical and hydrologic assumptions upon which the Mitigation Plan is premised.

Background

The Drainage Company

The Drainage Company is the direct successor to the Beaver Drainage District ("District"), which was organized under ORS Chapter 547 and which exercised powers allowed to statutory drainage districts under Oregon law, including, without limitation, the authority to locate necessary drainage or irrigation works on any lands within its jurisdiction deemed best for such purposes; to acquire all lands, rights of way, easements and other property necessary for the construction, operation or maintenance of drainage or irrigation works, including the enlargement, improvement or extension of any natural or artificial waterway for such purposes; and to apply for and exercise water rights for use by patrons within the district ORS 547.305 - .310.

In 1994, under authority of ORS 554.375, District landowners voted to dissolve the District and to reorganize as the Drainage Company, a public corporation under Oregon law, with authority to carry on the District's flood control, drainage, and irrigation functions in the same manner as permitted drainage districts under ORS Chapter 547. Article IV of the Drainage Company's Articles of Incorporation, filed May 13, 1994, states, "The particular lands to be improved by the works of the corporation are the same lands formerly included within the boundaries of the Beaver Drainage District."

Further, Article III of the Drainage Company's Articles of Incorporation provides in relevant part:

> The corporation shall continue operation and maintenance of the Beaver Drainage District's existing drainage works and any other works authorized under ORS Ch. 547. In addition to powers conferred by statute, the corporation may make improvements for these purposes, including the construction, operation and maintenance of flood control facilities and a system of sloughs, canals, ditches and waterways necessary to drain the benefitted properties, as well as make available water for the irrigation of the lands to be improved. … The benefits of the land to be improved, the owners of that land as a whole, and the public at large will be promoted by the formation, operation and accomplishment of an improvement plan by the corporation.

Finally, Article V confirms as follows:

> The corporation assumes all of the rights, duties, debts and obligations legally incurred under contacts, covenants, other agreements, lease and business transactions entered into or begun before the date of dissolution of Beaver Drainage District. …All lands subject to liens and encumbrances of these debts and obligations remain subject to those liens and encumbrances.

Separately, under Article 12 of the Drainage Company's 1994 Bylaws, a vote of the owners of two-thirds of all lands is required to covenant and bind their lands in all matters relating to the conduct of the corporation.

Currently, the Drainage Company actively maintains and operates an extensive system of drainage ditches, as well as the surrounding dike. A cursory review of title records concerning lands affected by the Mitigation Plan (the below-described "Mitigation Site") reveals no fewer than three easements granted by Drainage Company landowners (including predecessors to NEXT Fuels) to the predecessor District for flood control, drainage, and irrigation benefits of affected lands. In 1976, the District entered into arrangements with the Army Corps of Engineers ("Corps") for the construction of comprehensive improvements to District-owned levees. In connection therewith, landowners, pursuant to that certain *Easement*, recorded December 17, 1976, under Book 209, page 279, records of Columbia County, Oregon (the "1976 Easement," a true and correct copy of which is included herewith as Attachment "A"), granted to the District and its assigns, including the Corps, the following, *exclusive* real property access and use rights:

> The exclusive right, privilege and easement to go upon, maintain and keep in repair the levee and a private road situated thereon for the benefit of the landowners of said district. The district or its authorized agents shall have a perpetual right to go upon said lands to maintain, inspect, construct, rebuild and operate dikes, levees, or other flood control, drainage, or irrigation works…

Exhibit A to the 1976 Easement includes several, legally described permanent easement areas subject to the above, exclusive access and use rights in favor of the Drainage Company, including, apparently, at least two easement areas within portions of Section 34, recently acquired by NEXT Fuels for Mitigation Site purposes. Additionally, the 1976 Easement confirmed, "The district shall have the right to regulate any activity on the easement which may interfere with the district's Right of Use."

Additionally, the Drainage Company delivers water to landowners for the irrigation of more than 2,700 acres within its service area. Under Certificate 83174 issued to its District predecessor, water is directed southward to Drainage Company lands for use on specified lands lying within Township 8 N., Range 4 W., W.M. Certificate 83174 is an irrigation-only water right; it does *not* expressly allow "wetland enhancement" or specialized purposes of use for which water rights may be authorized under Oregon law. The below-discussed Mitigation Site lies entirely within Certificate 83174's authorized place of use.

Commercial agriculture dominates within the Drainage Company's service area, as it has for many decades. Additionally, there are a handful of commercial/industrial operators, whose operations do not impair the operation of the Drainage Company or its farming members.

The Mitigation Plan

The proposed Next Fuels Facility is located within the Drainage Company and entirely inside the dike. As acknowledged in the Application, most of the project site is used by Drainage Company landowners for agriculture and pastureland purposes, with mint fields to the north and west and a tree farm to the south. The Mitigation Plan is intended to mitigate for Facility impacts on agricultural lands, including what NEXT Fuels describes as the permanent removal of 117.64 acres of "wetlands." Mitigation is to be in the form of claimed "enhancements" to non-jurisdictional wetlands and waterways at a mitigation site located approximately one-quarter mile south of the Facility.

The proposed mitigation site comprises approximately 590 acres of Drainage Company lands recently acquired by NEXT Fuels, within specified portions of Sections 27, 28, 33, and 34, Township 8 N., Range 4 W., MW (the "Mitigation Site"). Under the Application, Next fuels proposes to offset permanent wetlands impacts by fundamentally changing Mitigation Site hydrology and function by, among other measures:

- Filling approximately 26,800 linear ft. of the existing Mitigation Site drainage ditches operated by the Drainage Company.
- Creating "dendritic" channels throughout the Mitigation Site, intended to mimic naturally occurring channels found elsewhere in Lower Columbia sloughs.
- Digging shallow pools for potential reproductive habitat for amphibians and other aquatic wildlife.
- Roughening Mitigation Site surfaces for diversification of surface hydrology and resultant vegetation.
- Creating upland buffer zones along public access paths between Mitigation site wetlands.

In order to accomplish the above measures, the Mitigation Plan envisions the overall lowering of Mitigation Site surface levels, together with construction of an extensive network of onsite dendritic channels. Excavation will be as deep as six feet at some locations, with net elevation reduction averaging one and one-half feet across the Mitigation Site. In connection therewith, approximately six to 12 inches of topsoil will be removed sitewide.

Analysis and Detailed Objections

"The protection, conservation and best use of the water resources of this state are matters of the utmost public concern. … Unregulated removal of material from the beds and banks of the waters of this state may create hazards to the health, safety and welfare of the

people of this state." ORS 196.805 Generally, "a person may not remove any material from the beds or banks of any waters of this state or fill any waters of this state without a permit issued under authority of the Director of the Department of State Lands, or in a manner contrary to the conditions set out in the permit…" ORS 196.810 In determining whether to issue a permit, the DSL Director must consider, among other factors:

- The public need for the proposed fill or removal and the social, economic, or other public benefits likely to result from the proposed fill or removal;
- The availability of alternative sites for the proposed fill or removal;
- Whether the proposed fill or removal conforms to sound policies of conservation and would not interfere with public health and safety.
- Whether the proposed fill or removal is in conformance with existing public uses of the waters and with uses designated for adjacent land in an acknowledged comprehensive plan and land use regulations; and

ORS 196.825(3); OAR 141-085-0565. Under its own regulations, DSL must "recognize the interests of adjacent landowners; tribal governments; public interest groups; soil and water conservation districts; drainage, irrigation and diking districts; watershed councils; state and federal agencies; and local government land use planning agencies" in evaluating fill and removal permit applications. OAR 141-085-0506(4).

As described below, NEXT Fuel's intended use of the Mitigation Site – including its anticipated *nonuse* of the Drainage Company's water right on those lands – is inconsistent with agricultural functions and values on all lands served by the Drainage Company. Further, the Mitigation Plan proposes changes that are inconsistent with the Drainage Company's statutory authority and violative of exclusive operational powers under its charter documents and land use permissions.

Water Rights Considerations

The Mitigation Plan makes only scant reference to Mitigation Site hydrology and proposed use of non-naturally occurring water (i.e., other than precipitation or onsite groundwater) in connection with the planned wetland enhancements. Our unconfirmed understanding at this time is that NEXT Fuels does not intend to make use of the Drainage Company's surface water irrigation right under Certificate 83174, at least on a continuous or extended basis, for wetlands enhancement purposes within the Mitigation Site.[1]

[1] Oregon regulations define "irrigation" to include artificial application of water to promote growth of plants, OAR 690-300-0010, which *might* allow application of water, on an initial and temporary basis, for development of wetlands habitat. That said, the Mitigation Plan makes no reference to use of irrigation water. Further, and even if NEXT Fuels intended to use any portion of Certificate 83174 during initial wetland development, irrigation of the Mitigation Site on a permanent basis would be incompatible with any notion of reclaimed and self-sustaining "wetlands" habitat.

In connection therewith, reduced or nonuse of Certificate water within the Mitigation Site is inconsistent with the interests of the Drainage Company and its member landowners under Oregon's statutory water right forfeiture provisions. Pursuant to ORS 540.610, if the owner of a perfected and developed water right ceases or fails to use all or part of the water appropriated for a period of five successive years, such failure creates a rebuttable presumption of forfeiture of all or part of the water right. Assuming NEXT Fuels will not or cannot by law use any substantial portion of the 2,700+ acre irrigation entitlement under Certificate 83174 within the Mitigation Site on a permanent basis, the Drainage Company and its landowners risk forfeiture of the water right. Cessation of irrigation use throughout the 590-acre Mitigation Site would force the Drainage Company to identify a commensurate number of currently non-irrigated acres elsewhere within the water right's authorized place of use that could be commercially irrigated, as necessary to ensure full, beneficial use of the right. Suffice it to say, that is a "two-way street," requiring not only Drainage Company operational capacity to reroute water to new lands, but also landowner willingness to put currently undeveloped or fallowed lands to new, commercial irrigation purposes. Unless both requirements could be fully and addressed – and absent an applicable statutory forfeiture exemption – the continuing viability of Certificate 83174 at OWRD-authorized "nameplate" levels, will be in jeopardy. Neither the Drainage Company nor its landowners can risk forfeiture of this valuable and vital irrigation asset.

Additionally, the Mitigation Plan raises serious concerns regarding real-world impacts to Drainage Company operations, including the essential irrigation and drainage requirements of its constituent landowners. Most concerning is NEXT Fuels' intention to fill nearly 27,000 liner feat of existing Mitigation Site drainage ditches operated by the Drainage Company. Of particular concern here are McLean Slough, as well as the Drainage Company's Ditch 6 – both of which are critical drainage paths and necessary for protection of farming operations throughout the Drainage Company service area. And while the Mitigation Plan asserts that hydraulic capacity will be maintained in at least certain ditches appurtenant to the Mitigation Site, the ultimate consequences of radically restructuring drainage facilities cannot be accurately predicted without comprehensive study of Mitigation Site hydrology, including particular irrigation and drainage requirements at particular locations throughout.

Shortcomings in the current level of hydrological understanding concerning the Mitigation Site are illustrated under a wetland delineation report that NEXT Fuels submitted in support of the Mitigation Plan, following DSL's preliminary acceptance of the Application and invitation for public comment. On page 12 of such report, there is a statement to the effect that Coastal Cutthroat Trout are present in McClean Slough. The Oregon Department of Fish and Wildlife has mapped these waters under its Oregon Fish Habitat Distribution utility,[2] on the basis of "Native origin, present within SMU prior to 1800" and "concurrence of professional opinion" – *NOT* on the basis of documented or suspected

[2] https://nrimp.dfw.state.or.us/FHD_FPB_Viewer/index.html

fish presence after 1800. The Drainage Company has no records of any presence of Coastal Cutthroat Trout within the sloughs or ditches inside the levee system at any time following its establishment nearly 100 years ago. The wetland delineation report also asserts that the Mitigation Site "may be accessible during periods of flooding". This inaccurately assumes that flooding does, in fact, impact the Drainage Company service area. In fact, the Provisionally Accredited levee system blocks all floodplain connection to adjacent rivers. Further, the sloughs and ditches do not combine or affect a junction with natural surface or underground waters, meeting the exception under OAR 340-041-0002(72).

In addition to NEXT Fuels' proposed elimination of drainage ditches, other above-cited Mitigation Site proposals, including creation of dendritic channels and "roughening" of Mitigation Site surfaces in the interest of creating more genuine wetlands features, are also problematic. While such changes would be laudable for purposes of restoring *bona fide* wetlands at other potential sites, they are inconsistent with productive, commercial agriculture functions that, in fact, characterize the Mitigation Site and adjacent Drainage Company lands. To cite but one example, the creation or recreation of sloughs or similar wetlands features on agricultural lands will alter the course and volume of water currently transported through the Drainage Company's network of irrigation and drainage ditches, which reduces overall efficiencies. In connection therewith, we need to point out an additional Drainage Company operations consideration, which apparently is not contemplated under the Mitigation Plan. Historically, the Drainage Company recognizes separate "summer" and "winter" water levels for irrigation and drainage purposes, which differ by several feet. Thus, and depending upon the depth of NEXT Fuels' excavation at various locations within the Mitigation Site, we expect the proposed mitigation "wetlands" could be either completely dry, or completely inundated. In either case, the desired wetlands would fail as a jurisdictional matter and mitigation for Facility impacts would be insufficient.

Collectively, the variously proposed "enhancements" under the Mitigation Plan reduce reliability and functionality of drainage systems, water delivery, and water storage capability, which introduce additional risks to capital intensive commercial agricultural operations throughout the Drainage Company service area. Based upon Mitigation Plan submittals to-date, we are not confident that irrigation water delivery and drainage services can be maintained at their current level of reliability – particularly on commercial agriculture lands downgradient to the Mitigation Site and impacted directly by the proposed fill and relocation of ditches and potential levee modifications.

<u>The Drainage Company's Authority under Law and Charter Documents</u>

Next, we need to emphasize that NEXT Fuels may not undertake any changes to Drainage Company infrastructure and operations without prior permission of the Drainage Company and its landowners. As described above, the Drainage Company, by statute, as well as under its duly enacted charter documents, has *exclusive* authority over the operation and maintenance of existing drainage and irrigation ditches within the Mitigation

Site, as well as sole power to determine the need for changes to and/or construction of new drainage, irrigation, and flood control facilities for the benefit of its landowners.

In connection therewith, we also note the above-summarized and attached 1976 Easement, which vests in the Drainage Company the sole and exclusive right "to maintain, inspect, construct, rebuild and operate dikes, levees, or other flood control, drainage, or irrigation works" within specified easement areas – including lands now owned by NEXT Fuels within the proposed Mitigation Site. Further, under the 1976 Easement confirmed, "The district shall have the right to regulate *any activity on the easement which may interfere with the district's Right of Use*." (Emphasis added.) Under our reading of the 1976 Easement, the Mitigation Site likely includes at least two legally described, permanent easement areas, or portions thereof, within Section 34, Township 8 N., Range 4 W., MW, subject to the Drainage Company's ultimate, operational authority. As described above, NEXT Fuels' intended changes to elevations and Drainage Company infrastructure within the Mitigation Site are inconsistent with the operational prerogatives and best interests of the Drainage Company and its other landowner/members. Accordingly, the Drainage Company has full authority to restrict and, if necessary, forbid NEXT Fuels' intended Mitigation Site changes under the Mitigation Plan.

Federal and State Water Quality Regulation

The federal Clean Water Act, 33 U.S.C. §1251 *et seq*. ("CWA") establishes the basic structure for regulating discharges of pollutants into jurisdictional waters and regulating quality standards for surface waters. Section 404 of CWA generally requires individuals to obtain a permit before discharging dredged or fill material into so-called "waters of the United States," including most wetlands. Under CWA regulations promulgated by the Environmental Protection Agency, waters of the United States generally include "waters which are currently used, were used in the past, or may be susceptible to use in interstate or foreign commerce, as well as waters tributary or adjacent thereto, typically including wetlands, ponds, and similar water bodies. 40 CFR § 230.3 By way of example only, activities within jurisdictional waters of the United States that ordinarily require permits include depositing fill, dredged, or excavated material; grading or clearing of wetlands; ditch excavation within wetlands; and construction of levees, dams, dikes, and weirs.

Similarly, the State of Oregon, regulates "waters of this state," which include rivers, perennial streams, lakes and ponds, and other specified features. ORS 468B.005 DSL requires permits for the removal or fill of material within such jurisdictional waters, including wetlands and waterways. ORS 196.795-990.

Because Drainage Company lands are in close proximity to the Columbia River and naturally occurring sloughs and other wetland features, such lands would ordinarily be regarded as jurisdictional wetlands under both federal and state law and, thus, subject to costly and time-consuming permitting and other regulatory requirements in connection with essential irrigation and drainage functions performed by the Drainage Company and

its member landowners on a routine basis. Fortunately, however, CWA Section 404 expressly excludes "prior converted cropland" from the definition of waters of the United States. *Id*. Similarly, Oregon law exempts from permitting requirements removal and filling on "converted wetlands," defined as "agriculturally managed wetlands that, on or before June 30, 1989, were brought into commercial agricultural production by diking, draining, leveling, filling or any similar hydrologic manipulation and by removal or manipulation of natural vegetation, and that are managed for commercial agricultural purposes." ORS 196.921(15)(a); OAR 141-085-0535(2). These exemptions from clean water permitting requirements are essential for normal farming and ranching activities conducted on Drainage Company lands, such as plowing, grazing, seeding, planting, cultivating, conventional crop rotation, and harvesting.

Importantly, the exemptions apply *only* on lands that are being actively managed to produce agricultural commodities; they do not apply to natural, i.e., unfarmed, wetlands. Fundamentally, NEXT Fuels' Mitigation Plan calls for the cessation of commercial farming activities within the Mitigation Site, in effect, to "reconvert" productive agricultural lands to their status as natural wetlands prior to the installation and operation of diking and drainage features by the Drainage Company and its predecessors. The implications of such unilateral reconversion of lands – including revocation of the essential clean water permitting exemptions – would be catastrophic for the Drainage Company and its members. The Drainage Company, for itself and on behalf of its farming and industrial members, opposes any measures that threaten continuing exemption from environmental permit requirements under federal and state law.

DSL Application Review

NEXT Fuels provided a project status update during the Port of Columbia County's September 22, 2021, Commissioner's Meeting. And we understand that you, Mr. Cary, appeared on behalf of DSL and also commented on the project and, particularly, regarding the Mitigation Plan. Apparently, all agreed that the Mitigation Plan is no more than 10-15% complete as of now. Further, we understand you expressed DSL's opinion that the proposed "wetlands" enhancements proposed by NEXT Fuels under the Mitigation Plan would never be able to mimic historic standards under DSL administrative rules – precisely *because* the proposed Mitigation Site lies within Drainage Service boundaries, on and adjacent to lands that have been purposefully modified to facilitate commercial agriculture. You also acknowledged that DSL has never evaluated a proposed wetlands mitigation site of the magnitude and complexity proposed by NEXT Fuels on lands under operation of a diked drainage district or company.

In order to be deemed complete for DSL's evaluation of fill and removal permit requests, applications must include the following, among other items:

> (f) A description of the project purpose and need for the removal or fill. All projects must have a defined purpose or purposes and the need for removal or fill activity to accomplish the project purpose must be documented. The project

> purpose statements and need for the removal or fill documentation must be specific enough to allow [DSL] to determine whether the applicant has considered a reasonable range of alternatives.
> ...
> (h) A written analysis of potential changes that the project may make to the hydrologic characteristics of the waters of this state, and an explanation of measures taken to avoid or minimize any adverse impacts of those changes, such as:
>
> (A) Impeding, restricting or increasing flows;
> (B) Relocating or redirecting flow; and
> (C) Potential flooding or erosion downstream of the project.

OAR 141-085-0550

Under our reading of the Mitigation Plan as developed to-date, and in light of acknowledged deficiencies thereunder, we question whether the Application should have been deemed complete for public comment purposes. At any rate, we think it important to bring these concerns to DSL's attention at this time, with the expectation that DSL conduct further investigation and insist upon further data and analyses concerning Mitigation Plan impacts on Drainage Company infrastructure and operations *before* rendering a final determination on the Application.

By regulation, DSL ordinarily must make a final permit decision within 90 calendar days after determining an application is complete; however, the permit decision deadline may be extended beyond 90 calendar days when the applicant and DSL agree to an extension. OAR 141-085-0560(6). In our view, much work remains to be done in this case. Accordingly, and unless DSL is prepared to deny the Application, we respectfully suggest that a substantial, additional extension will be required to allow collection of additional (and independently verified) data and analyses.

Conclusion

In summary, the Beaver Drainage Improvement Company objects to NEXT Fuels' Application – and particularly to the Mitigation Plan – on the grounds that wholesale changes to the Drainage Company's essential drainage, flood control, and irrigation infrastructure within the Mitigation Site will adversely impact water resources under the Drainage Company's operational control.

Further, NEXT Fuels' proposed Mitigation Site changes are inconsistent with the Drainage Company's power and authority under ORS Chapters 447 and 554, as well as under its charter documents and recorded easements, including the 1976 Easement. Should NEXT Fuels wish to alter or amend existing Drainage Company restrictions on lands within the Mitigation Site, it must undertake the Bylaws-prescribed process for

landowner direction to modify the conduct or operational authority of the Drainage Company as concerns the dike, levees, and ditches therein. And again, such institutional or operational changes require a super-majority (2/3) vote of all landowners.

Finally, the Mitigation Plan's proposal to "reconvert" currently farmed lands within the Mitigation Site to jurisdictional wetlands, subject to clean water permit requirements, is antithetical to the best interests of the Drainage Company and its landowners.

But/for the above-described risks and uncertainties, we would welcome NEXT Energy as a valued industrial partner within the overall Drainage Company operations area. Unfortunately, unless and until those risks and uncertainties can be mitigated with sufficient certainly, the Drainage Company cannot support the Application as presented.

We very much appreciate DSL's consideration of the Drainage Company's concerns in this case. Please feel free to contact me or my law partner, Paul Dempsey, if we can provide any additional information concerning the Drainage Company's rights, duties, and operational functions within the proposed Mitigation Site under the Application.

Very truly yours,

HALVERSON | NORTHWEST LAW GROUP P.C.

Lawrence E. Martin

Encls.

cc: (via email)

Mr. Warren Seely, Beaver Drainage Improvement Company President/Secretary
Mr. Tyler Joki, AKS Engineering & Forestry, LLC
Paul C. Dempsey, Esq.

Exhibit List 159

ASSESSMENT OF THE PORT OF COLUMBIA COUNTY'S COMPATIBILITY REPORT FOR INDUSTRIAL DEVELOPMENT AT PORT WESTWARD

By Richard R. Horner
Environmental Engineering and Science Consultant
1752 NW Market Street, #551
Seattle, Washington 98107

November 2, 2020

INTRODUCTION

I was requested by Columbia Riverkeeper and Crag Law Center to review documents pertaining to the Port of Columbia County (the "Port") proposal to rezone 837 acres of agricultural land for heavy industrial development at Port Westward in Columbia County, Oregon. The principal subject of my review was the Port's submission in support of its proposal, Port Westward Goal Exception, Comprehensive Plan Amendment, and Zone Change Supplemental Analysis: Land Use Compatibility, prepared by MacKenzie and dated July 21, 2020 ("Compatibility Report"). I was further asked to prepare a written report providing my assessment of the adequacy of the Port's submission and its conclusions with respect to stormwater management and anticipated stormwater-related impacts, which I present herein.

In addition to the Compatibility Report, I reviewed a relevant letter with attachment concerning the proposal[1] and a prior expert hydrology and hydrogeology report regarding the proposed development.[2] I cite other sources from the stormwater management and aquatic ecology literature in footnotes.

In assessing the Compatibility Report, I applied the experience of my 43 years of work in the stormwater management field and 11 additional years of engineering practice. During this period, I have performed research, taught, and offered consulting services on all aspects of the subject, including investigating the sources of pollutants and other causes of aquatic ecological damage, impacts on organisms in waters receiving urban stormwater drainage, and the full range of methods of avoiding or reducing these impacts. Attachment A to this report presents a more complete description of my background and experience, and Attachment B contains my full *curriculum vitae*.

SUMMARY OF CONCLUSIONS

A project put forward for approval to proceed should collect all underlying data pertinent to the required environmental assessments, conduct those assessments with the best available methods, and provide all of the information regulators and citizens need to make a full and confident evaluation of the proposal and its potential environmental effects. The Port Westward project documents do not meet this standard. They fail by not following regulations and legal decisions rendered in this matter calling for specificity and depth of analysis and prescription of mitigation measures sufficient to assure true compatibility with the proximate surroundings, including the aquatic environment. Specifically, the Compatibility Report is inadequate by:

- Being incomplete and ambiguous in defining the industrial activities that are anticipated in the new industrial development;
- Lacking reference to specific water pollutants that are likely to be produced by the industrial activities, installations, and products expected at Port Westward;

[1] From Spencer Q. Parsons of Beery Elsner & Hammond, LLP to Karen Schminke, and Matt Laird of Columbia County, July 22, 2020, with attachment ("the Parsons letter").
[2] By Jonathan J. Rhodes, untitled, undated.

- Ignoring the potential negative impacts of these water pollutants on the Columbia River and on-site wetlands and additional potential harm to the wetlands through draining, filling, incidental intrusion, and hydrologic modification;

- Proposing no mitigation measures for the potential negative impacts drawn from the many known and reasonable technologies existing for industries to avoid or reduce the discharge of pollutants to protect receiving waters; and

- Instead of thorough analysis and mitigation specification, relying on regulatory programs to address potential impacts and mitigate off-site effects, when the main regulatory mechanism applying to the issues covered in this report is a general permit, without site-specific conditions, relying mainly on self-reporting, and subject to infrequent agency enforcement.

CONTEXT OF THE PROPOSED DEVELOPMENT[3]

History of the Proposal

In 2013 the Port of Columbia County applied for approval from Columbia County (the "County") to rezone land adjacent to the Port Westward Industrial Park from Primary Agriculture-80 Acres ("PA-80") to Resource Industrial-Planned Development ("RIPD"), for incorporation into the Industrial Park. The application requested a Comprehensive Plan Amendment and Goal Exception to allow industrial development on resource land and was approved by Columbia County in early 2014. That decision was appealed to the Oregon Land Use Board of Appeals ("LUBA"). LUBA remanded the case in part and identified specific areas for the County to revisit in its record and findings.

In response, the Port modified its land use application to align with the direction provided by LUBA in its 2014 decision by limiting the number of uses permitted in the exception area to five identified industrial uses, each of which would be required to be dependent on the deep-water port and dock at Port Westward:

- Forestry and Wood Products;

- Dry Bulk Commodities;

- Liquid Bulk Commodities;

- Natural Gas and Derivative Products; and

- Breakbulk Cargo.

The Port retained Mackenzie to address the concerns raised by LUBA, resulting in the Port Westward Goal Exception, Comprehensive Plan Amendment, and Zone Change

[3] This account was derived from the Compatibility Report and the Parsons letter, except as noted.

Alternatives Analysis report, dated April 10, 2017. The Port then submitted an amended land use application to the County, which was approved in 2018. Columbia Riverkeeper and 1000 Friends of Oregon appealed the County's decision to LUBA. LUBA sustained one of the appellants' claims, remanding the case for the County to determine if the five identified uses will be "compatible with other adjacent uses or will be so rendered through measures designed to reduce adverse impacts." In response, Mackenzie was again retained to provide a comprehensive analysis of the compatibility between the five identified industrial uses and the existing adjacent uses, resulting in issuance of the Compatibility Report.

Site of the Proposed Development

The proposed development area consists of 837 acres adjacent to the existing Port Westward Industrial Park, 786 acres owned by the Port and the remaining 51 acres now in private (Thompson family) ownership. The overall parcel reaches east to the Bradbury Slough and north to deep-water Columbia River access.

The Port's property now is mainly occupied by tree farms and some smaller agricultural plots, with the only development being two unoccupied residences and some agricultural structures. This area is within the flood protection dike. The Thompson land is largely forested and outside the dike.

Land north of the proposed development area is primarily within the existing Port Westward 905-acre industrial park. This site contains a Clatskanie Public Utility District electrical substation, Portland General Electric's three natural gas-fired[4] power generation facilities, and the Columbia Pacific Bio-Refinery ethanol plant.

Ethanol has not been produced at Port Westward for a number of years, although there is still an active air quality permit that authorizes ethanol production. The facility is now owned by Global Partners. This firm has used it to load ships berthed at the 1500-foot Columbia River dock with Bakken crude oil hauled by train from North Dakota. The company has approval to handle diluted bitumen, a form of heavy tar sands oil.[5] This year the Oregon Department of Environmental Quality ("DEQ") renewed and updated an air quality permit for the plant, which will allow it to ship renewable diesel fuel ("biodiesel"), ethanol and crude oil.[6]

Wetlands occupy 479 acres, or 53 percent, of the existing industrial park. Some of the wetlands are naturally occurring, while others have been created as part of wetland mitigation activities.

Land between the proposed development area and the Columbia River to the west is undeveloped and forested. To the south is agricultural land primarily used for tree farms plus

[4] https://investors.portlandgeneral.com/news-releases/news-release-details/pge-build-additional-natural-gas-plant-port-westward (last accessed October 5, 2020).
[5] https://www.columbiariverkeeper.org/news/2019/9/groups-call-out-oregon-deq-columbia-river-ethanol-oil-terminal-decision (last accessed October 5, 2020).
[6] https://www.facebook.com/CRSteamship/posts/2658466361135943 (last accessed October 5, 2020).

some other crops, particularly heirloom mint and blueberry. Agriculture is again prominent to the east, but there are some residences too.

The Concept of Compatibility as Applied to the Proposed Development

The Compatibility Report provides an analysis of compatibility based on the framework identified by LUBA and the Court of Appeals. This concept potentially allows some degree of interference with or adverse impacts on adjacent land uses, if the impacts are adequately mitigated to allow the continuation of existing uses along with the new use.

The proposed development entails being granted a "Goal Exception" for industrial development on resource land. The passage from the Oregon Administrative Rules ("OAR")[7] relevant to obtaining an exception states that, "The exception shall describe how the proposed use will be rendered compatible with adjacent land uses," employing, "measures designed to reduce adverse impacts." Regarding those provisions, LUBA in its 2014 decision[8] observed that, "That language contemplates that the county … has identified and imposed specific measures [emphasis added] in the exception decision to reduce impacts and thus render the proposed use compatible". LUBA's second decision in 2018[9] elaborated on these requirements, stating that the assessment, "… would start by identifying the likely adverse impacts of typical uses authorized under the five approved use categories, evaluating each use category separately, and if necessary specific [emphasis added] types of uses within each use category." Furthermore, it should, "assess vulnerability to potential externalities from industrial uses in the exception area, such as impacts on water quality [emphasis added]." It is clear that the OAR and LUBA decisions call for specificity and depth of analysis and prescription of mitigation measures sufficient to assure true compatibility with the proximate surroundings, including the aquatic environment.

Scope of This Report

This report concentrates particularly on compatibility of the proposed development with the Columbia River aquatic ecosystem and its resources and beneficial uses. It is my opinion that this element of the territory adjacent to the proposed development is both the most crucial and most challenging in regard to achieving compatibility. In this assessment of potential compatibility, I rely on the applicable regulations and decisions rendered thus far in this case pertaining to compatibility, as summarized above. In particular, I evaluate the proponent's adherence to the directions concerning specificity in evaluation and imposition of mitigation measures and its highlight of water quality as a subject for assessment.

In addition to focusing on compatibility with the aquatic ecosystem within the river, this report also comments on the relationship of the proposed development with wetlands on the site itself. As noted above, wetlands actually comprise a majority of the site area. Some of the wetlands have been created to compensate for past losses of these ecologically important land features.

[7] OAR 660-004-0020(2)(d).
[8] LUBA No. 2014-017/018, page 44.
[9] LUBA No. 2018-020, page 36.

I found the Compatibility Report to be seriously deficient in these areas of my focus. It has excessively shallow coverage of the particular industrial activities that will occur at the site and the materials that will be used in these activities, the residues and contaminants that will be produced, and the precise mitigation measures that will be employed to ameliorate negative impacts of these agents. The Compatibility Report thus ignores the stipulations to be specific in evaluation and mitigation. It is virtually silent on potential effects on Columbia River and wetlands water quality and aquatic life and how deleterious impacts will be countered. This omission is vividly portrayed by not even including the river in its description of adjacent and non-adjacent (but nearby) uses or in its Table 3 (Comparison of Potential Adverse Impacts). As pointed out above, the 2014 LUBA decision decidedly charged the Port to consider not only neighboring land uses but also water quality, directly implying that the term "uses" applies to aquatic as well as terrestrial systems. This report documents these deficiencies and denotes the coverage necessary for a comprehensive compatibility investigation.

FAILURE TO DEMONSTRATE COMPATIBILITY WITH THE COLUMBIA RIVER AND WETLAND ECOSYSTEMS

Deficiencies in Defining Proposed Industrial Activities

As introduced earlier, the Port identified five industrial uses dependent on the deep-water port and dock at Port Westward. For each, the Compatibility Report lists several general categories of industrial activities that will be associated with each use and some examples of the possible installations that could be established and products that may be handled. Table 1 summarizes these classifications.

The Compatibility Report's compilation, summarized in Table 1, raises as many questions as it answers about what is really intended at Port Westward. Among the activity categories, transportation (in one case, "transfer") seems to be clear and directly related to the presence of the dock, as required by the 2014 LUBA decision. The report does not define what it means by "storage," but it can be reasonably inferred that it would be transitory between reception and shipping out, and thus also consistent with transportation over the dock.

The other two named activity categories, processing and production, are left more vague and at least somewhat questionable as dock-related. A pulp and paper mill would definitely constitute "production," but does the Port really contemplate perhaps installing such a mill, which is not dock-dependent? And what would dry bulk commodity production entail? Is there some idea of refining metals, which would greatly raise the probability of releasing potential water pollutants of concern? "Processing" is not defined and could range from minimal to extensive. There are two examples cited (log debarking and petroleum additive mixing) that suggest the Port is not foreseeing highly extensive work. Still, these processing operations would produce potential water pollutants that must be managed properly for compatibility with the aquatic ecosystems.

The anticipated industrial activities at the proposed installation are far broader than those occurring at the existing Port Westward industrial park. To the crude oil and petroleum product

shipping happening there, the new development will add wood products, grain, metals, food products, and large breakbulk items. As covered further in the following section, the potential pollutants generated and water quality impacts are correspondingly much broader.

Table 1. Proposed Port Westward Industrial Uses and Activities and Example Installations and Products

Industrial Use	Industrial Activity Categories	Example Installations and Products
Forestry and Wood Products	Processing Production Storage Transportation	Sawmill Pulp and paper mill Wood pellet production Utility pole production Log debarker Sawdust Semi-finished wood products Logs Lumber
Dry Bulk Commodities	Transfer Storage Production Processing	Grain Metals Lumber
Liquid Bulk Commodities	Processing Storage Transportation	Petroleum Ethanol Milk Cooking oil Other edible fluids
Natural Gas and Derivative Products	Processing Storage Transportation	Liquified natural gas Fertilizer Methanol
Breakbulk Cargo	Storage Transportation Processing	Wind turbine blades Turbines Heat exchangers Automobiles

The ambiguities noted and the great expansion of industrial presence at Port Westward undercut the overall claim that the proposed development is wholly compatible with its surroundings. The Compatibility Report should be extensively expanded to fill in the gaps and answer the open questions of the type this report poses.

Deficiencies in Assessing Potential Water Quality Impacts

The Compatibility Report makes no reference to specific water pollutants that are likely to be produced by the industrial activities, installations, and products anticipated at Port Westward. Of course, with this major omission, there was no estimation of the quantities of such contaminants that could be introduced to the Columbia River and how they may add to contaminants already present to create a cumulative burden. The broad range of proposed operations portends the production of a sizable array of quantities falling in all of the categories of water pollutants. Table 2 summarizes the potential water pollutants and sources at the proposed development.

Table 2. Potential Port Westward Water Pollutants and Their Sources

Pollutant Category	Common Pollutant Measures	Port Westward Sources
Particulates	Total suspended solids ("TSS") Turbidity	Forestry and wood products Grain Site construction Activities and vehicular traffic on unpaved land
Nutrients	Nitrogen Phosphorus	Forestry and wood products Grain Site construction Fertilizer
Oxygen-demanding substances	Biochemical oxygen demand ("BOD") Chemical oxygen demand ("COD")	Forestry and wood products Grain Site construction Ethanol and methanol Edible fluids
Metallic aquatic toxins	Copper Chromium Lead Nickel Zinc Mercury Cadmium Arsenic	Vehicles and other motorized equipment Dry bulk metals Petroleum additives Metallic breakbulk cargo
Petroleum and its derivatives	Oil and grease Total petroleum hydrocarbons ("TPH," measured as diesel, gasoline, and heavy oil fractions)	Crude oil and petroleum product storage and transportation Vehicles and other motorized equipment
Synthetic organic chemical toxins	Hundreds of chemicals derived from petroleum and natural gas and produced in combustion	Vehicles and other motorized equipment Pesticides for site maintenance
Pathogens	Bacteria indicators Viruses	Wildlife concentrating around exposed grain and food products

A comprehensive compatibility assessment, which I maintain is required by the controlling regulations and decisions, would perform an exercise of this type. It would then proceed to perform quantitative analysis to forecast pollutant production as input to further assessment of potential resource impacts and mitigation measures. I elaborate on those two subjects below.

Pollutants associated with the existing Port Westward industrial park are largely in the category petroleum and its derivatives. In contrast, the proposed new development would add numerous pollutants in the other six categories.

A notable, careless absence in the Compatibility Report is any mention of the potential construction-phase contaminants and impacts, other than a brief mention of the construction stormwater general permit. Poorly managed open ground is prone to erosion, producing particulates and other pollutants transported with them (especially nutrients and oxygen-demanding substances). While most of the proposed development area is isolated from the river by the dike, high water table will prevent substantial below-ground infiltration of particulate-laden storm runoff produced there. If that water interferes with construction activities, it will probably be directed to the river. Doing so without negative impacts there would require thorough sediment reduction. The Compatibility Report does not confront these issues.

Deficiencies in Assessing Potential Aquatic Resource Impacts

Introduction

The numerous water pollutants appearing in Table 2, if flowing into the Columbia River and on-site wetlands with stormwater runoff, would negatively affect water quality in those receiving waters, which would in turn harm the living organisms inhabiting them. The extensive discussion presented below is intended to demonstrate the broad extent of and serious potential threat posed by these pollutants, a matter almost entirely ignored by the Compatibility Report.

In addition to the water quality concern, wetlands could be lost by draining or filling to install developed features. Even without planned modification to that extent, incidental intrusion while performing construction activities would disrupt their ecological functioning or even eliminate them entirely. Also potentially degrading to wetlands is modifying their hydrology by draining stormwater runoff from developed surfaces into them. After characterizing the river and wetland resources at issue, this section of the report elaborates on all of these potential impacts.

Potentially Affected Aquatic Resources

Columbia River

The Columbia River in the Columbia County vicinity, as well as downstream to the mouth and for many miles upstream, is listed by DEQ as having a wide range of beneficial uses to the natural and human environments. They include, among others, salmon and steelhead migration, domestic water supply, wildlife support, and water contact recreation.[10] These ecological and societal services are at risk by water pollutants from industrial developments like that proposed at Port Westward.

Six species of Pacific salmonids are known to have inhabited the Columbia River Basin historically: Chinook, coho, sockeye, chum, and pink salmon, plus steelhead.[11] Pink salmon are now extinct in the Columbia River. Chinook salmon spawn in the mainstem Columbia and its larger tributaries. There is a distinct lower-river run, pertinent to Columbia County, and a distinct upriver run. Chinook are divided among spring, summer and fall subspecies. Steelhead, coho, and sockeye use the mainstem river during in- and out-migration but mostly spawn in tributaries (steelhead, coho) or lakes (sockeye). These salmonids are prized by recreational and commercial fishers. Chum salmon are not abundant in Oregon, inhabiting just the lower Columbia River and a few coastal streams,[12] and no harvest is permitted in the Columbia.

[10] https://www.oregon.gov/deq/Rulemaking%20Docs/table101a.pdf, https://www.oregon.gov/deq/Rulemaking%20Docs/table101b.pdf (last accessed on October 12, 2020).
[11] https://www.nwcouncil.org/reports/columbia-river-history/salmonandsteelhead#:~:text=Six%20species%20of%20Pacific%20salmon,and%20pink%20salmon%2C%20and%20steelhead (last accessed on November 2, 2020).
[12] https://oregonwild.org/wildlife/chum-salmon (accessed on October 15, 2020).

Columbia River chum and Lower Columbia River chinook, coho, and steelhead are listed as threatened under the federal Endangered Species Act. Lower Columbia River coho also has Oregon state endangered status.[13]

Sturgeon is another esteemed fish in the Columbia River, which hosts greater numbers than any other river. Among the river's sturgeon populations, those in the lower river (*i.e.*, in the Columbia County vicinity) are the most stable, probably because of the absence of flow and temperature alterations by dams. Sturgeon also possibly benefit in that reach because they can utilize habitat in both the river and the estuary, where there are abundant food fish.[14]

Wetland Resources

Regulations issued under the federal Clean Water Act define wetlands as, "… those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions."[15] There are diverse wetland types in freshwater, saline, and brackish water environments. All possess several ecological characteristics that distinguish them from upland or other aquatic ecosystems; specifically, unique hydrologic, soil (substrate), and biotic conditions.

The hydrological regime, which is determined by the duration, frequency, and extent of inundation, is the primary factor driving the other ecological elements. A site has wetland hydrology when it is wet enough to produce hydric soils, saturated with water for part or all of the year, that support hydrophytic vegetation (plants that are adapted to waterlogged environments). Saturated soils become anaerobic (without oxygen) as water stimulates the growth of microorganisms, which use up the oxygen in the spaces between soil particles. This condition significantly changes soil structure and chemistry, making wetland soils unsuitable for terrestrial plants. The hydrophytic plants that thrive instead include submerged, floating, and emergent (above the water surface) plants, as well as shrubs and trees.

Wetlands benefit ecosystems and society in a variety of important ways:

- Providing essential habitat for birds, fish, small mammals, amphibians, and reptiles—Eighty percent of America's breeding bird population, and more than 50 percent of the 800 species of protected migratory birds rely on wetlands. Amphibians are in worldwide decline, and nearly all of the approximately 190 species in North America depend on wetlands for breeding.[16]

- High biological productivity—Wetlands tend to be highly productive ecosystems because they are rich in organic matter and nutrients. Some of these materials are transferred to

[13] https://www.dfw.state.or.us/wildlife/diversity/species/docs/Threatened_and_Endangered_Species.pdf (accessed on October 15, 2020).
[14] https://www.nwcouncil.org/reports/columbia-river-history/sturgeon (accessed on October 15, 2020).
[15] 33 CFR 328.3(b).
[16] Interagency Workgroup on Wetland Restoration. Undated. An Introduction and User's Guide to Wetland Restoration, Creation, and Enhancement. National Oceanic and Atmospheric Administration, Silver Spring, Maryland.

nearby aquatic systems (lakes, rivers, and estuaries), enhancing productivity there and supporting human uses such as fisheries.

- Biodiversity protection—Wetlands generally have a relatively high diversity of species, many unique and rare. These organisms are important to overall ecosystem functioning and, ultimately, to the health of the environment upon which humans depend. Among them are many plant species used for food, drugs, and other commodities.

- Flood and stream channel damage reduction—Wetlands intercept and store storm runoff, thereby changing rapid and high peak flows to slower and smaller discharges over longer periods of time. Because it is usually the peak flows that cause flood and channel erosion damage, the effect of wetlands is to reduce the risk of these events.

- Water quality improvement—Wetlands capture sediments, other pollutants transported with the solids, and dissolved contaminants too. Physical, chemical, and biological processes sequester some of these pollutants or transform them to less harmful forms.

- Aesthetics and recreation—Human society benefits from wetlands in many ways. They provide open space and the beauty and sounds of nature, contribute places to learn about the natural environment, moderate the climate, and offer healthy recreational activities ranging from relatively passive to highly active.

Water Pollutants and Their Potential Negative Impacts

Particulates

Particulates are an instrumental feature of water quality because of their numerous ecological consequences, including:

- Covering and seeping into coarse bed materials where fish spawn and eggs develop; in filling the pore spaces, sediments restrict the flow of water carrying dissolved oxygen, resulting in asphyxiation of the young;

- Covering the surfaces serving as habitat for fish food sources (e.g., insects, algae);

- Filling deeper areas, tending to produce a more homogeneous bed and less habitat diversity and specifically reducing pools where fish rest and seek refuge from predators;

- Reducing visibility, making it harder for fish to find food and avoid predators;

- Reducing light penetration to underwater plants and algae;

- Abrading the soft tissues of fish, especially gills; and

- Transporting other pollutants contacted in transport.

Regarding the latter impact, sediments are a transport medium for many contaminants in other categories of water pollutants: metals, nutrients, organic chemicals, and pathogens.

Nutrients

Phosphorus and nitrogen are nutrients required by plants, both terrestrial and aquatic, to support photosynthesis and growth. These processes are controlled by, among other factors, the nutrient present in least supply relative to needs, known as the limiting nutrient. Nitrogen tends to be limiting in saline waters and phosphorus in fresh waters. However, the limiting nutrient can switch when the other nutrient is reduced for some reason. The Columbia River at Port Westward is tidal, meaning that salinity varies according to the relative proportions of salt and fresh water over the tidal cycle. Thus, both nutrients are at issue.

When the limiting nutrient enters natural water bodies and raises the amount of this substance present in the water, it can stimulate increased growths of algae and aquatic plants, a process known as eutrophication. In these circumstances the forms of algae tend to change from single-celled organisms to filamentous forms, which are less desirable for several reasons. They are generally an inferior food source for wildlife; clog water intakes, conveyances, and boat motors; and foul beaches when they wash up on them. When the increased masses of algae die, bacteria decomposing them exert a large demand on the oxygen dissolved in the water and reduce the amount available for fish and invertebrates.

It is not unusual for slowly flowing streams and rivers and gradually flushed embayments to have little or no oxygen in relatively deep areas and reduced oxygen even near the surface. Thus, these water bodies are vulnerable to dissolved oxygen reduction through discharges of nutrients.

Oxygen-Demanding Substances

The Compatibility Report names forestry and wood products as components of the proposed development's business. Sawdust and bark, removed from raw logs by a debarker, are anticipated residues. Grain is another prominently mentioned material.

Wood, its residues, and grain decompose over time from their original complex organic formulations to constituent compounds and, ultimately, chemical elements. The decomposition process starts on land, for example when bark and other log residues remain exposed on an outdoor surface. The breakdown begins as a physical deconstruction, with reduction of larger pieces, like bark strips, to smaller particles, and less visibly, to very small dust particles. Simultaneously, a biochemical process begins in which heterotrophic bacteria and fungi exploit the wood material as a carbon source to support their growth. This process both advances the particle size reduction and converts some of the solid material to liquid, termed "leachate." When the solid particles and leachate flow into a water body, the decomposition process continues; and the microorganisms consume oxygen taken from the water, thus exerting what is termed an "oxygen demand." BOD and COD are laboratory measures and expressions of that demand.

Leachate is composed of soluble organic compounds, which are especially high in oxygen demand when entering water, because they can be degraded rapidly. Wood leachate COD has generally been measured as high as or higher than the COD of raw sewage.[17] Furthermore, wood already broken down into relatively small particulates degrades more rapidly and, consequently, exerts more oxygen demand than a larger piece of equivalent mass.[18]

Oxygen dissolves from the atmosphere into water bodies, but the oxygen demand exerted by decomposing microorganisms can exceed the rate of oxygen dissolution with a large supply of degradable organics. Aerobic aquatic life, including fish and their invertebrate food sources, require sufficient oxygen to support their physiological processes. Highly depleted dissolved oxygen is fatal, at somewhat different levels depending on species. Salmonids, including threatened and endangered salmon, are the most sensitive fish in this respect. Even if not drawn down to a lethal level, somewhat depleted oxygen interferes with such processes as feeding, avoiding predators, and growth.

Metallic Aquatic Toxins

Among the various metals associated with industries and urban land uses, copper and zinc are almost always present in detectable, and often substantially elevated, concentrations. Both are toxic to fish and other aquatic life, much more so than to mammals. Copper is one of the most toxic metals in fact.[19] Other metals listed in Table 2 are also toxic at various levels. The effects of metals on aquatic organisms can be directly lethal or sublethal but detrimental to such life cycle functions as migration, reproduction, rearing, feeding, growth, disease resistance, and predator avoidance.

For copper, mechanisms bringing about these adverse effects in fish include fraying of gills, diminishing their physiological processes, and reduction of olfactory ability (sense of smell).[20] The onset of negative consequences depends on species and water pH, dissolved organic carbon, and hardness but begins as low as approximately 5 µg/L or even less (*e.g.*, Baldwin *et al.* 2003).[21] A wide range of lethal copper concentrations has been reported in the literature for different fish species and varying test conditions. The U.S. Environmental Protection Agency ("USEPA") compiled chronic (multi-day) test data from numerous studies. The maximum reported copper concentration lethal to 50 percent of the test organisms ("LC_{50}")

[17] *E.g.*, Kannepalli, S., P.F. Strom, U. Krogmann, V. Subroy, D. Giménez, and R. Miskewitz. 2016. Characterization of Wood Mulch and Leachate/Runoff from Three Wood Recycling Facilities. *Journal of Environmental Management* 182(1):421- 428.
[18] *E.g.*, Rex J., S. Dubé, P. Krauskopf, and S. Berch. 2016. Investigating Potential Toxicity of Leachate from Wood Chip Piles Generated by Roadside Biomass Operations. *Forests*, 7, 40.
[19] Solomon, F. 2009. Impacts of Copper on Aquatic Ecosystems and Human Health. MINING.com, January 2009, pp. 25-28. http://www.ushydrotech.com/files/6714/1409/9604/Impacts_of_Copper_on_Aquatic_Ecosystems_and_human_Health.pdf (last accessed on October 22, 2020).
[20] Solomon, *Ibid.*
[21] Baldwin, D.H., J.F. Sandahl, J.S. Labenia, and N.L. Scholz. 2003. Sublethal effects of copper on coho salmon: Impacts on nonoverlapping receptor pathways in the peripheral olfactory nervous system. *Environmental Toxicology and Chemistry* 22(10):2266-2274.

was 29 µg/L.[22] Copper is routinely present in industrial stormwater runoff samples in concentrations several times as high.

For zinc, the gills are the main toxicity targets, where calcium uptake is disrupted, leading to its deficiency, harm to physiological processes requiring it, and, *in extremis*, death. Other points of damage are the liver, the kidneys, and skeletal muscle tissue.[23] As with copper, sensitivity depends on species and the same general water quality conditions. A small amount of data from chronic tests on different fish species shows zinc LC_{50} over a wide range of 32-854 µg/L.[24] Industrial stormwater runoff concentrations regularly reach into hundreds of µg/L, much higher than the low end of the LC_{50} range. Sublethal effects at even lower concentrations include avoidance of rearing habitat and inhibited immune response.[25] Such negative effects interfere with growth, ability to avoid predators, and resistance to disease.

The negative effects of metal toxins are not necessarily limited to short-term, acute lethal or medium-term sublethal impacts. Over time an organism can accumulate metals in tissue, a process known as bioaccumulation. When predators consume organisms with bioaccumulated metals, they concentrate them in their tissues. The top predator in an aquatic ecosystem tends to have the highest concentrations, through biomagnification up the food chain. Fish relying on the Columbia River habitat and their food sources in the benthic macroinvertebrate community are subject to these impacts.

Aquatic sediments become repositories for particulate metals through gravity settling and for dissolved metals through various adsorption and ion exchange processes. Bottom-dwelling organisms are negatively affected by contact with contaminated sediments. The captured metals can become remobilized into the water column by high-flow disturbance and dissolution, and thus harm aquatic life throughout the water column long after their initial release.

Petroleum and Its Derivatives (Including Synthetic Organic Toxins)

Petroleum-based materials contain many chemicals, certain ones of which are toxic to aquatic life. These compounds cause lethal effects in high concentrations and reproductive, developmental, and behavioral sublethal effects at lower levels. Refined products like lubricating oils also generally contain additives, often organo-metallic compounds that introduce other toxic contaminants such as copper and zinc.

Petroleum and its derivatives decompose in the aquatic environment, but relatively slowly, and tend to accumulate. The gradual decomposition reduces the oxygen supply needed by fish and other water life. This process also reduces oxygen supply to the aerobic

[22] https://www.epa.gov/sites/production/files/2015-06/documents/wi_al_304_07012001.pdf (last accessed October 22, 2020).
[23] Authman, M.M.N., M.S. Zaki, E.A. Khallaf, and H.H. Abbas. 2015. Use of Fish as Bio-indicator of the Effects of Heavy Metals Pollution. Journal of Aquatic Research and Development 6(4):328.
[24] Davies, P.H. 2001. Water Pollution Studies. Colorado Division of Wildlife, Fish Research Section, Fort Collins, Colorado. https://cpw.state.co.us/Documents/Research/Aquatic/pdf/Publications/WaterPollutionStudies2001.pdf (last accessed October 22, 2020).
[25] Price, M.H.H. 2013. Sub-lethal metal toxicity effects on salmonids: a review. Report prepared for SkeenaWild Conservation Trust. Smithers, BC.

microorganisms that break the oil down into non-hazardous compounds, thus progressively slowing the process.

Petroleum is the raw material, along with natural gas, for the production of most synthetic organic chemicals serving as the base for myriad industrial, commercial, agricultural, and household products. Some industrial examples that could enter the stormwater runoff at an operation like the proposed Port Westward site are solvents, paints and other coatings, and pesticides. Generally, these chemicals are toxic to aquatic life at some level.

Polycyclic aromatic hydrocarbons ("PAHs") are some of the synthetic organics most often detected in industrial and urban stormwater runoff, because they originate from petroleum products and their combustion. Since it is highly likely that the Port Westward development will have a large volume of heavy truck traffic, along with handling petroleum materials, PAHs are likely to be the major synthetic organics in its stormwater runoff.

There are numerous chemicals in the PAH class, varying in their molecular weight and the number of rings around which the carbon and hydrogen atoms composing them are arranged. Naphthalene and phenanthrene, relatively simple compounds with two and three rings, respectively, constitute the majority of the PAHs in both diesel fuel and motor oil.[26] Most PAHs are insoluble in water, which limits their mobility in the environment, although PAHs sorb to fine-grained, organic-rich sediments. The two-ringed compounds, and to a lesser extent three-ringed PAHs, do dissolve in water, making them more available for biological uptake.

Diesel fuels vary in PAHs as a function of the crude oil feedstock and refining processes. Work in Finland on the relationship between fuel and exhaust PAHs studied two diesel fuels containing 1 and 5 percent PAHs,[27] although there are reports in the literature of higher percentages.

It has been found that PAHs are relatively low in unused motor oil but increase substantially in use. For example, in one study naphthalene rose from an initial concentration of 0.3 µg/g to 108 µg/g in the motor oil of a vehicle driven 3635 km. The total concentration of 99 PAHs in that sample was 5199 µg/g, amounting to 0.52 percent of the used motor oil. The majority of the compounds were the relatively soluble two- and three-ring PAHs, the more mobile and bioavailable chemicals.[28] Another investigation found naphthalene alone to constitute 69 percent of the PAHs in used motor oil.[29]

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[26] de Souza, C.V. and S.M. Correa. 2016. Polycyclic Aromatic Hydrocarbons in Diesel Smission, Diesel Fuel and Lubricant Oil. *Fuel* 185:925–931.

[27] Aakko, P., T. Harju, M. Niemi, and L. Rantanen-Kolehmainen. 2006. PAH Content of Diesel Fuel and Automotive Emissions, Research Report No. VTT-R-1155-06. VTT Technical Research Centre of Finland, Helsinki, Finland.

[28] Wang, J., C.R. Jia, C.K. Wong, and P.K. Wong. 2000. Characterization of Polycyclic Aromatic Hydrocarbons Created in Lubricating Oils. *Water, Air, and Soil Pollution* 120:381–396. The total PAH concentration quoted above is the sum of values from the last column of Table II.

[29] Wu, X., B. Yue, Y. Su, Q. Wang, Q. Huang, Q. Wang, and H. Cai. 2017. Pollution Characteristics of Polycyclic Aromatic Hydrocarbons in Common Used Mineral Oils and Their Transformation during Oil Regeneration. *Journal of Environmental Sciences* 56:247-253.

The PAHs naphthalene and methyl naphthalenes are the most common, well-studied, water soluble, and toxic components of petroleum and are accumulated by organisms.[30] Some studies have concluded that the toxicity of an oil appears to be a function of its di-aromatic hydrocarbon (that is, two-ring hydrocarbons such as naphthalene) content. Environmental effects of such compounds often are the result of exposures to complex mixtures of chronic-risk chemicals.[31] Laboratory bioassays have shown that naphthalene is moderately toxic to rainbow trout (*Onchorynchus mykiss*), bluegill sunfish (*Lepomis macrochirus*), and fathead minnows (*Pimephales promelas*). In coho salmon (*Onchoryncus kisutch*), chronic naphthalene exposure resulted in reductions in feeding, growth, and survival rates.[32]

Additional Potential Negative Impacts to Wetlands

In addition to the potential negative effects of the water pollutants discussed above on wetland fauna, development can harm wetland ecosystems in three other ways: (1) filling or draining, (2) incidentally intruding into them, and (3) altering their hydrology. Placing fill or any developed features requires a permit from the U.S. Army Corps of Engineers. Incidental intrusion might occur, for example, when the wetland boundary and its designated buffer are not marked to warn construction equipment from entering.

As pointed out earlier, wetland ecosystems form as a function of their hydrology. Draining obviously would thoroughly alter the hydrology and result, sooner or later, in conversion to a terrestrial environment. Hydrologic inputs are precipitation, surface runoff, and groundwater. Generally, artificially lowering the water table would be sufficient to drain the wetland, and it is likely that the surface drainage system would also be altered at the same time. There is no mention in the Compatibility Report how the proponent intends to manage wetlands on the site, specifically no reference to any plans to fill or drain.

Besides diminishing the hydrologic input, development can increase it in a way that causes ecological harm and reduces some of the functions described above that wetlands provide. A major finding of the Puget Sound Wetlands and Stormwater Management Research Program was a decline in the biotic diversity of wetlands associated with increase in water level fluctuation ("WLF")[33] caused by expanding impervious area within the contributing basins (Chin 1996, Horner et al. 1997, Reinelt et al. 1998, Azous and Horner 2001).[34] Increase of mean

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[30] Liu, D. and B.J. Dutka (eds.). 1984. *Toxicity Screening Procedures Using Bacterial Systems* (p. 392). Marcel Dekker, Inc., New York, NY.

[31] Irwin, R.J., M. VanMouwerik, L. Stevens, M.D. Seese, and W. Basham. 1997. Environmental Contaminants Encyclopedia. National Park Service, Water Resources Division, Fort Collins, Colorado. .

[32] From National Pesticide Information Center, http://npic.orst.edu/factsheets/naphtech.html.

[33] WLF was computed as the difference between crest stage and average base stage. Crest stage was determined with a crest-stage gauge, which records the maximum stage in a time period through the deposition level of cork dust on a plastic tube within a pipe housing. Average base stage was calculated as the mean of the stage at the beginning and end of the time period.

[34] Chin, N.T. 1996. Watershed Urbanization Effects on Palustrine Wetlands: A Study of the Hydrologic, Vegetative, and Amphibian Community Response Over Eight Years. M.S.C.E. thesis, Department of Civil and Environmental Engineering, University of Washington, Seattle, WA.

Horner, R.R., D.B. Booth, A. Azous, and C.W. May. 1997. Watershed Determinants of Ecosystem Functioning. *In* L.A. Roesner (ed.), *Effects of Watershed Development and Management on Aquatic Ecosystems*, American Society of Civil Engineers, New York, New York, pp. 251-274.

annual WLF above 20 cm is a critical point for biodiversity (Horner et al. 1997). Vegetation species richness in emergent and scrub-shrub wetland zones was statistically significantly lower with WLF above compared to below 22 cm. More than 14 plant species never occurred in emergent plant zones, and rarely did in scrub-shrub zones, with mean annual WLF > 22 cm. Up to 25 species were found in each of those zones in wetlands with WLF below that point. While up to eight amphibian species were found in wetlands with relatively low urbanization and WLF, more than three species never occurred with mean annual WLF > 20 cm.

Development without awareness of these intricate relationships and measures to counter their effects is likely to increase storm runoff drainage to the wetlands on the Port Westward site. This outcome would alter hydrology and, probably, also the floral and faunal diversity.[35]

Deficiencies in Assessing Mitigation Measures

As discussed earlier, the applicable concept of compatibility potentially allows some degree of interference with or adverse impacts on adjacent uses, if the impacts are adequately mitigated to allow the continuation of existing uses along with the new use. Being granted a Goal Exception requires the applicant to identify and impose specific measures to reduce adverse impacts. The Compatibility Report fails entirely to adhere to these directives with respect to the adjacent water resources. Of course, meeting this responsibility is impossible with inadequate definition of the proposed industrial activities and virtually no attention to potential water quality and aquatic resource impacts.

Known and reasonable technologies exist for industries to prevent the discharge of pollutants or reduce their concentrations in stormwater discharges to levels protecting receiving waters and meeting regulatory criteria. Broadly speaking, stormwater management practices can be classified as outlined in Table 3. The overall suite of methods is commonly termed best management practices ("BMPs").

The general view in the stormwater management field is that emphasizing preventive source and retention controls is preferable to relying on remedial controls. Avoiding the contact of pollutants with rainfall or runoff and retaining all runoff on-site, if complete, are 100 percent effective, in terms of keeping contaminants out of receiving waters. Preventive methods are also frequently lower in cost than treatment. The most common, and effective, preventive BMPs in the structural subcategory utilize straightforward methods like coverings (permanent or temporary), to keep rain from falling on and percolating through contaminant sources, and measures such as site grading and berms to direct runoff away from these sources.

Reinelt, L.E., R.R. Horner, and A. Azous. 1998. Impacts of Urbanization on Palustrine (Depressional Freshwater) Wetlands: Research and Management in the Puget Sound Region. *Urban Ecosystems* 2:219-236.

Azous, A.L. and R.R. Horner (eds.). 2001. *Wetlands and Urbanization: Implications for the Future*. Lewis Publishers, Boca Raton, Florida.

[35] Chin, Horner et al., Reinelt et al., Azous and Horner; *Ibid.*

Table 3. Categories of Stormwater Best Management Practices

Category and Definition	Subcategory and Definition	Relative Effectiveness	Example Methods
Source controls—Preventive techniques to avoid the generation of pollutants, or at least their introduction to storm runoff	**Operational**—Programmatic improvements to industrial activities to eliminate pollutant exposures	Necessary for effective application of BMPs in other subcategories	Establishing a pollution prevention team, employee training, good housekeeping, equipment preventive maintenance, spill prevention, inspection, illicit discharge elimination, measures to discourage littering
	Structural—Installations to isolate contaminants from contact with rainfall and runoff	100% if complete isolation	Overhead covering to avoid rainfall contact, side enclosure to avoid wind-blown precipitation contact, installing berms or cut-off channels to prevent on-site runoff or off-site run-on from flowing over a contaminated area, removing or coating polluting building materials
Retention controls—Methods to prevent release of storm runoff as a surface discharge	**Infiltration/evapotranspiration**—Installations to introduce water to the soil for downward percolation and/or release to the atmosphere as a vapor	100% if complete retention; proportionately less to the extent incomplete	Infiltration basin, bioretention cell (rain garden), bioretention swale, bioretention filter strip,[a] infiltration trench, pervious pavement
	Rain harvesting—Collecting rainfall and/or runoff for a beneficial use (*e.g.*, irrigation, toilet flushing, industrial washing)	100% if complete collection	Cistern (large scale), rain barrel (small scale)
Remedial controls—Techniques to recapture pollutants before they can discharge into a receiving water	**Pollutant recovery**—Actions to retrieve pollutants released to the environment before they can enter runoff	Varies but not approaching 100%, especially in recovering smallest particles	Spill clean-up, sweeping, equipment washing, trash pick up
	Conventional runoff treatment—Methods to remove some contaminants already carried in runoff	Varies but not approaching 100%, especially in removing smallest particles and dissolved substances	Treatment pond, treatment wetland, basic sand filtration, conventional swale, conventional filter strip,[a] trash collecting drain inserts and screens
	Advanced runoff treatment—Methods to remove most contaminants already carried in runoff	Never 100% but can approach with the most advanced technologies	Polymer-enhanced sand filtration, advanced media filtration coupled with ion exchange and/or carbon adsorption

[a] The bioretention cell, swale, and filter strip are constructed with amended soil if necessary to maximize soil storage and attendant infiltration and evapotranspiration. The conventional swale and filter strip are constructed in the existing site soil and vary in retention capacity in relation to the geohydrologic characteristics of that soil.

Port Westward can and should make the maximum use of source controls to address these pollutant sources. However, because of the size and nature of the proposed operation, it is highly unlikely that the industrial site could apply source controls sufficiently to avoid impacts to storm runoff receiving waters through these measures alone. Port Westward has land area of sufficient size to employ retention remedial controls. While specific, detailed on-site investigation is necessary to determine if infiltration is feasible, high water table, and possibly other conditions, may render this practice unworkable at Port Westward. Still, the operation may have need for industrial water supply, and thus could make use of the rain harvesting retention control.

If infiltration is indeed infeasible, runoff treatment will almost certainly be necessary to meet mitigation requirements. Table 3 notes the available options. Advanced treatment systems are decidedly superior to conventional treatment and are now well developed for and being commonly employed in industrial stormwater treatment applications. Always in developing a mitigation plan, it should be kept in mind that whatever can be accomplished with preventive controls will reduce the complexity and cost of treatment.

The Compatibility Report (page 52) concludes that, "The dike between the zone change area and the Columbia River separates the bulk of the zone change area (excluding the Thompson property) from the waterway, allowing for effective stormwater management approaches… ." This is an empty statement without saying what those "effective" approaches would be. It is true that the dike isolates most of the site from the river (although not from the wetlands); but if full mitigation with source and retention controls is impossible, the remaining industrial runoff has to go somewhere. The most likely repository would be the river, probably via pumping, requiring high quality treatment to mitigate its potential negative effects.

THE ROLE OF REGULATORY PROGRAMS IN ACHIEVING COMPATIBILITY WITH AQUATIC RESOURCES

The Compatibility Report (page 52) states the opinion that, "The extensive Federal, state, and local regulatory programs applicable to industrial development address the potential impacts from new development and require measures to safeguard that offsite effects are limited to acceptable levels as determined by the regulating agencies and programs." The chief regulatory program pertaining to the issues covered in this report is Oregon's General Permit, National Pollutant Discharge Elimination System, Stormwater Discharge General Permit No. 1200-Z (effective August 1, 2017), which covers facilities that discharge industrial stormwater to surface waters or to conveyance systems that discharge to surface waters.

Being a general permit, 1200-Z specifies certain terms applying to all industrial stormwater dischargers in the state and others covering all those in a particular industrial sector (designated according to the Standard Industrial Classification code). Thus, the permit cannot take into account site-specific circumstances. Some proposed activities would be new to Oregon (*e.g.*, petroleum processing, methanol production) and thus beyond the existing experience with permit 1200-Z. The permit is enforced largely through self-reporting by permittees. The main reporting obligation is submitting the results of discharge water quality monitoring, based on only four samples per year. DEQ has performed only eight enforcement actions under permit 1200-Z thus far in 2020.[36] Hence, this regulatory mechanism is limited in its ability to ensure aquatic resource protection.

A superior approach would be an individual permit tailored to the particular facility and all of its circumstances. Individual permits usually require more frequent monitoring by the permittee to assure that permit limitations are being met, as well as monitoring for a greater variety of pollutants. While DEQ currently has over 800 facilities under National Pollutant

[36] https://www.oregon.gov/deq/Pages/enforcement-actions.aspx (accessed October 21, 2020).

Discharge Elimination System and Water Pollution Control Facilities individual permits,[37] the 2019 Annual Report on Oregon's Water Quality National Pollutant Discharge Elimination System Permit Program indicates that none of these permits have been issued specifically for industrial stormwater discharges.[38] Apparently, DEQ's policy is not to use the individual permit mechanism for this wastewater stream and to rely on the general permit instead.

As demonstrated in the account above, the types of industrial activities proposed at Port Westward will introduce many contaminants in all of the categories of water pollutants. The scale of these proposed operations makes the potential releases of these pollutants substantial in magnitude. The Compatibility Report's glaring inadequacy in defining and assessing these matters provides no basis to develop the terms of an individual stormwater permit, even if DEQ were inclined to issue one. In this regulatory environment, protection of the aquatic resources potentially affected by the proposed Port Westward development is not guaranteed. The proponent should be required to conduct a comprehensive potential impact and mitigation assessment, such as outlined in this report.

[37] https://www.oregon.gov/deq/wq/wqpermits/Pages/FAQ.aspx (accessed October 21, 2020).
[38] https://www.oregon.gov/deq/FilterDocs/WQNPDESProgramUpdateFY2019.pdf (accessed October 21, 2020).

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> Flooding In The Columbia River Basin Expected To Increase Under Climate Change, Study Finds



Flooding in the Columbia River basin expected to increase under climate change, study finds

Feb. 10, 2021

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Story By

Michelle Klampe, 541-737-0784, michelle.klampe@oregonstate.edu

CORVALLIS, Ore. – The Columbia River basin will see an increase in flooding over the next 50 years as a result of climate change, new modeling from Oregon State University indicates.

The magnitude of flooding – the term used to describe flooding severity - is expected to increase throughout the basin, which includes the Columbia, Willamette and Snake rivers and hundreds of tributaries. In some areas, the flooding season will expand, as well.

“The flood you’re used to seeing out your window once every 10 years will likely be larger than it has been in the past,” said the study’s lead author, Laura Queen, a research assistant at OSU’s Oregon Climate Change Research Institute.

The findings are based on natural river conditions and do not take into account potential flood control measures, including dams, but the increases are significant nonetheless, said study co-author Philip Mote, a professor in the College of Earth, Ocean, and Atmospheric Sciences and dean of the Graduate School at OSU.

“We don’t know how much of this increased flood risk can be managed through mitigation measures until we study the issue further,” Mote said. “But managing a 30% to 40% increase, as is predicted for many areas, is clearly beyond our management capabilities.”

The findings were published recently in the journal Hydrology and Earth System Science. Co-authors are David Rupp of the Oregon Climate Change Research Institute and Oriana Chegwidden and Bart Nijssen of the University of Washington.

The study emerged out of Queen’s work on her honors thesis as an undergraduate in the University of Oregon’s Robert D. Clark Honors College.

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Queen, a Corvallis native, continued the work at OCCRI and is now enrolled in a doctoral program at Victoria University of Wellington in New Zealand.

The goal of Queen's research was to better understand how flooding in the Columbia River basin might change as the planet warms. The Columbia River drains much of the Pacific Northwest, including portions of seven states and British Columbia. It has the fourth-largest streamflow volume in the United States.

The Pacific Northwest has a history of costly and disruptive flooding. The largest flood in modern history occurred in late spring 1948 when flooding from the Columbia River destroyed the city of Vanport, Oregon, displacing more than 18,500 people. Floods on the Chehalis River in 2007 and 2009 closed Interstate 5 in Washington and floods along the Willamette River in 1996 and 2019 caused hundreds of millions of dollars in damage.

Queen ran simulations using hydrology models and a previously collected set of streamflow data for 396 sites throughout the Columbia River basin and other watersheds in western Washington. The data included a 50-year window from the past, 1950-1999, as well as a 50-year window of expected streamflows in the future, 2050 to 2099, that was developed using several different climate models.

Previous studies predicting future streamflows showed mixed results, but the results of this new analysis were clear and surprising, Mote said.

"This was the best and most complete set of data," he said. "It shows that the magnitude of one-, 10- and 100-year floods is likely go up nearly everywhere in the region. These are profound shifts."

The Willamette River and its tributaries are expected to see the biggest increase in flooding magnitude, with 50% to 60% increases in 100-year floods. The streamflows are expected to be smaller downstream and grow larger upstream.

On the Snake River, streamflows will grow larger as they move downstream until they reach the confluence of the Salmon River tributary and then will drop abruptly. Parts of the Snake River will see a 40% increase in 10-year floods and a 60% increase in 100-year floods. But below the confluence with

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the Salmon River on the Oregon-Idaho border, the increase drops to 20% for 10-year floods and 30% for 100-year floods.

The model also suggests a significant increase in the flood season on the Snake River, which is largely concentrated in late spring now but could start as early as December or January in the future, Mote said.

One of the drivers of the change is warmer winters that will see precipitation fall more as rain instead of snow. Lower spring snowpack will lead to earlier spring streamflows in many rivers. The cold upper Columbia River basin in Canada is projected to experience little change in snowpack volume, but the snow will melt faster.

The study's findings could have implications for flood management policy in the coming decades, Mote said. A logical next step in the research is to run the models again and include existing dams to see the role they may play in mitigating flooding.

"This work provides information and impetus for the people who manage flood risk," he said. "We'll need to know how much of this can be mitigated by existing flood control."

About the OSU College of Earth, Ocean, and Atmospheric Sciences (CEOAS):

The college is renowned for research excellence and academic programs that span the earth, ocean and climate sciences, as well as the human dimensions of environmental change. CEOAS inspires scientific solutions for Oregon and the world.

Source

Laura Queen, queenl@oregonstate.edu; Philip Mote, 541-913-2274, Philip.mote@oregonstate.edu

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Exhibit List 184

Island Drift

Launch/Landing: Abernathy Creek Boat Ramp, WA. River mile 54
Distance: 8 miles round trip (overnight option)
Skill Level: Intermediate to Advanced
Charts: NOAA 18523, Columbia River: Harrington Point to Crims Island and 18524, Columbia River: Crims Island to St. Helens
Tide Tables: Pacific Beaches with correction for Abernathy Point, WA

Directions: From milepost 48 on Highway 4 (about 14 miles west of Kelso), turn north onto Abernathy Creek Road, then turn left and follow a dirt road to the launch. At low tide, launch the small beach at the mouth of the creek.

Description: Many islands of the lower Columbia appear to be surrounded by small isles that were once part of a whole. Three-mile-long Crims Island is such a site, with Gull Island and four small unnamed islands around it, and another two nearby in Bradbury Slough, making it an island "complex" with byways for exploration. Lewis & Clark called it "Fanny's Bottom," presumably after Clark's sister Frances. Beginning at Abernathy Creek Boat Ramp in Washington, this paddle route crosses the shipping channel for a circumnavigation around Crims, then a jaunt downstream past Oak Point to Quill Island before a return to the Abernathy ramp. In the late 1800's, Astoria was known as the "salmon canning capital of the world" and the area around Oak Point contributed to that catch, with about fifty horse-drawn seine net crews and hundreds of wooden fishing traps at work. Primitive camping is available on Quill Island.

Exhibit List 185

Submitted to: Planning@ColumbiaCountyOR.gov

To the Columbia County Commission:

My name is Mike Seely, and I own and operate Seely Mint Farm next to Port Westward. We require access to fields from Kallunki Rd, on the north side of Kallunki Rd. Kallunki Rd now provides our only reliable access to areas we farm.

NEXT proposes to block Kallunki Rd. with long trains carrying feedstock or other materials, at least six times per week (three trains in, three trains out). Due to trains slowing as they approach the rail yard or gaining speed as they leave, the train will block the road for lengthy periods of time. NEXT and the Staff Report fail to address this issue adequately. I have personally experienced long delays from train traffic in the area up to 45 minutes. The issue of blocking Kallunki Rd. is also important for emergency access for people who live in the area, which includes Johns District.

The proposed rail yard will negatively impact our farm business. The portion of the rail yard on agricultural land will interfere with road access to farm land north of the proposed rail development. Staff refers to this as a "branch line," a description that LUBA rejected. Their proposal involves two applications for a rail yard that straddles industrially zoned land and agriculturally zoned land. Attempting to piecemeal the operation of one portion from the other makes little sense when the rail yard will be accepting mile-long trains that will impact a large area when trains arrive or leave.

Additionally, the addition of ponds in both agricultural and industrial areas will impact drainage, and the impacts to the drainage system are not yet understood well enough to determine that they can be adequately mitigated. It is unreasonable to conclude that these impacts can be mitigated in the absence of an agreement, or at least a common understanding, with the BDIC.

Additionally, NXT's proposed realignment is a drastic change to the proposed project. The change could impact groundwater levels, water in drainage systems, and the interconnected water systems and dikes that both protect our area from floods and provide irrigation. NXT now proposes ponds in new areas, a departure from the previous application. NXT does not fully understand groundwater levels. NXT relies on an outdated Geotechnical report, over 20 years old. The drainage distinct and its dikes have subsided significantly since that report. These are flaws that cannot be ignored, and the County must find that the application does not identify and mitigate potential water-related and erosion-related impacts to farms.

My business would be negatively impacted if water levels become unpredictable or water becomes too polluted for use, both of which are very likely in the current proposal.

My business would be negatively impacted by traffic and train delays. Delays of hours or even minutes - any delay whatsoever - will have a negative impact on our farming. When mint is

ready for harvest, we move quickly. We work multiple shifts in a day to complete harvest when the mint is ready. The timing of harvest is unpredictable mostly due to weather conditions and sometimes breakdowns/repairs. County rules require NEXT to consider and mitigate impacts to land uses in the area.

We harvest over many months, depending on the weather in any given year. Mint farming is nuanced, and soil moisture is highly important. Spearmint cannot handle standing water for more than 36 hours even when dormant. It kills it, and so changes to water levels will have a major impact on our operation. Changes in weather will cause mint to be ready for harvest on short notice. Once mowed, spearmint cannot have rain on it. It turns the oil red and is unmarketable (see attached photo). It cannot sit in a mint tun waiting to get to the still for very long (that turns it red too). Also, if the mint gets too dry from changes in weather conditions we have to modify when and how we harvest. (Too dry and the leaves fall to the ground when we try and harvest. Thus, losing the crop.)

NXT has not provided adequate information to determine how the rail yard, in its entirety, wil limpact farmers in the BDIC. Farming is a long-recognized land use in the area. Our mint can become unusable if not properly handled, quickly after harvest. Weather is a major factor in our operation, and weather is highly variable. Hence, access to fields needs to be flexible, and we access fields for harvest exclusively from Kallunki Rd. Further, delays in mint processing that could be caused by the proposed modification will impact our ability to fill our orders in a timely manner.

Our farm grows high-value mint, producing unique mint products. We simply cannot afford the risk that the modification would create for our business. Additionally, our farm relies on water supplies and drainage provided by the Beaver Drainage Improvement District (BDIC). The farm will be negatively impacted if the proposed modification alters the drainage infrastructure in our area. The system of drainages and ditches are interconnected. Pollution entering the water system could harm our mint crops. Altered drainage could impact soil moisture levels in ways that harm our farm and others in the area. No alterations to the operations of the BDIC and the distribution of water resources are allowed without permission from the BDIC and two-thirds of its members.

Air-borne pollution from the proposed rail yard and other modifications could also potentially impact area crops. NEXT and the Staff Report do not evaluate these impacts. Particulate matter or other pollutants could harm mint crops, causing crop failures or unusable products for producing high-grade mint oil.

For these reasons, as well as reasons identified by other commenters, I request that the Commission reject the proposed modification. The findings are inadequate and do not evaluate or mitigate impacts to area farmers.

I request that you keep the record open for no less than 7 days following the public hearing.

Sincerely,

Michael P. Seely

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BEAVER DRAINAGE IMPROVEMENT COMPANY, INC.
P.O. Box 201
Clatskanie, OR 97016
Email: ajvelke@yahoo.com Telephone (360)751-8778

To the Columbia County Planning Commission:

NEXT's application fails to adequately address criteria from Columbia County Zoning Ordinance (CCZO) 683.1.B. The code requires NEXT to show that the "potential impact upon the area resulting from the proposed use has been addressed and any adverse impact will be able to be mitigated." NEXT has not specifically analyzed the impact of the rail yard, a particular land use and improvement that will impact the Beaver Drainage Improvement Company(BDIC). NEXT must address physiological characteristics of the site, including drainage and the suitability of the site for the particular land use and improvements. NEXT must also show that it has considered impacts to existing land uses and both private and public facilities and services in the area, and mitigated these impacts.

These are specific ways in which NEXT fails to meet the standard for addressing and mitigating impacts upon the area.

Effective drainage is vitally important to farms and farmers at Port Westward. Disrupted drainage could impact people in the area, not just the site itself. NEXT states that its culverts "will be sized during final design when more information about the wetland drainage conditions becomes available." At the same time, NEXT proposes culvert sizes that will be insufficient.

- The 36" diameter culvert in waterway D is insufficient. 48" required.
- The 36" diameter culvert in waterway F is insufficient. 48" required.
- The BDIC reserves the right to require field fit modification to ensure all culverts are placed at correct depth to prevent flow restriction.

NEXT fails to address impacts to the BDIC from interference with access to the drainage systems caused by the proposed modification, the rail yard, gravel road, fencing, and buffers. The BDIC operates a public drainage system, attached to private improvements. The drainage and irrigation provided are highly important to people in the BDIC. Specifically,

- Sediment fencing along waterways is to be removed following construction to ensure access to waterways for maintenance.
- Proposed tree buffers along waterways are on ditch banks and will contribute debris, creating blockages. Additionally, they will restrict maintenance capabilities of the BDIC and thus will not be approved by the BDIC.

- Proposed fencing along waterways could impact BDIC ability to maintain waterways. Additional information needed for review.

NEXT will have additional impacts to the BDIC and people within the BDIC that are not adequately addressed in the application for the modification.

- The soils at the proposed rail yard and facility sites are at high risk of liquefaction in an earthquake. Spill containment plans for the facility and rail yard must be approved by the BDIC prior to any County approval of this proposal.

- No ditch or waterway alterations have been approved by the BDIC Board. Without specific agreements with the BDIC, NEXT cannot claim to have addressed impacts to the BDIC, its resources, or its operations. Further, the BDIC's activities are a recognized land use in the area that is vital to the overall function of the Port Westward area, including the industrial areas. NEXT fails to adequately address conflicts with BDIC's use of the area, its control of the land, and the public services it provides.

- The application provides no provisions for existing irrigation points on waterway G. Interference with irrigation from this waterway and potential pollution of the water resources will impact and harm local farming.

- The application provides no provisions for existing power to be relocated at the Hermo Rd intersection. The power supply in this specific location supports local agriculture.

- No engineering analysis of drainage and irrigation impacts has been presented to the BDIC Board for approval. The BDIC cannot agree to major alterations of BDIC infrastructure without a more in-depth description of the proposed impacts. NEXT cannot claim to have mitigated the impacts without an agreement with the BDIC. The application is premature.

- No engineering impact analysis or compatibility analysis has been performed for the current proposal. Prior submissions for county and BDIC approval are inadequate as location of rail yard has changed, thus impacts have changed. NEXT cannot rely on previous analyses to make conclusions about the impacts in the area. The previous proposals and the current amendment are not the same in scope or intensity with respect to impacts on farmers within the BDIC.

- Increased rail and heavy truck traffic could have impacts on the levee crossing including increased subsidence. This could require a USACE section 408 review. No Engineering analysis has been provided to the BDIC for review. Additionally, the BDIC reserves the right to restrict any and all levee traffic during periods of high water. Kallunki Road sits atop a levee that protects the entire area, including the proposed modification, from flooding.

- The BDIC has broad authority for maintenance of ditches/waterways within its boundaries. Restrictions in this authority, including ability to access for maintenance and alterations to maintenance activities must be approved by a ⅔ majority shareholder vote.

- The BDIC retains broad authority over the lands within its boundaries and approval from the BDIC is required for alterations or impacts to the systems. The BDIC has not approved the offsite wetlands mitigation plans required under state and federal law(1536(B)). Restrictions in the ability of the BDIC to perform maintenance must be approved by a ⅔ majority shareholder vote. Failure to obtain these approvals will result in violation of 1536(B).

- The levee system protecting the Port Westward Development site has not been certified for well over a decade. USACE defines the BDIC levee system as being “Previously certified, but not currently certified”. FEMA inspections in 2014 determined that the BDIC Levee system was 3ft height deficient and required so much work to protect from a 100 year flood that “further analysis for certification at this time is pointless”. Additional significant subsidence has since been noted on both the Erickson Dike Road and Kallunki Road levees. Subsequent construction of a wetlands mitigation site near the Port Westward docks in 2016(completed without BDIC approval) introduced “over 800 ft of clear, active seepage” and has been noted as active several times in recent USACE Periodic Inspections, resulting in Unacceptable ratings on the levee system. It is unknown at this point when the levee system will be certified. The Port Westward Development Exception heavily relies on a certified levee system as a condition of approval(1536(A) Standards for approval, CCZO 1100). Next is using outdated information to justify a FEMA flood zone X and has not met the standards required by CCZO 1100. The Port Westward Development Site, including the proposed driveway, pipe rack, railyard and associated plant site has been, is currently, and will for the foreseeable future, remain at risk of a 1% annual chance of flooding and therefore falls within the Special Flood Hazard Area.

Sincerely,

Beaver Drainage Improvement Company Board of Directors

Exhibit List 191

Study finds juvenile coho salmon at risk from deadly tire chemical

Juvenile coho salmon. Photo: Conrad/Adobe Stock

KEYWORDS: CONTAMINANTS OF EMERGING CONCERN, SALISH SEA CURRENTS MAGAZINE, SALMONIDS, TIRES AND TOXICS (6PPDQ), TOXIC CONTAMINANTS, ONCORHYNCHUS KISUTCH

By Jeff Rice

Published January 12, 2026

Exhibit List 192

Untold numbers of hatchery fish may be dying from exposure to tire-contaminated runoff, according to a new study.

When it was first identified in 2020, the deadly tire chemical 6PPD-quinone (6PPD-Q) was seen mostly as a threat to adult coho salmon. Fish returning in the fall were found disoriented and gasping shortly after entering creeks that had even trace amounts of the chemical. In some cases, as many as 90 percent of those fish died before they could spawn, a problem that continues to threaten some local populations with extinction.

For the first time, a new study reveals that 6PPD-Q may be just as harmful to juvenile coho as adults. The findings suggest a year-round hazard for already stressed wild populations and raises big questions about the viability of coho coming out of hatcheries, where hundreds of thousands — perhaps millions — of fish may become poisoned and die before they can reach adulthood.

The paper, published this week in the journal *Environmental Science & Technology*, describes results from a study at Miller Creek, a small stream flowing into Puget Sound south of Seattle. Earlier laboratory results had shown that 6PPD-Q was toxic to juvenile cohos, but this is the first time that scientists have been able to gauge the extent of the impact among juveniles in the wild.

“This allowed us to demonstrate that the streams receiving that runoff are absolutely killing juveniles,” said Jenifer McIntyre, director of the Aquatic Toxicology Lab at Washington State University, one of the paper’s co-authors and a leader of the study. Collaborators on the study included researchers at the University of Washington Center for Urban Waters, Washington State University, and the U.S. Geological Survey.

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Scientists tested the fish over the course of three spring storms that carried runoff containing 6PPD-Q into Miller Creek. Each time, about 80 percent of the fish exposed to the creek water died. Fish were placed in the water as it flowed, simulating the kind of conditions that coho would experience naturally in the stream.

“We were surprised that it was that consistent, but that was the outcome,” said McIntyre. “The fish were dying in about six hours.”

If those numbers are typical, the authors say, it could mean the early deaths of tens of thousands — or in some cases hundreds of thousands — of hatchery-raised coho in small creeks around Puget Sound each year. Citing Miller Creek as an example, the paper reports that “from 1981 to 2024, between 24,000 and 240,000 hatchery-spawned coho salmon fry were annually released to Miller Creek in early winter to aid in salmon conservation.”

The implications statewide would be much broader. “For context,” the authors wrote, “from 2019-2023, combined state, federal and tribal hatcheries released an average of 26 million coho salmon annually in Washington State alone.”

Wild coho would presumably also be hard hit in these same systems, but the studies have so far focused on hatchery fish which were more readily available for the study. Not all streams are as impacted by 6PPD-Q as Miller Creek, the authors noted, but coho are often found in small streams where water quality is most impacted by roads.

“Miller Creek looks like other systems that are in the same land use area,” said McIntyre. “Miller Creek looks like Des Moines Creek looks like Fauntleroy Creek looks like Thornton Creek. So, we feel that Miller Creek is completely representative of these same types of streams, which coho favor.”

Now known as one of the deadliest chemicals ever found in an aquatic environment, 6PPD-Q was first identified at the Center for Urban Waters at the University of Washington Tacoma. *[The Puget Sound Institute is a Center for Urban Waters affiliate.]* Scientists there discovered that 6PPD-Q is a derivative of the tire preservative 6PPD, which becomes more deadly after exposure to ozone — a compound readily found in the roadway environment.

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A preservative in vehicle tires that keeps them from breaking down too quickly, known as 6PPD, reacts with ozone and transforms into multiple chemicals, including 6PPDQ—the toxic chemical researchers found is responsible for killing coho salmon. Photo: Mark Stone/University of Washington

That work, based on earlier research by scientists at WSU, NOAA and other organizations, resulted in a landmark paper that has set off studies across the world. Coho are especially susceptible to 6PPD-Q, but other species such as coastal cutthroat trout and steelhead are also considered vulnerable, and scientists continue to raise questions about impacts on other species including humans.

While early studies of 6PPD-Q focused on spawning adult coho, some scientists began wondering immediately if juveniles were also affected. But understanding those impacts in the environment proved difficult, according to paper co-author Ed Kolodziej of the University of Washington, who led the team that first identified 6PPD-Q.

Deaths of juvenile salmon in the field are notoriously hard to confirm. Coho do not float when they die, and they are naturally camouflaged, making them easy to get lost in the sediment and debris at the bottom of the creek. Plus, other animals eat them quickly.

“When they die, the water is high; it’s muddy,” said Kolodziej. “They get washed in the leaves and under logs. We had all these conversations — would we even know if you saw juveniles die?”

To get around this problem, the scientists set up a lab near the creek where fish from a nearby hatchery were exposed to creek water while control groups were exposed to uncontaminated water. Studies of

Exhibit List 195

"environmental" DNA collected from the water, called eDNA, also showed the presence of fish throughout the creek. The scientists say the next phase of their work will look at how resident fish, including wild coho, handle exposure to 6PPD-Q.

In the meantime, the published study raises questions about current coho recovery efforts, including the management of hatchery fish, the authors say. Could hatcheries adjust the location and timing of their releases to minimize the impacts from 6PPD-Q? Hatchery coho are often released in the spring, when waters are high due to spring rains. That is thought to help protect the fish from predators but is also a time when 6PPD-Q is most prevalent in the creeks due to spring runoff.

"We think if they're there and it rains, they're potentially at risk," Kolodziej said. "I think there's a resource question around making sure water quality is suitable for hatchery augmentation efforts."

Researchers have also looked at ways to filter and potentially minimize the amount of 6PPD-Q entering streams, something especially critical for wild coho that reproduce there naturally.

Ultimately, scientists argue, the best approach is to find a replacement for 6PPD itself.

"We still have to deal with the water quality problem," McIntyre said. "Our results help explain what is going on, but they don't allow us to prevent the problem unless we are willing to do the hard work of making sure the chemical is not getting into the water."

This year, legislation to ban 6PPD in Washington has been proposed, and tire companies are facing pressure in the form of lawsuits to find alternatives to the chemical, but those changes may not come quickly. Immediate questions remain about how to protect already imperiled coho stocks, including three populations in Washington, Oregon, and California listed as Threatened under the Endangered Species Act. As the paper shows, 6PPD-Q exposure is a much more serious problem than previously identified, affecting potentially all life stages of this species.

Paper citation:

Brown, M. L., Ivy, N., Gonzalez, M., Greer, J. B., Hansen, J. D., Kolodziej, E., & McIntyre, J. K. (2026). Roadway Runoff Induced Acute Mortality in

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Juvenile Coho Salmon During Spring Storm Events. *Environmental Science & Technology.*

Related Link

Scientists worldwide are immersed in studies of a deadly tire chemical

About the Author

Jeff Rice is the managing editor of the Encyclopedia of Puget Sound.



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Exhibit List 197

Ports for People

Marine decarbonization is the path forward.

The Problem

According to the Department of Environmental Quality, the Portland region faces elevated levels of numerous toxic pollutants. One of the highest-risk pollutants is diesel particulate matter (DPM), which is emitted largely from on-road and nonroad diesel engines such as marine sources.

Research by Portland State University has shown that practices like requiring Electrification of Commercial Marine Hoteling Power, such as California Air Resources Board (CARB) At Berth rule, would achieve significant reductions in modeled concentrations in the northwest industrial area of the Portland Metro region. The images below from PSU research demonstrates the reductions that could be achieved.

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Tons Per Year

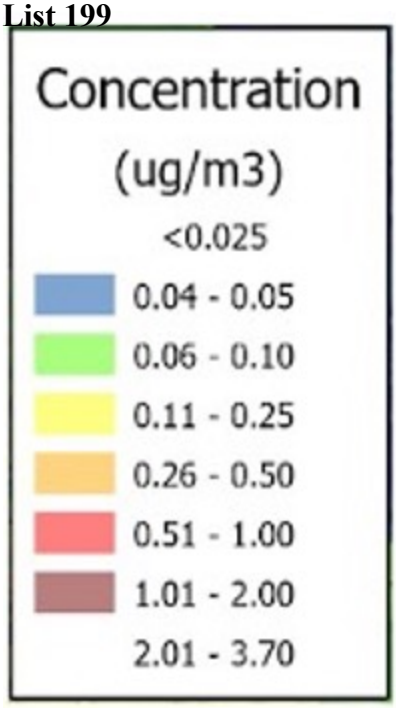
5%

Mobile Diesel Particulate Emissions

Emissions from diesel-powered mobile sources such as ships are a climate and public health threat. In Oregon, commercial marine vessels are responsible for 119 tons per year of diesel particulate emissions, representing 5 percent of mobile diesel particulate emissions in the state.

Changes in Diesel Particulate Matter concentration due to commercial electrification of ships of at berth.

Exhibit List 199



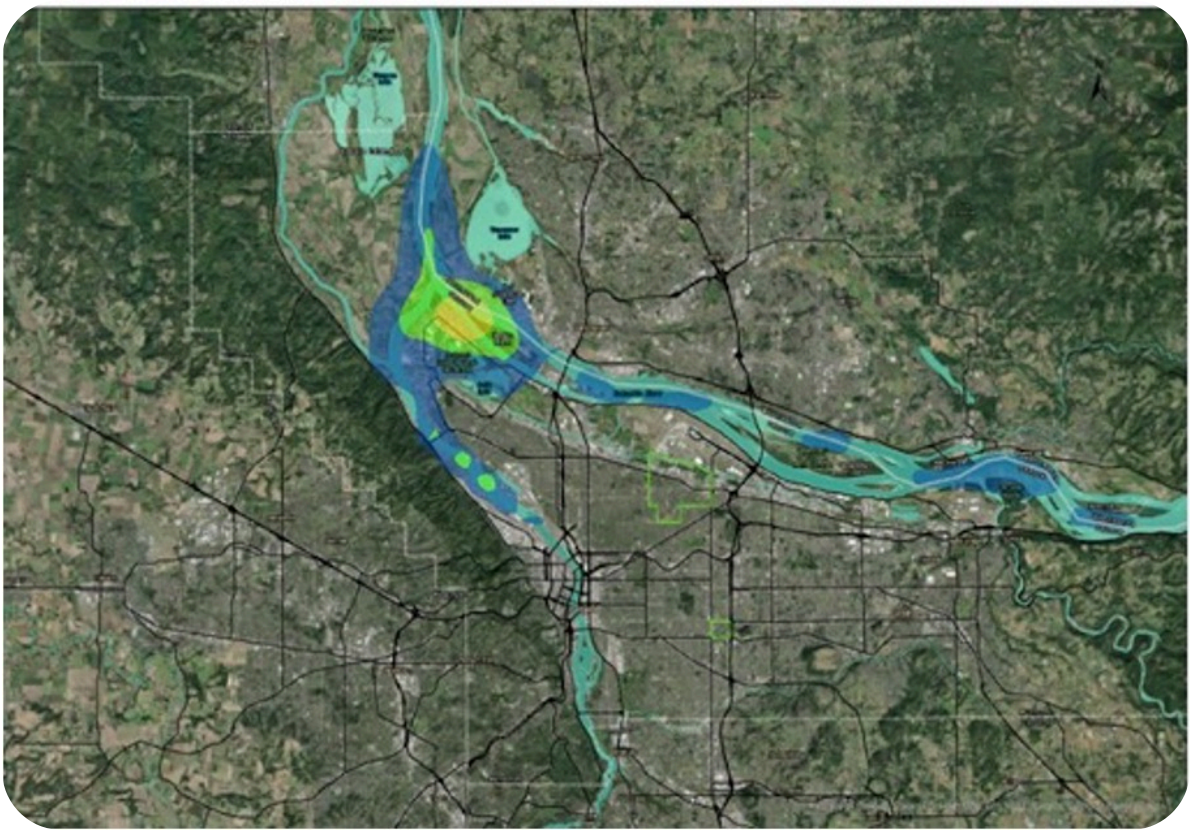


Exhibit List 200



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The Solution: Electrification At Berth

Oregon can reduce maritime pollution by adopting emission standards for vessels at berth, which ensures that the most polluting ships such as cargo vessels and cruise ships reduce in-port emissions such as by plugging into shore power and using electricity from the grid rather than dirty oil-based fuel. California and Washington are ahead of Oregon in adopting shore power, but before we can move forward, we need more information on maritime activity and vessel emissions in Oregon state, as well as opportunities to reduce emissions.

The Benefits of Electrification

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Pollution Reduction

According to a 2022 study from Portland State University, electrification of shore power while commercial marine vessels are hoteling at major ports along the Willamette and Columbia Rivers would reduce annual DPM emissions from 7.19 tons per year to 5.1 tons per year. This scenario would lead to a significant reduction in pollution in the northwest industrial area of the Portland metropolitan region, as well as in the Willamette River along the northern downtown area.

DONATE NOW

Exhibit List 203



Public Health Impacts

In California, where the At Berth Rule has already been adopted, the regulation is expected to save 237 lives, yield $2.31 billion in public health benefits, and reduce NOx emissions by 17,500 tons and carbon dioxide equivalent (CO2e) emissions by 356,000 metric tons between 2021 and 2032.

DONATE NOW

Exhibit List 204

LOCAL SPOTLIGHT

Vigor Industrial

Exhibit List 205

2016



Vigor signed a Good Neighbor agreement with many contingents, one of them being that all vessels at their Swan Island facility must plug into electric power within 36 hours of arriving at berth.

2,045

2,045 is the average number of metric tons of CO2 emissions reduced each month at Swan Island due to vessel shore power.

200,000+



An estimate of the total number of metric tons of CO2 emissions reduced at Swan Island since Vigor instituted vessel shore power in 2016.

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Despite needing more information before we adopt emission standards for ships at berth, Oregon does have a local success story with Vigor Industrial, located on Swan Island in Portland. In 2016, Vigor signed a Good Neighbor Agreement with the local neighborhood association and advocacy group Neighbors for Clean Air. Through the Good Neighbor Agreement, a key facet of Vigor's permit renewal is a requirement that all ships docked in their shipyard turn off their engines and plug into electric power within 36 hours of docking. This is a home-grown example of successful maritime electrification efforts.





Exhibit List 207

Next Steps

Learn More

Pursue a study bill in the Oregon legislature to gain a better understanding of current maritime activity and vessel emissions in the state. This information is essential to understanding marine and port vessel economic development contributions and related environmental and public health concerns statewide and among port communities and workers.

Establish At Berth Rules

Ensure state and port stakeholders incorporate vessel emission reduction strategies into their existing programs. This includes the Department of Environmental Quality's updated diesel strategy and the Port of Portland's climate and air quality planning grant from the U.S. EPA Clean Ports Program.

Stay Engaged

Interested in learning more about Oregon's Ports for People campaign and how you can get involved? Contact Mackenzie Springer at mackenzie@neighborsforcleanair.org.

Exhibit List 208



Designed + Developed: Bridgetown Marketing, LLC

PNNL-15400

Pacific Northwest
National Laboratory
Operated by Battelle for the
U.S. Department of Energy

A Study of Stranding of Juvenile Salmon by Ship Wakes Along the Lower Columbia River Using a Before-and-After Design: Before-Phase Results

W. H. Pearson
J. R. Skalski
K. L. Sobocinski
M. C. Miller
G. E. Johnson
G. D. Williams
J. A. Southard
R. A. Buchanan

February 2006

Prepared for
the U.S. Army Corps of Engineers, Portland District
Portland, Oregon
under a Related Services Agreement
with the U.S. Department of Energy
Contract DE-AC05-76RL01830

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Exhibit List 211

PNNL-15400

A Study of Stranding of Juvenile Salmon by Ship Wakes Along the Lower Columbia River Using a Before-and-After Design: Before-Phase Results

W. H. Pearson
J. R. Skalski[(a)]
K. L. Sobocinski
M. C. Miller
G. E. Johnson
G. D. Williams
J. A. Southard
R. A. Buchanan[(a)]

Marine Sciences Laboratory
Sequim, Washington

February 2006

Final Report

Prepared for
the U.S. Army Corps of Engineers, Portland District
Portland, Oregon
under a Related Services Agreement
with the U.S. Department of Energy
Contract DE-AC05-76RL01830

Pacific Northwest National Laboratory
Richland, Washington 99352

(a) University of Washington
Seattle, Washington

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Abstract

Ship wakes produced by deep-draft vessels transiting the lower Columbia River have been observed to cause stranding of juvenile salmon. Proposed deepening of the Columbia River navigation channel has raised concerns about the potential impact of the deepening project on juvenile salmon. The Portland District of the U.S. Army Corps of Engineers requested that the Pacific Northwest National Laboratory design and conduct a study to assess stranding impacts that may be associated with channel deepening. The basic study design was a multivariate analysis of covariance of field observations and measurements under a statistical design for a before-and-after impact comparison. We have summarized field activities and statistical analyses for the "before" component of the study here. Stranding occurred at all three sampling sites and during all three sampling seasons (summer 2004, winter 2005, and spring 2005), for a total of 46 stranding events during 126 observed vessel passages. The highest occurrence of stranding occurred at Barlow Point, Washington, where 53% of the observed events resulted in stranding. Other sites included Sauvie Island, Oregon (37%) and County Line Park, Washington (15%). To develop an appropriate impact assessment model that accounted for relevant covariates, regression analyses were conducted to determine the relationships between stranding probability and other factors. Nineteen independent variables were considered as potential factors affecting the incidence of juvenile salmon stranding, including tidal stage, tidal height, river flow, current velocity, ship type, ship direction, ship condition (loaded/unloaded), ship speed, ship size, and a proxy variable for ship kinetic energy. In addition to the ambient and ship characteristics listed above, site, season, and fish density were also considered. Although no single factor appears as the primary factor for stranding, statistical analyses of the covariates resulted in the following equations:

- Stranding Probability ~ Location + Kinetic Energy Proxy + Tidal Height + Salmonid Density + Kinetic energy proxy × Tidal Height + Tidal Height × Salmonid Density
- Stranding Probability ~ Location + Total Wave Distance + Salmonid Density Index
- Log(Total Wave Height) ~ Ship Block + Tidal Height + Location + Ship Speed
- Log(Total Wave Excursion Across the Beach) ~ Location + Kinetic Energy Proxy + Tidal Height

The above equations form the basis for a conceptual model of the factors leading to salmon stranding. The equations also form the basis for an approach for assessing impacts of dredging under the before/after study design.

Executive Summary

Ship wakes produced by deep-draft vessels transiting the lower Columbia River have been observed to cause stranding of juvenile salmon. Proposed deepening of the Columbia River navigation channel has raised concerns about the potential impact of the deepening project on juvenile salmon stranding. The Portland District of the U.S. Army Corps of Engineers requested that the Pacific Northwest National Laboratory design and conduct a study to assess stranding impacts that may be associated with channel deepening. The basic study design is a multivariate analysis of covariance of field observations and measurements under a statistical design for a before-and-after impact comparison. The report presented here is a summary of field activities and statistical analyses for the "before" component of the study.

Three previous studies have documented fish stranding caused by wakes from deep draft vessels along the Lower Columbia River (Bauersfeld 1977, Hinton and Emmett 1994, Ackerman 2002). The studies suggest that under certain conditions, deep-draft vessels (but not small vessels) can produce wakes that strand juvenile salmon. The factors that are thought to influence the occurrence of stranding include

- fish availability in the shallow nearshore zone along the beach
- nearshore ship-wake properties and wave run-up characteristics (wave height and period as well as direction, speed, and extent of wave draw-down and run-up on the beach)
- river elevation (river stage and tidal height)
- beach characteristics (slope, distance to navigation channel).

The overall goal of this study is to assess the impact of the channel-deepening project on juvenile salmon stranding along the Lower Columbia River. The specific question is whether the channel deepening project changes the risk that wakes of deep-draft vessels will increase stranding of juvenile salmon. The two objectives of the study are to

- assess the effect of channel deepening on the risk (probability) of juvenile salmon stranding with a before-and-after comparison
- determine the properties of ship wakes and resulting wave run-up generated by passing deep-draft vessels before and after channel deepening, and relate these properties to ship characteristics and shoreline conditions with factors analysis.

The basic design to assess stranding impacts is a multivariate analysis of covariance of field observations and measurements under a statistical design for a before-and-after impact comparison. The statistical analysis will test for the main effect of a period (i.e., "before" [2004 and 2005] channel deepening versus "after" channel deepening [estimated to be 2007]) after accounting for covariate effects (fish availability, wake characteristics, and other factors). Analysis of covariance will be used to assess period effects after adjusting pre- and post-periods to common conditions.

The work undertaken thus far included a planning phase (early 2004), a pilot study (spring 2004), and the "before" sampling (summer 2004, winter 2005, and spring 2005). Methods were largely developed during the pilot study, with additional modifications made during the first sampling period of the extended study.

Study sites for both the before and after phases are Barlow Point, Washington (Rive Mile [RM] 62), County Line Park, Washington (RM 51), and Sauvie Island, Oregon (RM 97). All beaches have a low slope (<5%) and are on the mainstem of the river. Substrate ranges from very fine sand (Barlow Point) to coarse sand (County Line Park).

We collected and analyzed data in four categories: site and ambient river characteristics, ship characteristics, wake characteristics, and fish characteristics (fish availability index and fish stranded). From the data, we developed 19 independent variables to be considered as potential factors affecting the incidence of juvenile salmon stranding, including tidal stage, tidal height, river flow, current velocity, ship type, ship direction, ship condition (loaded/unloaded), ship speed, ship size (length, beam, draft), and a proxy for ship kinetic energy. The proxy for kinetic energy was the ship block coefficient (length X beam X draft) multiplied by the square of the ship speed. A physics-based measure of kinetic energy is $KE = ½ mv^2$, where m = mass and v = velocity. Because we did not have a measurement for ship mass, we used a proxy variable related to displacement, which, in turn, is related to mass. In addition to the ambient and ship characteristics listed above, site, season, and fish density were also considered.

Stranding occurred at all sites and during all three sampling seasons (summer 2004, winter 2005, and spring 2005), for a total of 46 stranding events during 126 observed vessel passages. The highest occurrence of stranding occurred at Barlow Point, Washington, where 53% of the observed passages resulted in stranding. Stranding occurred with less frequency at Sauvie Island (37% of the observed passages resulted in stranding) and County Line Park (15% of the observed passages resulted in stranding). The sites were found to differ significantly in stranding occurrence, and there was no significant seasonal effect when site was accounted for.

Several ship types were observed, including car carriers, bulk carriers, tankers, and container ships. All of the observed passages used in the analysis of stranding were made by deep-draft vessels, as previous studies and field observations during the pilot study showed that other vessels produce small wakes. Ship and wake characteristics were evaluated to further understand how ship wakes are produced and interact with local bathymetry in the lower Columbia River.

The before-and-after comparison needed to account for covariates so that the comparison will not be confounded by changes in the covariates between the before and after phases. One covariate obvious during the design phase was fish availability, which received attention during design and dedicated sampling during the before-phase sampling. Other potential covariates were expected to be among the ambient conditions (e.g., tidal height, river flow) and among the ship and wake characteristics. However, precisely which of the several ambient conditions and ship and wake characteristics would be appropriate covariates was not evident during design or even the pilot-phase sampling.

Single-variable and multivariate regression analyses were used to discern which ambient conditions and ship or wake characteristics would be appropriate covariates. First, we examined the incidence of stranding events versus the ambient conditions and ship characteristics. Second, we examined the incidence of stranding events versus ambient conditions and wave characteristics. Third, we examined wave characteristics versus ambient conditions and ship characteristics. No single factor appears to be the cause for juvenile salmon stranding. Statistical analyses of the covariates resulted in the following multivariate equations:

- Stranding Probability ~ Location + Kinetic Energy Proxy + Tidal Height + Salmonid Density Index + Kinetic Energy Proxy × Tidal Height + Tidal Height × Salmonid Density Index.
- Stranding Probability ~ Location + Total Wave Excursion + Salmonid Density Index.
- Log(Wave Height) ~ Ship Block Coefficient + Tidal Height + Location + Ship Speed.
- Log(Wave Excursion) ~ Kinetic Energy Proxy + Tidal Height + Location

The covariates in the above equations are described below:

Stranding: probability that fish are stranded on a beach by a ship wake

Location: study site (Barlow Point, County Line Park, Sauvie Island)

Kinetic Energy Proxy: $KE' = [\text{Block Coefficient} \times (\text{Speed})^2]/1 \times 10^{-8}$

Tidal Height: predicted tidal height at the time of ship passage (from local tide chart)

Salmonid Density Index: salmonid (*Oncorhynchus* sp.) density in beach seine hauls; the Fish Availability Index for salmonds.

Total Wave Excursion: maximum distance across the beach of the draw-down and run-up of the onshore wave

Ship Block Coefficient: ship length x beam x draft, as provided by the Columbia River Pilots

Ship Speed: speed over ground in knots.

These equations indicate that location, a proxy for ship kinetic energy (which accounts for ship size and speed), tidal height, total wave excursion, and an index of salmon density along the beach are the primary factors in stranding occurrences. We have created a conceptual model to illustrate how these significant factors and interactions are linked together (Figure i).

Although the mechanisms of stranding are still not completely understood, the linkages in this model are all statistically significant, are consistent with what is known about biological and physical processes, and represent a substantial advance in our understanding of fish stranding by ship wakes. It is now clear that no single factor governs the process of stranding. Rather, a series of interlinked factors act together to produce stranding during a ship passage. The kinetic energy proxy derived from the size and speed of the vessel provides the energy producing the wake. Tidal height influences both the fish availability and the interaction of the wake with the beach at each site. Increasing total distance from draw-down to run-up is the wake characteristic that increases the probability of stranding. Increasing juvenile salmonid density in

the nearshore increases the probability of stranding and remains a significant factor even after the location is taken into account. The multivariate regression equations, the video observations of waves, and presence of stranding "hot spots" all indicate that fine-scale site characteristics at a specific location play a dominant role in structuring the processes that produce the onshore wave and subsequent fish stranding.

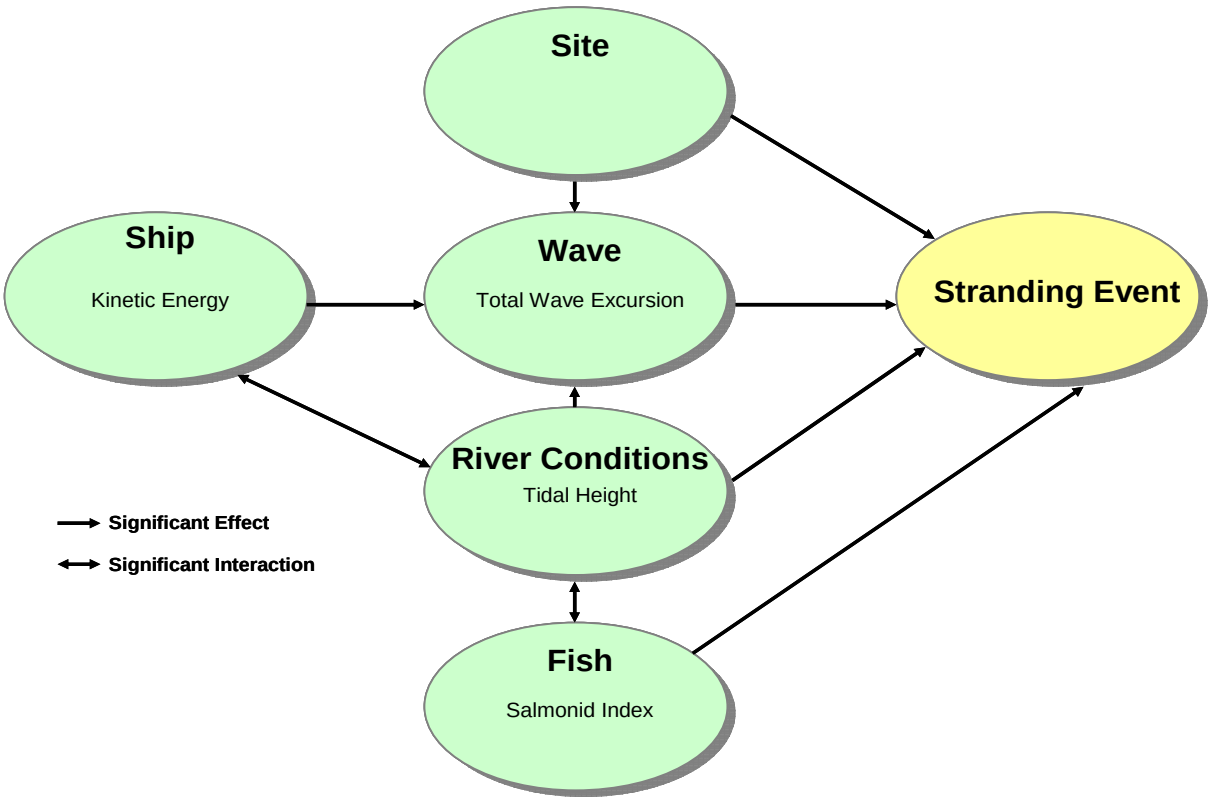


Figure i. Conceptual Model Illustrating Statistically Significant Factors and Linkages

The purpose of the before-and-after impact assessment is to determine whether the probability of juvenile salmon stranding will increase once the lower Columbia River is deepened ("post-dredging"). There are two questions to be examined:

1. For similar ambient river conditions, fish availability, and vessel conditions, does the probability of stranding relative to pre-deepening conditions increase after channel deepening?
2. If yes to the above question, then do the patterns of use by deeper-draft vessels change after deepening and, holding other factors equal, is greater probability of stranding associated with such changes compared with pre-deepening conditions?

The post-deepening impact assessment will examine both questions using the above multivariate regression equations derived from the pre-deepening data. For juvenile salmon stranding by ship wakes, we recommend the impact assessment decision process illustrated in Figure ii.

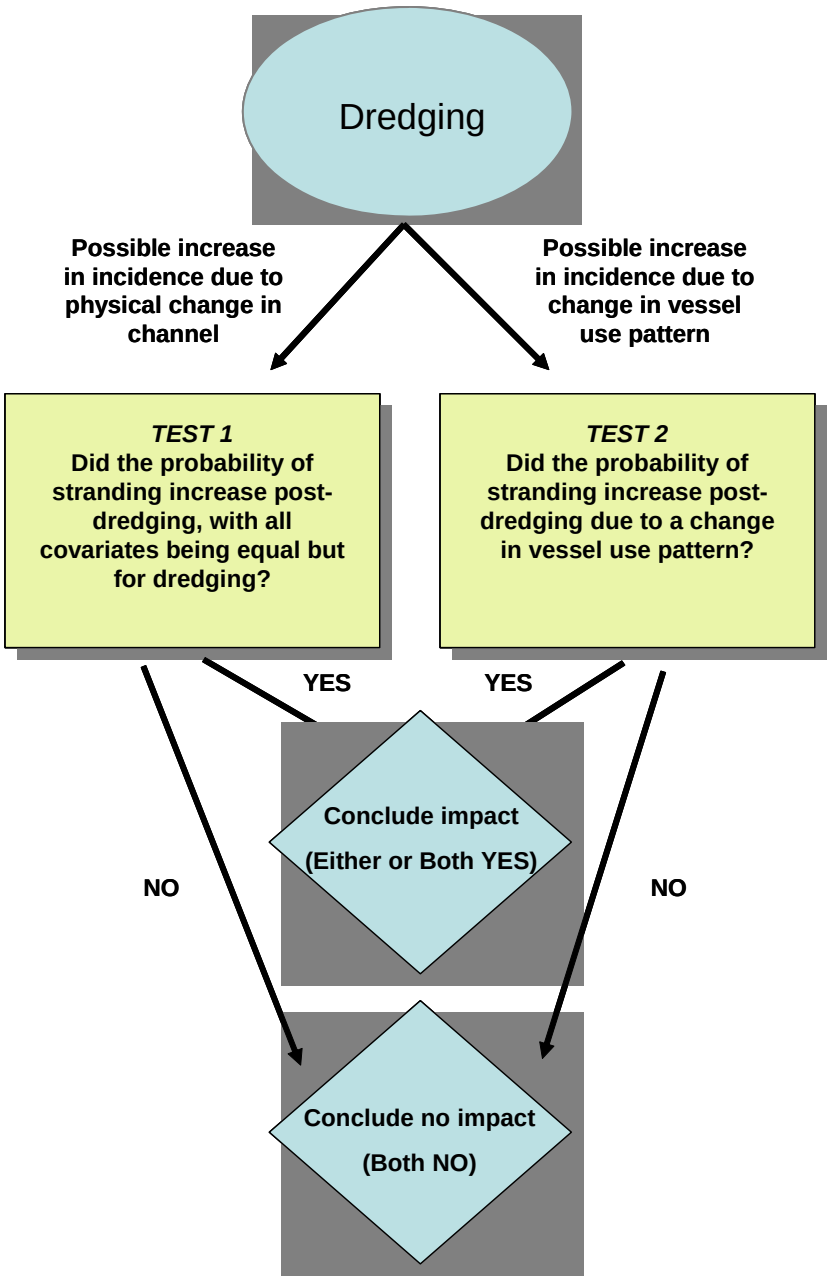


Figure ii. Schematic of the Decision Rules for Assessing Impact of Channel Deepening on the Incidence of Juvenile Salmon Stranding

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Exhibit List 220

Glossary

ANOVA	analysis of variance
BP	Barlow Point
CL	County Line
Corps	U.S. Army Corps of Engineers
CPU	central processing unit
CRP	Columbia River Pilots
CV	coefficient of variation
dGPS	differential global positioning system
DIDSON	Dual-frequency Identification Sonar
FAI	Fish Availability Index
Fd	Froude number
GPS	global positioning system
KE	kinetic energy
LCR	Lower Columbia River
MLLW	mean lower low water
NAVEFF	Navigation Effects model
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
PCA	principal component analysis
PNNL	Pacific Northwest National Laboratory
RM	river mile
SI	Sauvie Island
USGS	US Geological Survey

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1.0 Introduction

1.1 Background

Wakes and subsequent beach run-up (swash) from deep-draft vessels transiting the Lower Columbia River (LCR) have been observed to strand juvenile salmon and other fish (Bauersfeld 1977, Hinton and Emmett 1994, Ackerman 2002). Proposed deepening of the Columbia River navigation channel has raised concerns about the potential impact of the deepening project on juvenile salmon stranding. The Portland District of the U.S. Army Corps of Engineers (Corps) requested that the Pacific Northwest National Laboratory (PNNL) design and conduct a study to assess stranding impacts that may be associated with channel deepening. The basic study design calls for conducting a before-and-after comparison while taking into account several covariables in the biological and physical processes leading to stranding. Two sets of such covariables encompass fish availability and wake characteristics in the nearshore area of the study sites. A separate work plan (Pearson et al. 2004) was the outcome of the design phase of this stranding study and provides more detail on the study design, technical approaches, and statistical analyses. This document serves as a summary report of the "before" phase of the study by describing field activities and providing results from activities undertaken in 2004 and 2005.

The Corps maintains the Federal Navigation Channel in the Columbia River through operations and maintenance dredging. Currently, the navigation channel is maintained to a depth of 40 ft. The Corps has proposed improvements to the main navigation channel that include deepening the channel to 43 ft. A deeper channel would lessen existing depth constraints to vessel movement, thereby improving access to the ports of the LCR for deep-draft vessels.

As a result of formal consultation under Section 7 of the Endangered Species Act, the National Marine Fisheries Service (NMFS) issued a Biological Opinion on the Corps' Columbia River Channel Improvements Project in May 2002 (NMFS 2002). The conclusion of the Opinion was that "the proposed action is not likely to jeopardize the continued existence of the 13 ESA-listed species potentially affected by the Project, or result in the destruction or adverse modification of designated critical habitat." However, the Opinion included terms and conditions to be implemented by the Corps. One such term and condition in the Opinion called for a before-and-after study of stranding. Another stated that "the Corps shall minimize effects from stranding through the following actions." The one action applicable to this study is paraphrased below:

> *Develop and implement a stranding study to evaluate parameters that influence stranding. Potential factors include river cross-sectional area, velocity, water level, bank configuration, location along river, slope of bank, ship traffic past site, and type, size, draft, and speed of vessel.*

Three prior studies have documented fish stranding caused by wakes from deep-draft vessels along the LCR (Bauersfeld 1977, Hinton and Emmett 1994, Ackerman 2002). Each of these three studies is qualitative in some aspects of its approach, while at the same time providing new information that increases understanding of fish stranding and making recommendations for future research. The sum of

the three studies above suggests that under certain conditions, deep-draft vessels (but not small vessels) can produce wakes that strand juvenile salmon. The factors that influence the occurrence of stranding include the following:

- fish availability in the shallow nearshore zone along the beach
- nearshore ship-wake properties and wave run-up characteristics (wave height and period, as well as direction, speed, and extent of wave draw-down and run-up on the beach)
- river elevation (river stage and tidal height)
- beach characteristics (slope, distance to navigation channel).

Ship-wake properties are related to vessel size and speed and characteristics of the channel, prompting the need for comprehensive vessel and wake data collection. An analysis to compare pre-deepening stranding with post-deepening stranding needs to take into account fish availability along the beach, as well as the physical processes that result when ship wakes interact with gently sloping beaches. Thus, beach seining was proposed and used to provide an index of the availability of fish in the nearshore zone. To better characterize the factors that promote fish stranding, the present study measured vessel range and speed, the characteristics of waves resulting from vessel passage, and the extent of wave run-up on the beach. To better understand the wake properties, the study used the considerable body of theoretical and field research on the development of vessel wakes conducted by the Corps on the Upper Mississippi River-Illinois Waterway system. Measured wake and run-up data were used in conjunction with a physics-based numerical model, and field data were compared with model predictions to determine whether predictive models could be further developed specifically for use in other LCR reaches. Data collection was designed to support a statistical multivariate covariance analysis that will ultimately account for known confounding factors in comparing fish stranding before and after channel deepening.

1.2 Objectives

The overall goal of this study is to assess the impact of the channel-deepening project on juvenile salmon stranding along the LCR. The specific question is whether channel deepening changes the risk that wakes of deep-draft vessels will increase stranding of juvenile salmon. The two objectives of the study are to

1. assess the effect of channel deepening on the risk of juvenile salmon stranding with a before-and-after comparison
2. determine the properties of ship wakes and resulting wave run-up generated by passing deep-draft vessels before and after channel deepening, and relate these properties to ship characteristics and shoreline conditions with factors analysis.

Quantifying the total fish losses from stranding (loss determination) along the Columbia River cannot be supported by the statistical design proposed in the work plan (Pearson et al. 2004). Loss determination will require a substantially different statistical sampling design than the before-and-after comparison. The tasks outlined in the work plan provide information that will be useful in the design of a full loss determination. Also, loss determination should be conducted after channel deepening. Data collected before channel deepening may not be perceived as representative of post-deepening conditions.

1.3 Study Design and General Approach

The basic design to assess stranding impacts is a multivariate analysis of covariance of field observations and measurements under a statistical design for a before-and-after impact comparison. The statistical analysis will test for the main effect of a period (i.e., before [2004 and 2005] channel deepening versus after channel deepening [estimated 2007 or later]), after accounting for covariate effects (fish availability, wake characteristics, and other factors). Analysis of covariance will be used to assess period effects after adjusting pre- and post-periods to common conditions. Figure 1 illustrates the basis for the analysis under idealized conditions. Any difference in the amplitude of the regression lines after adjustment for covariate effects would be attributed to channel deepening effects. In practice, multivariate regression is used to assess treatment effects instead of the univariate regressions illustrated in Figure 1. A more complete discussion of the statistical modeling approach to assess impacts appears in Section 7.

The general approach to the fieldwork contains two interrelated elements. The first element consists of physical monitoring at beaches to measure and characterize vessel wakes during ship passage. This element is used to identify key parameters to characterize wakes, to compare these wake parameters pre- and post-channel deepening, and to provide covariates for the analysis of covariance. Ship-wake properties are measured with an electronic wave staff gage, and wave run-up is measured using a linear run-up gage designed and constructed by PNNL and video camera and video analysis software. Observations of ship characteristics also provide data to relate ship and wake properties. The second element is biological sampling. Beach seining is used to estimate fish presence and abundance and to provide covariates for comparing stranding between pre- and post-channel deepening. The biological sampling includes observations to provide a fish availability index (FAI). Together, these two elements provide the necessary data for statistical analysis to determine whether the channel deepening has, or has not, increased the risk of juvenile salmonid fish stranding in the LCR.

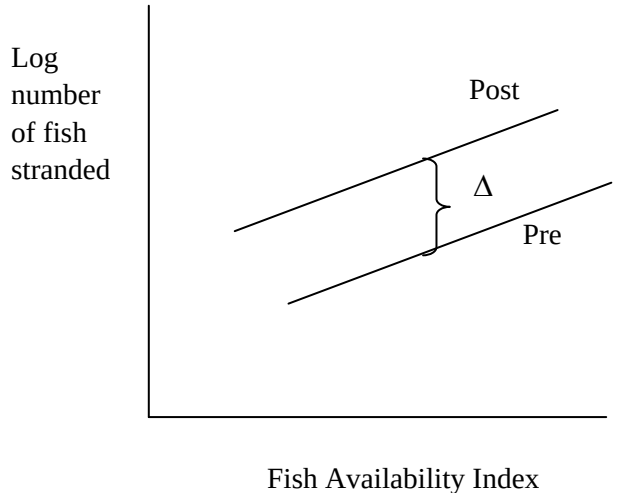


Figure 1. Profiles for Numbers of Fish Stranded as a Function of the Fish Availability Index and Pre- and Post-channel Dredging. Value of Δ is an estimate of the fractional increase in stranding due to direct and indirect effects of channel improvement.

The assessment of the effects of channel deepening on stranding of juvenile salmon will evaluate both physical and biological responses. Statistical analyses include regression analysis to relate ship wake run-up and other wake properties to ship characteristics and river elevation for both pre-deepening and post-deepening. Multivariate analysis of covariance is used to assess whether the risk of juvenile salmon stranding changes after deepening, adjusting for fish availability, run-up characteristics, and river elevation. Together, the assessments of the potential changes in physical and biological variables are used to infer the degree and extent of any changes due to channel deepening. If increased fish stranding is observed after channel deepening, it might be hypothesized that the extent of swash caused by ship wakes has also increased. Therefore, assessments of the changes in ship-wake properties and fish stranding before and after channel deepening provide supporting and confirmatory evidence if additional stranding occurs (see Section 7, Discussion).

1.4 Work Plan and Task Breakdown

The work plan (Pearson et al. 2004) presented to the Corps provided a task breakdown and proposed methods organized under four phases, described below.

1.4.1 Phase I. Design and Planning (January Through May 2004)

The objective of Phase I was to develop an appropriate statistical design and sampling scheme for "before and after" field studies. Three sites were selected where stranding was known to occur—a characteristic necessary to before-and-after comparison (see Section 2, Study Sites). The product of Phase I was a written plan for the fieldwork and data analysis (submitted January 2004).

1.4.2 Phase II. Pilot Study, Including Preliminary Testing of Prototype Run-up Gage and DIDSON Acoustic Camera (March Through June 2004)

Field deployments of various technologies proposed for the study were needed to validate equipment and refine methods. Development of the work plan led to the conclusion that a Dual-frequency Identification Sonar (DIDSON) acoustic camera might provide a less intrusive sampling method to capture fish availability. As part of Phase II, the DIDSON was evaluated along with other acoustic technologies. Additionally, the measurement of wave run-up or swash required instrumentation that needed to be tailored to riverine environments; this equipment was field-tested during this phase.

1.4.3 Phase III. Extended Field Sampling Pre-Channel Deepening (June 2004 Through May 2005)

We monitored three fixed sites (Sauvie Island, Oregon, and Barlow Point and County Line Park, Washington) (Section 2, Study Sites) during each of three outmigration periods (winter, spring, and summer). This work was initiated in summer 2004 (June through September) during the summer outmigration period and continued through May of 2005 (February and March for the winter sampling period, and April and May for the spring period). The basic unit of observation was the passage of an individual deep-draft vessel by a study beach and the subsequent number of fish stranded. Also, wake characteristics and fish availability were measured.

1.4.4 Phase IV. Extended Field Sampling Post-Channel Deepening (Estimated at 2007 or After)

Eventually, nearshore ship-wake properties and stranding will be measured over three outmigration periods, at all three sites, and comparisons between pre- and post-deepening will be made. Phase IV work is scheduled to commence in 2007, after channel deepening.

Phases I and II were completed and Phase III was initiated during FY04. Phase II was competed in FY2005. The work plan was the output of Phase I, and this report provides the results relating to the activities in Phase II and Phase III. Essentially, this report summarizes the pre-deepening field sampling activities and results.

Exhibit List 236

2.0 Study Sites

In July 2003, as part of the planning process, approximately 12 potential study sites were considered and narrowed to 3 candidate sites, selected on the following basis:

- All sites are known to have previously had juvenile salmon stranding (for the before-and-after comparison, it is important to select sites where the events of interest are known to occur)
- All sites should have gently sloping beaches (previous work indicates this beach type is prone to stranding)
- All sites should be exposed to ship wakes from the navigation channel
- All sites should have evidence of fairly stable beach morphology.

Three candidate sites were visited in July 2003 by representatives from PNNL, the Corps, National Oceanic and Atmospheric Administration (NOAA) Fisheries, US Fish and Wildlife, the Port of Portland, the Washington Department of Fish and Wildlife, the Oregon Department of Fish and Wildlife, the Washington Department of Ecology, and the University of Washington to confirm the sites' suitability for the project. The three selected sites are the same LCR sites studied by Ackerman (2002) (Figure 2). Photographs of the sites appear in Appendix A.

As part of the field sampling, we collected data on beach slope, sediment grain-size composition, and infiltration rates at each beach to characterize beach structure (Table 1). Using a tripod, stadia rod, and range finder capable of calculating percentage of slope, we measured beach slope along a reference line at each site during each sampling period (Section 4.2, Materials and Methods, provides a complete discussion of site layout). We measured the relative infiltration rate of each site using a 0.5-m long, 10-cm diameter PVC pipe, driven 10-cm into the sediment and gradually filled with 4.5 gal of water at each of three locations per site. We recorded the time of infiltration for the known quantity of water, as it drained completely through the sediment at the base of the pipe. We performed this procedure at approximately the same elevation at each location, and approximated the midwater tide level at each site. In addition, we collected sediment grain-size samples from each site during each sampling period (composite samples of ~90 g at each site from low, medium, and high tide marks at each of three locations at the site). Samples were stored on ice and shipped within 5-days of collection for analysis. Particle size determinations were made by Columbia Analytical Services following standard Puget Sound Estuary Program protocols (Table 2.)

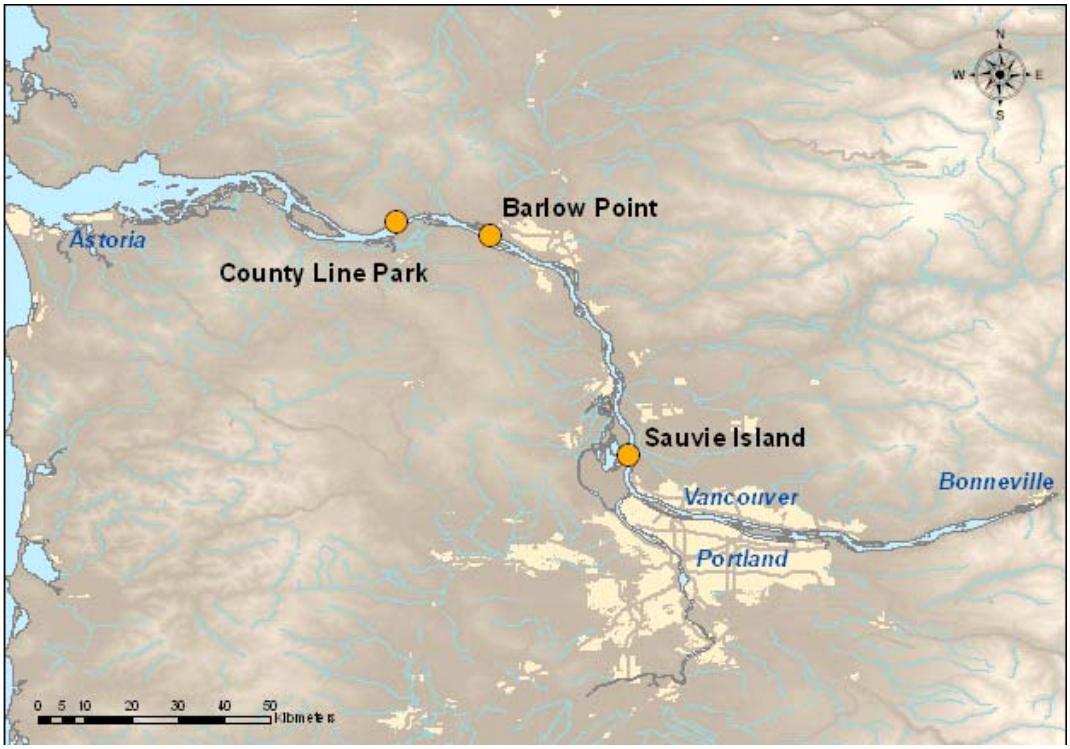


Figure 2. Study Site Locations, Including 1) Sauvie Island, 2) Barlow Point, and 3) County Line Park

Table 1. Physical Characteristics of the Three Study Sites: Sauvie Island, County Line Park, and Barlow Point

Site	River Mile	Tidal Datum	Average Infiltration Rate (l/m)	Season	Beach Slope (%)
Barlow Point	62	Longview, WA	0.11	Summer Winter Spring	2.3 2.1 2.2
County Line Park	51	Eagle Cliff, WA	2.45	Summer Winter Spring	4.1 4.1 3.9
Sauvie Island	97	St. Helens, OR	0.94	Summer Winter Spring	2.6 2.1 2.8

Table 2. Grain Size Analysis From the Three Sampling Sites During the Three Sampling Periods

Site	Season	Gravel	Very Coarse Sand	Coarse Sand	Med. Sand	Fine Sand	Very Fine Sand	Silt	Clay
Barlow Point	Summer	0.02	0.14	1.23	4.82	44.16	38.63	8.75	0.35
	Winter	0.04	0.04	0.24	4.11	41.83	45.30	6.60	0.05
	Spring	0.00	0.03	0.29	6.63	47.38	40.17	5.55	0.13
County Line Park	Summer	4.86	13.02	48.10	24.33	5.59	2.9	0.57	0.07
	Winter	0.73	5.98	54.57	32.00	4.95	1.25	0.12	0.02
	Spring	2.15	5.63	51.95	33.55	5.60	1.72	0.28	0.02
Sauvie Island	Summer	2.55	8.42	16.52	44.20	22.10	3.77	1.43	0.1
	Winter	0.78	3.08	11.64	47.97	30.20	4.53	0.55	0.01
	Spring	0.26	0.73	3.84	47.60	39.90	6.08	1.53	0.14

Note: Categories with the highest proportions are underlined.

2.1 County Line Park, Washington (RM 51)

The site is near the boundary between Wahkiakum and Cowlitz Counties on the north (Washington) side of the river. The survey reach extends 200 m east of the parking area at County Line Park. The beach is backed by riprap which protects State Route 4 and, at the downstream end, the County Line Park camping area, from erosion (Figure A-1). The beach is the narrowest (from the ordinary water line to the rip-rapped and vegetated backshore) of the three in the study. Additionally, the channel deepens very quickly at this site, producing stronger nearshore currents than at the other sites. Much of the beach is covered by debris that has sloughed off the rip-rap. County Line Park has the steepest beach slope (~4.0%), fastest water infiltration rate (Table 1), and coarsest sediment, with over 90% of the sediment collected composed of medium sand or larger particle sizes (Table 2). Tidal elevations were calculated from the Eagle Cliff datum; County Line Park, being the furthest downstream of the sampling sites, also has the largest tidal amplitude, with a mean range of 1.4 m (4.5 ft).

2.2 Barlow Point, Washington (RM 62)

This site is located on the north (Washington) side of the river. The survey reach is over 300 m long (Figures A-2 and A-3). At low tide, the expansive shore (over 100 m from the waterline to the backshore) is covered with rippled bedding characteristic of tidal flats (Figure A-4). This beach is the widest and most gradually sloping of the study beaches. The upper part of the beach on the upstream end is protected from erosion by a gabion structure referred to as "Reno Mat." The mat is wetted at high tide (Figure A-3) and redirects wave energy so that it travels laterally along the mat, generally in the downstream direction. At the downstream end of the beach, patches of vegetation (likely *Carex* sp.) occur at mid-tide level. Barlow Point has the most gradual beach slope (~2.2%), slowest water infiltration rate (Table 1), and finest average sediment grain size (Table 2). Over 90% the sediment collected from Barlow Point was

composed of fine sand or smaller particle sizes. Tidal elevations were determined from the Longview, Washington, datum; Barlow Point has a mean tidal range of 1 m (3.3 ft).

2.3 Sauvie Island, Oregon (RM 97)

This site is located on the Oregon side of the river. The survey reach is ~300 m long. Some vegetation (shrub alder and grasses) is emergent on the beach face and is located ~75 m landward of the ordinary water line (Figure A-5). The reach is terminated at each end by an erosional bank and narrower beach face (Figure A-6). Sauvie Island's physical characteristics were intermediate between Barlow Point and Country Line Park with respect to beach slope (~2.5%), infiltration rate (Table 1), and sediment grain size (Table 2). Tidal elevations were determined from the St. Helens tidal datum, located downstream of the site; the mean tide range at St. Helens, is 0.6 m (2.0 ft).

3.0 Pilot Study

3.1 Introduction

Pilot field studies conducted at a single survey site (Sauvie Island) on the Columbia River during March 24–26, April 1, and April 21–22, 2004, evaluated the field sampling protocols and statistical design proposed in Phase I and detailed in Phase III. Many aspects of the extended field-sampling plan (Phases III and IV) were tested during the day and night, including run-up gage measurements, wave-sensor measurements, vessel characterization, monitoring of fish-stranding events, and development of the best technique for FAI measurements. The available literature related to wake generation in navigational channels was reviewed and used to guide the placement of the instrumentation.

3.2 Fish Availability Index

The statistical design for the before-and-after comparison uses the FAI in the nearshore area of a site to prevent the comparison from being confounded by changes in fish availability with time. Bauersfeld (1977) and Hinton and Emmett (1994) conducted beach seining to assess nearshore fish availability, and Ackerman (2002) recommended beach seining to assess fish availability in future stranding studies. It was recognized that beach seining is an intrusive sampling method and may itself confound stranding observations that closely follow seining activities.

In developing the work plan, it became clear that a less intrusive alternative to seining could be of advantage and that the use of the DIDSON acoustic camera might provide that alternative. The DIDSON has been used successfully in other fishery applications, including the identity, abundance, and behavior of juvenile salmon and their potential predators at a Washington State ferry terminal (Williams et al. 2003). The DIDSON camera, developed by engineers at the University of Washington Applied Physics Laboratory (http://www.apl.washington.edu/ programs/DIDSON/DIDSON.html), uses multi-channel acoustic reflections, rather than light, to create images of fish and other objects. The DIDSON can capture near-video-quality images, regardless of visibility. Therefore, the camera is especially useful at night and in turbid water. The pilot study included trials with the DIDSON camera to assess its potential effectiveness before undertaking the full study.

The results of the pilot study trials with the beach seine, acoustic camera, and split beam hydroacoustics did not lead us to recommend acoustic technology for this shallow-water application. The extremely shallow water of the study site caused difficulties with target recognition for the DIDSON camera. In response, we tried a narrow split-beam transducer, but this acoustic device also did not provide acceptable results. Limitations with push nets and snorkeling did not lead us to recommend those two techniques, either. Push nets do not sample larger fish or demersal fish in the water column. Snorkeling will not provide consistent observations in shallow, turbid water.

We recommended beach seining as the most practical basis for the FAI. Beach seining at the downstream end of the stranding survey area will be done to minimize disruption of the stranding data, because the fish of interest are more likely to be moving downstream than moving upstream (Figure 3).

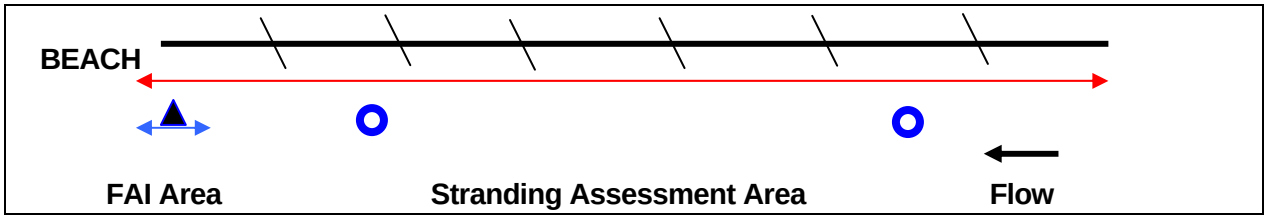


Figure 3. Schematic of FAI Relative to Flow and Stranding Assessment Area. The triangle represents the main seining site and the circles are supplemental seining sites, corresponding to fish stranding "hot spots."

Sampling for the FAI at the beginning, middle, and end of a study day is necessary because we probably will not know the vessel passage schedule precisely enough to do it before each passage event. Finally, spreading the three seine sets over the day rather than concentrating them at one time of the day increases the accuracy of the FAI for the same cost. In addition, we proposed to collect two more seine samples along the stranding assessment area at the end of a study day. These supplemental samples are to be chosen based on known fish stranding locales (stranding "hot spots"). They will provide additional data for the FAI and enable us to address the assumption that fish index data from seining at the designated location at the downstream end of the stranding assessment area is representative or proportional to the whole stranding assessment area.

Abundance data from beach-seining efforts will be used to estimate the FAI. Size information gathered from onshore stranding observations and seining efforts will indicate any differences in length between stranded fish and fish captured offshore of the beach. Information from seining efforts will also allow comparison of the ratio of wild to hatchery fish of the nearshore population with the ratio of those that are stranded, as well as the relative proportion of a given species in both the seined and stranded populations.

3.3 Fish-Stranding Measurements

During the pilot study, procedures for determining the number of fish stranded were tested. A strip-transect sampling technique was initially recommended. However, field crews were capable of covering 100% of the beach, from high water mark to standing water mark, after a vessel passed, and therefore, a full beach survey was recommended.

In general, stranding surveys of the beach are conducted upon arrival at the site and immediately following vessel passage and cessation of the wake impingement on shore. The start and end times for each survey are recorded. When fish are found, they are identified to species, salmonids are classified as native or hatchery stock (as determined by adipose fin clips), and length is measured. Live fish are placed in a bucket of river water for holding prior to being measured and released downstream. Dead fish are removed from the beach.

3.4 Wake Properties

The wake-waves generated by a ship making headway in a channel are of several types. The short-period waves generated at the bow of the vessel, along with the transverse stern wave, are developed as a result of the near-normal pressure distribution along the hull. The bow wave is formed as the water is accelerated along the flared portion of the bow and elevates the surface above the still-water level. Along the sides of the vessel, the accelerated water is lowered in accordance with Bernoulli's principle, which requires that pressure decrease as velocity increases. The transverse stern wave is formed by the return pressure and separation at the stern of the vessel.

If the vessel is in a channel, long-period waves characterized as draw-down and the following run-up or surge wave may also develop. These waves are observed if the draft of the vessel is greater than about half of the channel depth and a considerable portion of the water in the channel is displaced as the vessel proceeds. A large volume of water is pushed up at the bow of the vessel with an exaggerated lowering of water level along the sides (Figure A-7). The wave travels along the shoreline at the speed of the ship and may provide a significant lowering of the water followed by an up-rush. Depending on the slope of the channel flanks, the draw-down and run-up may affect a large portion of the shore perpendicular to the waterline.

Wave run-up has been measured on marine beaches with linear arrays of capacitance sensors that are triggered by high-salinity seawater. However, capacitance sensors are problematic in low-salinity riverine environments. PNNL developed an in-house prototype wave run-up gage, which is intended to measure three parameters: 1) the extent of wave run-up across the beach face, 2) the speed of run-up, and 3) the rate at which the wave withdraws or falls as the water sinks into the sediment. The device consists of a rigid horizontal frame to which floats are attached at 0.3-m (1-ft) intervals (Figure A-8). The run-up gage is laid across the beach face, perpendicular to the beach, and just above the beach surface. As the run-up wave lifts each float, the movement activates a series of reed switches (Figure A-9). A data logger records the events. The device is assembled in 3.1-m (10-ft) sections to cover a portion of the beach at a sampling site. Field trials at beaches near the PNNL Marine Sciences Laboratory examined the mechanical operation of an approximate 3.1-m (10-ft) section and the effectiveness of the data logger in recording the run-up characteristics. The field trials in March indicated that better anchoring for the run-up gage was needed. Improved anchoring was used in subsequent field work. The run-up gage was scaled up to cover a distance of ~30.5 m (100 ft) for the extended field sampling. Part of the device was deployed below the water line to measure the horizontal distance over which both draw-down and run-up occur.

Additionally, commercially available wave staffs from Ocean Sensor Systems were used to measure wave height and changes in water elevation along the shoreline (http://www.oceansensorsystems.com). We deployed two 3-m long staffs (Figure A-10, far right). These staffs are fast, capacitive-type water-level sensors. They operate from 5.5 volts to 40 volts, and output to the RS232 serial port on a laptop PC. We used the interface software provided by Ocean Sensor Systems.

3.5 Analysis and Modeling

The pilot study included analysis and modeling of wake properties generated by deep-draft vessels. The short- and long-period ship-generated waves on the LCR were evaluated using empirically developed relationships available in the engineering literature. The short-period waves from passing vessels, commonly observed as wake, were estimated using the method of Kriebel et al. (2003). The authors evaluated laboratory and field data of waves generated by a variety of ship types and sailing conditions and developed relationships that were shown to be superior to those previously available in the literature. The draw-down and subsequent run-up generated by large displacement ships in confined navigation channels were estimated using empirical relationships developed by Maynord (1996, 2003) for the upper Mississippi River and the Sabine-Neches Waterway. During the pilot study, qualitative observations revealed that the draw-down, run-up, and wakes generated by large ships passing the Willow Bar site on Sauvie Island were dramatic and were judged to be of the order of magnitude predicted by the models.

Because the ship-wave estimation methods depend on empirical data, they should not be used outside of the range of conditions over which they were developed without confirmation. If the field studies provide sufficient confirmation of the methods, they may be used to estimate generated vessel waves for other known ships transiting the LCR. The following steps are being taken to confirm the wave estimation procedures before they are used to predict wakes on the LCR:

1. Measure ship-generated waves using one or more wave staffs at the Sauvie Island, Barlow Point, and County Line Park study sites

   Measurements were made during the field work in Phase III for as many ship passages as possible. Other parameters of interest are beach slope, sediment characteristics, river current, river stage, tidal elevation, water depth, channel cross-section, ship speed and other ship characteristics (length, draft, displacement, hull shape, entry length) as available.

2. Measure the resulting draw-down and run-up from the ship passage

   We used measured or reported vessel characteristics and speed, as well as empirical data collected from passing vessels to calculate wave characteristics. We will compare the measured short- and long-period waves with those predicted from the Kriebel et al (2003) and Maynord (1996, 2003) methods.

We collected the following information on ship-wake properties and wave run-up for vessels passing during the survey:

- extent of beach run-up and draw-down (run-up gage)
- nearshore ship wake period (wave sensor)
- nearshore ship wake height (wave sensor)

- river stage: Flow stage information, both volume and current, for the river below the confluence with the Willamette River (USGS Beaver Army Terminal Gaging Station, RM 53.8) was obtained from the US Geological Survey (USGS) website: http://waterdata.usgs.gov
- tidal height: Tide predictions available through the "Tides and Currents" computer software program were used to estimate tide levels for the LCR.

Eventually, nearshore ship-wake properties and run-up will be measured at a variety of river stages (i.e., river elevations) over three outmigration periods, and comparisons between pre- and post-deepening at comparable river elevations will be made. Regression techniques will be used to characterize the relationship between wake properties, run-up, and river elevation and to assess whether channel deepening altered that relationship. The data collected from each vessel will be used to establish the wake-river elevation relationship. Nearshore wake properties will also be described as a function of vessel characteristics. The vessel characteristics found most helpful in predicting nearshore wake properties will be used as covariates in subsequent modeling efforts of fish-stranding numbers.

3.6 Pilot Study Recommendations for Data Collection During Extended Sampling

As mentioned previously, to account for the anticipated variability between fish-stranding events, several potential covariates will be measured for each vessel that passes, including vessel speed, draft, size, and direction of travel; nearshore wake properties, including wave height, period, direction, and resulting wave run-up; fish abundance; and river elevation. Water-quality parameters, including temperature, salinity, dissolved oxygen, and pH were also measured; water clarity (secchi depth) cannot be measured because of low light levels at night and the shallow depths where sampling occurs. A summary of the data collected during the 2004-2005 field sampling appears in Table 3.

Table 3. Summary of Data being Collected for the Extended Study of Stranding of Juvenile Salmon along the Lower Columbia River

Parameter	Collection Method/Source	Use of Data
Ship direction	Observation	Wake properties
Ship speed	Transit time over known distance	Wake properties
Distance from shore	Range finder, navigational chart	Wake properties
Ship name	Read from ship, confirm with Columbia River Pilots	Wake properties
Vessel type	Record type as: Bulk carrier, Car carrier, Oil tanker, Container ship, other	Wake properties
Ship characteristics (Draft, Beam, Length)	Confirm from Pilots records	Wake properties
Ship wake measurement	Wave staff gages	Relate to run-up
Channel bathymetry	COE data, Navigation chart	Wave transformation
Beach and nearshore slope	Transit measurement	Wave transformation
Wake run-up	MSL Run-up gage and video camera	Relate to stranding and ship characteristics
Beach material	Grain size analysis and field observation	Beach infiltration rate estimates
Beach permeability/drainage	Drainage test	Beach infiltration rate estimates
Stranding	Survey and count stranded fish on arrival at site and after each ship passage	Presence, abundance, and size distribution, of stranded fish
Positions	Geographic positions to be determined by dGPS.	Document positions of all measurements, strandings, and instruments
Fish in nearshore	Beach seining	Fish Availability Index, species, size, hatchery or wild
Water temperature	YSI Sonde multi-parameter probe	Fish conditions
River stage and flow	USGS Station at Beaver Army Terminal, Quincy, OR, www.usgs.gov	Wake properties
Tidal height	Tide prediction tables	Wake properties
Weather conditions	Record each 4 hours	Wake properties
Dissolved gas (Bonneville)	Columbia River Data Access in Real Time. www.cqs.washington.edu/dart/dart.html	Fish conditions
Dissolved gas (on site)	In-situ dissolved oxygen measurement	Fish conditions
Salmon release data	DART web site: www.cqs.washington.edu/dart/dart.html	Fish outmigration timing

4.0 Extended Sampling for Pre-Deepening Phase

4.1 Introduction

Extended sampling for the "before" component of the study comprised three sampling periods: summer, winter, and spring. The basic unit of observation was the passage of an individual deep-draft vessel by a study beach and the subsequent number and species of fish stranded, if any. Additional data regarding vessel characteristics, river condition, and fish availability were collected according to Table 3. To obtain sufficient numbers of observations, we attempted to observe a minimum of 14 vessels at each site; thus the entire study ("before" component) was to yield a total of 126 potential stranding events (14 vessels x 3 sites x 3 outmigration periods = 126 observations). Observations were limited to deep-draft vessels (e.g., bulk carriers, oil tankers, car carriers, and container ships), because smaller vessels and barges have not previously produced significant stranding, and initial observations in 2004 revealed small vessels produced wakes without draw-down. The order in which the sites were visited was randomly selected for each trip.

4.2 Materials and Methods

Methods and materials for the extended sampling initiated during summer 2004 were largely developed during the pilot study. Some refinement of sampling procedures occurred early in the summer field work and again in the winter sampling season. A full discussion of statistical analyses and the methods used relative to fish stranding was provided in the work plan (Pearson et al. 2004). The FAI was used in conjunction with records of observed stranding and vessel-passage characteristics to assess the characteristics most likely to cause fish stranding.

4.2.1 Vessel Characteristics

During ship passage, the characteristics of the vessel were recorded on a field form. These included: site, date, time of passage, weather conditions, direction of passage, ship name, ship type (e.g., car carrier, container), whether the ship was loaded or unloaded, its relative position in the channel (near, mid, far), and the vessel's speed. Additional notes regarding gage operation, vessel behavior, other vessel traffic in the area, and any other information of relevance were also made on this data sheet.

Vessel speed was measured by recording the time it took the vessel to travel 200 m. Gun-site stakes were installed upon arrival at the site; these stakes were set 200 m apart and were oriented in the same direction using a compass. Field personnel communicated via radio to start and stop the measurement, and an average of the two times collected by two observers was used. The time of passage and the vessel type were later given to the Columbia River Pilots (CRP) to retrieve positive identification on vessels. Vessel characteristics (e.g., length, draft, beam) were also gathered from the CRP or US Coast Guard Port State Information Exchange Vessel Search web portal (http://cgmix.uscg.mil/PSIX/PSIX2/VesselSearch.asp) for confirmation.

4.2.2 Wake Measurements

Two types of instruments to measure ship wakes were installed at each site during each sampling event: wave run-up gage and wave staff gage. Additionally, during the winter and spring sampling periods, a digital video camera was used to measure wave run-up speed. These instruments collectively measured a variety of wave characteristics, as discussed above in Sections 3.4 and 3.5. The placement of the gages varied slightly between sampling events; however, exact positions were noted using global positioning systems (GPS). Field measurements from a known reference stake were also collected.

4.2.2.1 Wave Run-Up Gage

The wave run-up gage captured wave extent and speed of run-up and draw-down. This 33-m long instrument is composed of 10 sections of equal length, set just above the substrate (the base of the float shields ~10 cm above the sand) at the mid-tide level of the beach (Figures 4 and A-8 through A-10). Placement was determined prior to installation by estimating minimum and maximum tide height during the sampling event. Placement was intended to maximize beach coverage (thus data collection) during the tidal cycle, though both the Sauvie Island and Barlow Point beaches were too broad at low tide to allow for full beach coverage. The gage was held in place by screw-anchors to prevent movement during wake events.

Once connected, the sections of the gage can each send 1000 mV of current when all floats are triggered (submerged). The gage was connected via cabling to a battery and a data logger, which wrote to a computer card. During vessel passage, the wave run-up gage data logger was manually activated as the ship neared the site. Once wave action ceased, the data logger was stopped. Data were downloaded to a permanent storage medium at the end of each sampling day using a laptop computer.

Post-processing of the wave run-up records involved filtering out errant readings and plotting the event. Qualitative observations were made regarding the condition of the record, as some records were partial or otherwise imperfect. Wave run-up gage plots show the voltage expressed during the event over time. Each 1000 mV corresponds to one section of the run-up gage, or ~3.1 m (10 ft).

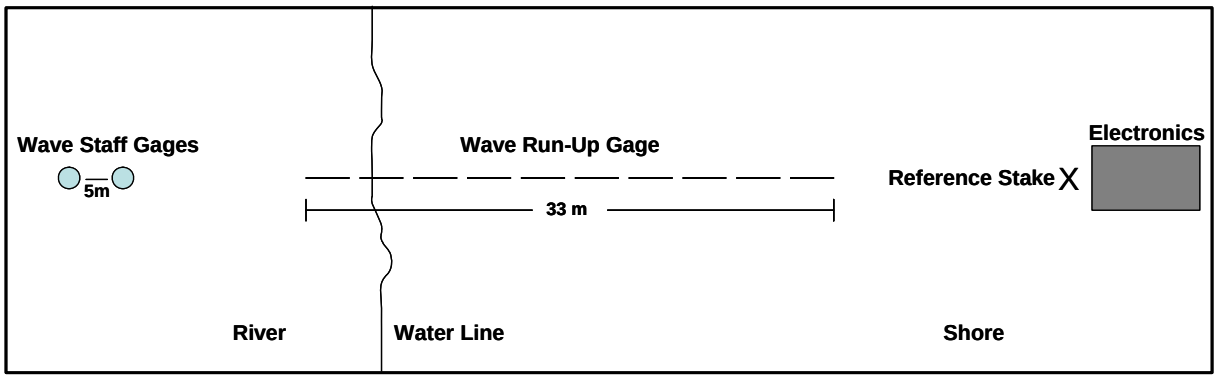


Figure 4. Plan-View Schematic of Gage Placement and Site Set-Up at a Stranding Study Site

When the gage was positioned optimally on the beach for a given tide height, the maximum extent of the draw-down and run-up were captured. Because of the large amplitude of the tidal cycle on the LCR and the difficulty in repositioning the gage once installed, many records did not capture the full extent of the wave event. However, even partial measurements from the wave run-up gage allowed for estimation of run-up velocity. The initial run-up was evaluated to determine speed of the wave. The calculation was done from visual examination of the plots by determining the extent of the run-up and the time between the beginning and end points of the wave.

4.2.2.2 Wave Staff Gage

Two wave staff gages set 5-m apart (extending perpendicular from the beach) were used to record wave characteristics (Figures 4 and A-10). The wave staffs are capacitive-type water-level sensors, and each consists of a 3-m long staff and housing (http://www.oceansensorsystems.com). These gages were placed at the deepest extent possible (Figure A-10) and were mounted on posts driven into the sediment. The tip of each staff was set ~15 cm above the substrate, with actual distance noted for each staff. Each staff was connected to a laptop computer and a 12-V battery via a cable (maximum extent is ~95 m), which was secured at several locations across the beach for stability during vessel passage. During each event, the staff-gage software was manually started in advance of the vessel passage to record stable conditions. Data were recorded for ~20 min after vessel passage until waves subsided and water elevation returned to near normal. Data were saved to a compact disk at the end of the field day.

Post-processing of the wave staff records involved filtering errant readings and plotting the event. Qualitative observations were made regarding the condition of the record, as some records were partial or otherwise imperfect. Voltage output was converted to elevation using a direct scaling algorithm, and plots of the near and far wave staffs were compared. In all cases in which both gages returned data, the plots were virtually identical, except for a slight phase shift, which accounts for the 5-m separation in installation. The deeper wave staff was selected for further processing, because it was less frequently subject to dewatering by the draw-down and low tide. If only one gage record was useable, it was used for the processing and considered to adequately represent the waves.

The raw data readings from the single gage selected were normalized to the still-water level by subtracting the mean of that entire time series from each successive measurement. The data were then filtered using a 60-point (6 sec) moving average to filter the short-period waves and emphasize the long-period waves. The 3 seconds at the beginning and end of each record was discarded since they were not averaged with all 60 points. Plots of the data were made on a single graph which showed the short- and long-period waves produced by the vessel passage. Examples are provided below in the results section.

4.2.2.3 Video Camera

A digital video camera was mounted on a t-post and tripod at the water line to capture wave events. Stakes were installed parallel (at a distance of ~20 m) to the camera's view at 5-m intervals so that the video would capture wave speed over a known distance. An additional stake was placed perpendicular to the camera so that any cross waves could be evaluated. The camera was manually started prior to vessel passage. A narrative of the approaching vessel, site, date, time and conditions, and a time-date stamp

were used to validate vessel passage. Once the vessel passed, the camera ran until the waves subsided. The camera was moved with the tide to ensure similar positioning for all events.

In the lab, video was transferred from the tapes to a PC using Pinnacle Studio Deluxe version 8 movie-making software (Pinnacle Systems 2002). We watched the first part of each scene to confirm the ship name and time of vessel passage. The part of the event containing the wave draw-down and run-up was identified and a segment containing these features was recorded to the PC using the Studio software. In some cases, the run-up was either not identifiable or so slight as to not be measurable, in which case additional video was recorded to the computer to show that nothing measurable happened before secondary waves began.

Once the video clips were transferred to the computer, they were analyzed to determine the wave run-up speed using internal video analysis software. This software was designed for a separate project, but was modified to measure the speed of the wave as it passed between the stakes. As the wave crossed the first stake, a built-in timer was manually started; this timer was stopped as the wave crossed the farthest measurable stake. The distance measured could be adjusted depending upon the extent of the wave excursion (5 m, 10 m, or 15 m), though most of the measurements were made using the 5-m increment. The software calculated the time (m/sec) based upon user input for distance. Video clips were reviewed in slow motion and each wave was measured three times to arrive at an average speed measurement. The average speed for each event was entered into a spreadsheet.

4.2.2.4 Field Measurements of Wake Run-up Event

As a backup to the run-up gage, stakes and tape measures were used to obtain the maximum extent of run-up and draw-down. Prior to vessel passage, the still-water line was marked with a stake. As the vessel passed, the maximum extent of the wave draw-down and run-up were also marked with stakes. These three stakes were then measured from the reference point (geo-referenced) to get measurements of draw-down and run-up across the beach, as well as the sum of the two (total wave excursion).

4.2.3 Water Quality

Water quality measurements were taken with each beach seine using a hand-held YSI Sonde (Model 556, Yellow Springs Instruments 2001). The probe was held in the middle of the water column, ~0.5 m deep, in all cases. Temperature, dissolved oxygen, pH, and salinity were measured, recorded to a data sheet in the field, and entered into a spreadsheet in the laboratory.

4.2.4 Fish Availability Index

Fish were collected with a beach seine five times per sampling day, as noted above. Reference sites and fish hot spots remained the same throughout the sampling period. A standard Puget Sound floating beach seine (Simenstad et al. 1991) was used to collect fish for the FAI. Depending upon water depth, the net was set parallel to the beach approximately 30 m from shore. The depth of the water at deployment varied, but was generally 0.8 m to 1.2 m at the deepest point. The net was hauled evenly and gradually pursed as it reached the waterline. Fish were removed from the net and placed in buckets with fresh river water until processed. Fish were identified to species, counted, and measured (fork length for salmonids,

total length for other species, in mm), up to 20 fish per species, per size class. To minimize handling, salmonids were placed in a glass graduated cylinder filled with river water for identification and measurement. Data were recorded on a field form and later entered into a spreadsheet for analysis.

4.2.5 Fish Stranding

After a vessel passed and wave action subsided, the field crew walked the beach looking for stranded fish. The line demarking maximum extent of wave-run up was covered first, as most fish tended to be stranded there, with subsequent passes on the river side of the high-water mark. Stranded fish were flagged by the observer. Fish were identified, their lengths measured, and their positions recorded in a handheld GPS unit. Their condition (dead or alive) and relative position (at water line or not) were noted along with any miscellaneous information. Alive fish were removed from the beach as soon as possible and placed in a holding bucket before being returned to the river; dead fish were removed from the beach to prevent confusion in subsequent events.

4.3 Results

Summary statistics and analyses for measured variables are provided below. Additional figures and data tables can be found in Appendixes B-D. A more thorough description of model development and analyses using multivariate analysis of covariance is discussed in Section 7.

Summer 2004 was the first of the "before" sampling periods. Field sampling began in June and ended in September 2004, with a total of four sampling trips. The first field trip used daytime observations and subsequent field trips used nighttime observations, because literature indicated higher stranding rates at night during the summer (Hinton and Emmet 1994). Two week-long winter sampling trips (February 8-13 and March 16–22, 2005) totaled 13 sampling days. For the spring sampling period, we spent a total of 14 field days at the three sites. The first trip was from April 11–16 and the second was from May 16–23, 2005. For both the winter and spring sampling periods, all observations were made during the daytime. The period of observation was 8 hours, though the field crew was often on site longer and therefore included observation of all ships that passed while they were present.

4.3.1 Ship Passages

During the three sampling periods, we observed a total of 126 vessels (Table 4). Although we did realize our total observation goal, we were unable to capture 14 events at each site during each period. Sauvie Island proved to be the most difficult site at which to obtain observations, possibly because it is upstream of the ports of Longview and Kalama, Washington. Ship passages were sporadic, with as many as 8 per observation period; several observation periods had 0 to 2 ships pass during the time of measurement (8 hrs minimum). For each vessel passage, data were compiled in a spreadsheet; Table 5 shows an example of the summary data available for a ship.

Table 4. Ship Passages Observed at Each Site During Each Sampling Period

Site	Observed Ship Passages			
	Summer	Winter	Spring	All
Barlow Point	23	14	12	49
County Line Park	17	14	8	39
Sauvie Island	14	12	12	38
All	54	40	32	126

Table 5. Summary Data for an Individual Vessel Observation

Summary of Event	
Period	Before
Season	Summer
Site	CLP
Diel Phase	Night
Date	08/09/04
Time	1950
Vessel Name	_____
Vessel Type	Bulk Carrier
Direction	Downstream
Condition	Loaded
Position in Channel	Far
Speed Over Ground	13.15 kts.
Stranded Fish	0
Tide Height at Eagle Cliff Datum (MLLW)	3.0 ft.
River Stage at Beaver Army Terminal (RM 53)	107,000 CFS
Current Velocity at Beaver Army Terminal (RM 53)	-0.17 ft./sec.
Duration of Event	14 mins., recorded
Maximum Draw-Down (wave gage)	36 ft.
Maximum Run-Up (wave gage)	14 ft.
Distance Between Draw-Down and Run-Up (wave gage)	50 ft.
Speed of Draw-Down	1.67 ft./sec.
Speed of Run-Up	1.46 ft./sec.

Of the total observed passages, 46 vessel passages resulted in stranding events (Figure 5). Barlow Point had the highest number of observed vessel passages (49) and the highest proportion of stranding events (26 of 49, 53% of passages). County Line Park and Sauvie Island had a similar number of observed passages (39 and 38, respectively), but Sauvie Island had a higher incidence of stranding with 14 events (37% of passages). We observed only six stranding events at County Line Park (15% of passages). There is a significant difference in stranding occurrence between the three sites ($p = 0.001$, chi-square test).

Stranding occurred at all times of day and during all seasons. A total of 80 passages were observed during the day, with 40% of those resulting in stranding events. 46 vessel passages were observed at night, with 30% resulting in stranding events. There was no significant difference between day and night stranding occurrence ($p = 0.283$, chi-square test, Figure 6). Due to seasonal differences in river flow and fish movement, season was hypothesized to be a factor in stranding occurrence. Although overall there was a significant season effect ($p = 0.040$, chi-square test), this effect is most evident at Barlow Point ($p = 0.007$, chi-square test), most likely because of the lower proportion of events that resulted in stranding during the summer period (7 of 23) than during the winter (9 of 14) and spring (10 of 12) sampling periods. At County Line Park and Sauvie Island, season is not significant in stranding occurrence (Table 6). At these sites, the proportion of stranding events was similar during all seasons.

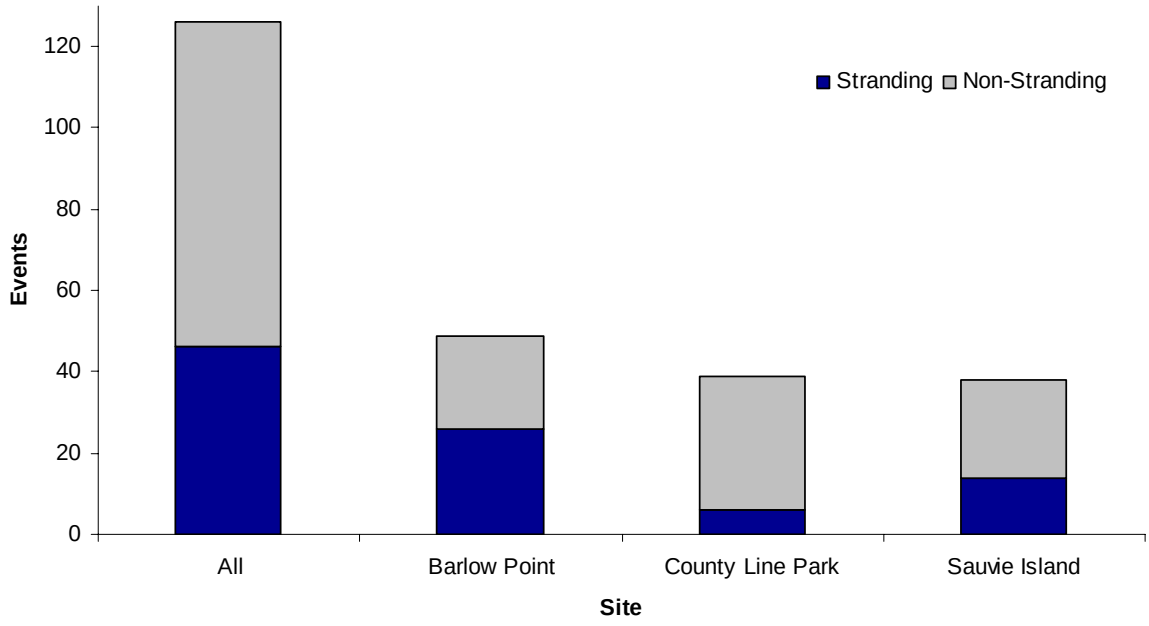


Figure 5. Stranding Events by Study Site and for all Sites (Left), Where the Total Number of Observances Is 126 and the Total Number of Observed Stranding Events Is 46

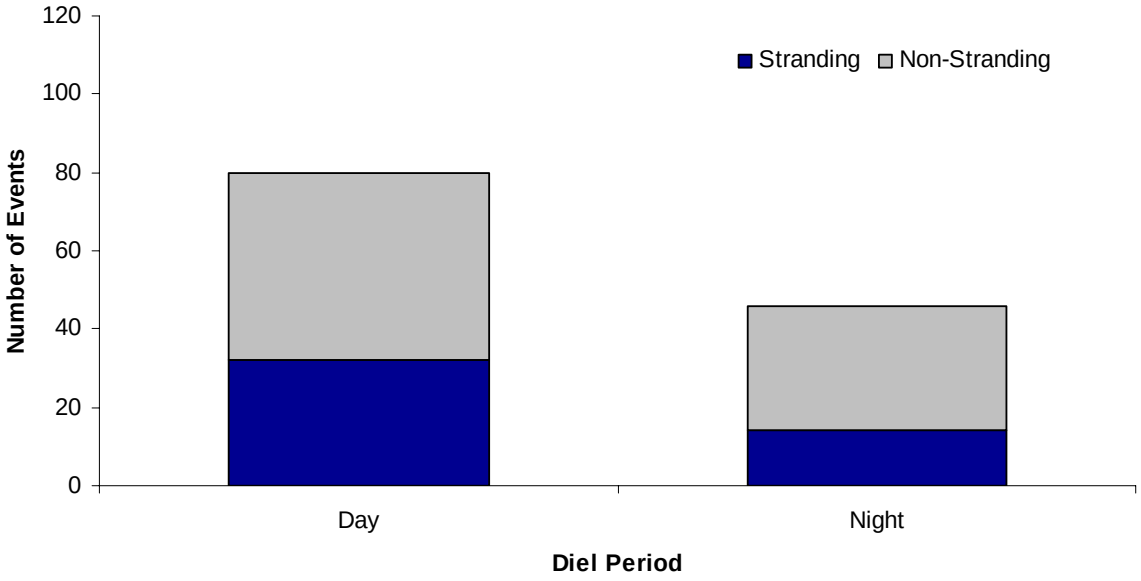


Figure 6. Stranding Events by Diel Period

Table 6. Chi-Square Test Results for Seasonal Effect at Each Study Site

Site	Proportion of Events Resulting in Stranding	p-value
Barlow Point	53%	0.007
County Line Park	15%	0.505
Sauvie Island	37%	0.722

4.3.2 Vessel Characteristics

Most observed vessel passages were bulk carriers, with car carriers being the next most common type of vessel observed (Figure 7). Other deep-draft vessel types included oil tankers, container ships, and other vessels such as military ships and research vessels. In some cases, the type of vessel could not be identified; in these cases, the vessel was considered "other" for analysis. Chi-square analysis showed vessel type to be marginally non-significant in stranding ($p = 0.099$). It is important to note that oil tankers produced the highest proportion of stranding occurrences (7 of 10 observed passages resulted in stranding). This was the only vessel type for which stranding occurred in more than 50% of the vessel passages.

Equal numbers of deep-draft vessels were observed going upstream and downstream ($n = 63$ in both cases). There was a significant difference ($p = 0.026$, chi-square test) in stranding occurrence between upstream- and downstream-bound vessels.

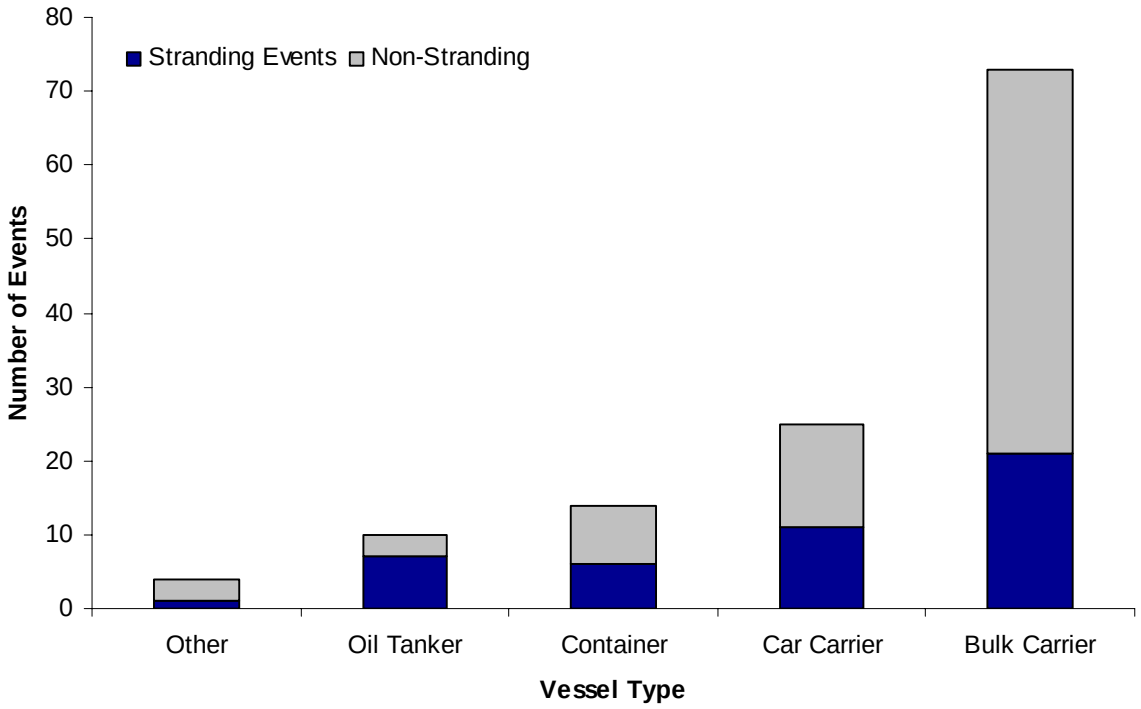


Figure 7. Number of Stranding Events Observed by Vessel Type for all Sites and Seasons

Vessel speed was analyzed in relation to stranding events (Figure 8). Speed over ground was used for calculations, though speed through the water likely differed from this measurement due to tides and currents. Stranding occurred during passages at a range of speeds; when the data were parsed out by site and season a similar result was seen.

Data on individual ships were obtained from the Columbia River Pilots. Ship beam, length, draft and block coefficient (beam x length x draft) were plotted with stranding events. Ships ranged in length from 91.4 m to 290 m (300 ft to 950 ft), with an average of 191 m (626 ft). The draft for all vessels was under 12.1 m (40 ft), though several had drafts of 11.8 m (39 ft). There was no direct relationship between ship size and stranding occurrence.

Because ship wake is a function of vessel size and vessel speed, we evaluated a kinetic energy proxy in relation to fish stranding (Figure 9). Kinetic energy (KE) is the energy of motion and is defined as follows:

$$KE = \tfrac{1}{2}\, mv^2 \qquad (1)$$

where m is the mass and v is velocity.

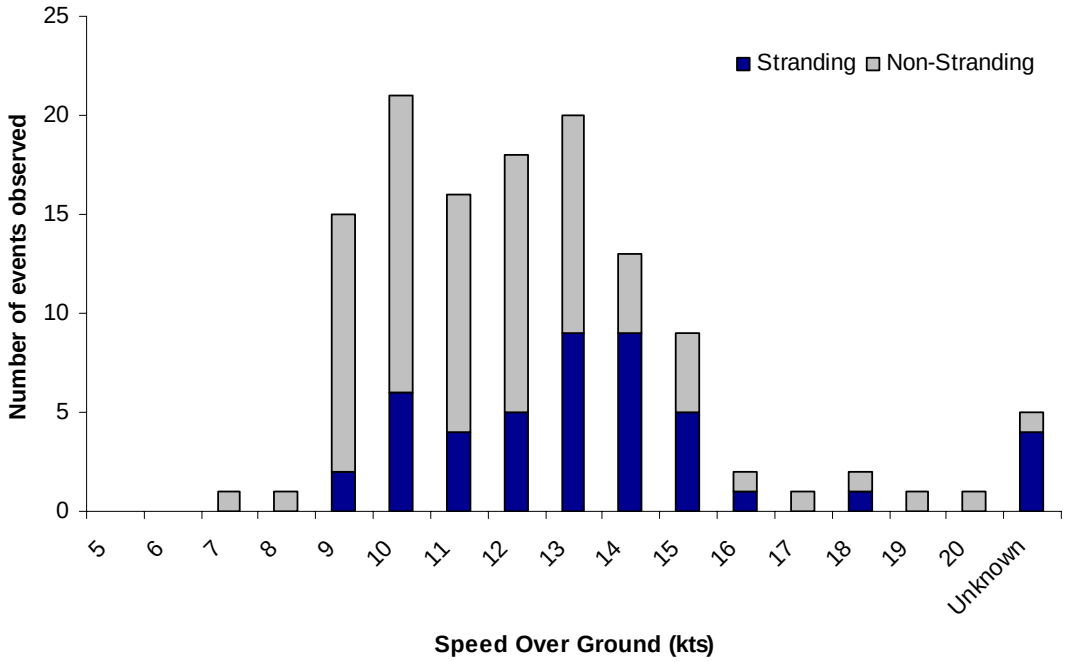


Figure 8. Stranding Events by Vessel Speed for all Sites and Dates

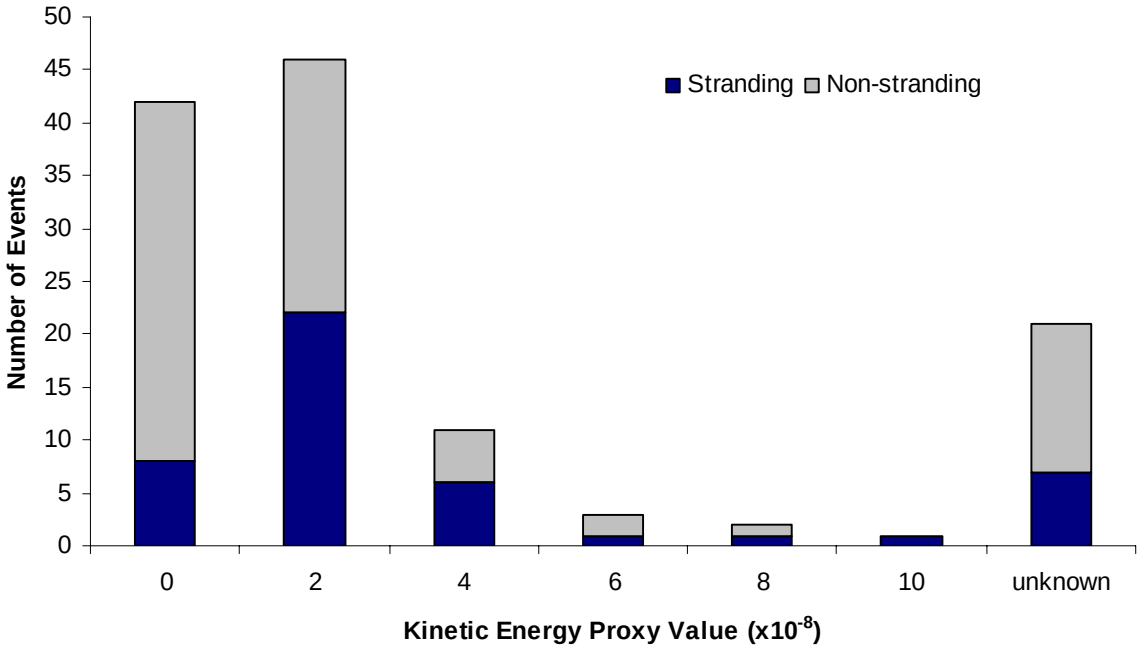


Figure 9. Stranding Events by Kinetic Energy Proxy

Because we did not have a direct measure of mass, we used the ship block factor, which is related to displacement, to arrive at a proxy. Therefore, though we have called this factor kinetic energy, it is actually a proxy for kinetic energy, whereby

$$KE' = [\text{Block Factor} \times (\text{Ship Speed})^2]/1 \times 10^{-8} \quad (2)$$

where block factor is the ship length x beam x draft, as provided by the Columbia River Pilots. Kinetic energy is significant with regard to fish stranding ($p = 0.042$, chi-square) when all sites and sampling periods are pooled.

4.3.3 River Characteristics

A number of characteristics related to river condition were obtained for each observation. These included tidal height, river flow or discharge (cfs), and river velocity (ft/sec). River discharge ranged from -100,000 cfs to 450,000 cfs during the study period. River velocity ranged from -0.3 to 1.2 m/sec (-1 to 4 ft/sec) (negative discharge and velocity result from a rising tide reversing the flow in the LCR). Greater discharge and velocity occurred during the spring sampling period (mean of 327,000 cfs over all sampling days) than the other sampling periods (winter mean was 102,000 cfs; summer mean was 154,000 cfs) as a result of unusually high run-off. Stranding events were observed over a range of river discharge and velocity levels.

Tidal height was also considered as a variable for stranding occurrence (Figure 10). Each of the study sites was subjected to a different tidal regime, given position on the river. County Line Park, the most downstream site, had the highest mean tide range (1.4 m [4.5 ft] mean lower low water, or MLLW), whereas Sauvie Island had the lowest mean tide range (0.6 m or 2.0 ft, MLLW) being the farthest from the river mouth. For all sampling periods and sites, tidal height is significant ($p = 0.024$, chi-square test); however, when each site is analyzed individually, only Barlow Point shows tidal height to be significant ($p = 0.026$). At this site, tides from 0 m to 0.3 m (0.0 ft to 1.0 ft) had the highest proportion of stranding events. It is important to note that season and river flow influence tides considerably and that predicted tides were used in these analyses.

4.3.4 Wake Description

For each event, plots of ship wakes were created from gage data. In general, a ship wake consisted of a draw-down event followed by a run-up event, with smaller waves being generated after the initial run-up. A full description of wake generation and prediction can be found in Section 5. Although the first run-up tended to be the most extreme, several events had later waves that reached farther up the beach than did the initial run-up. Most events continued for 15 to 20 min before wave action subsided to ambient conditions; occasionally an event would continue for 40 min or more. On several occasions, a second vessel passed before the first event ended. These occurrences were noted in the field notes.

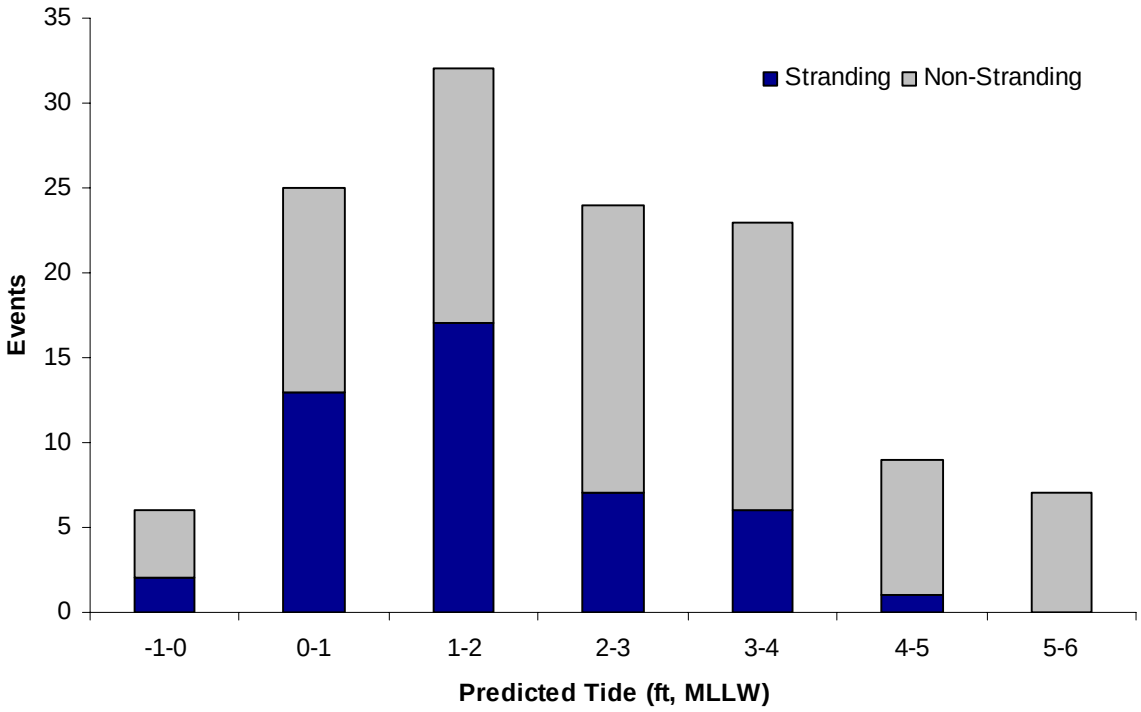


Figure 10. Stranding Events by Tide Height for all Sites and Seasons

At all sites, but particularly at Barlow Point, cross waves were observed. The anticipated ship-wake wave (onshore wave) was one that traveled from the channel up the beach face (Figure 11). The cross waves traveled across the beach face and typically met oncoming waves, which muted their force (Figure 12). Cross waves were seen in areas with complex shoreline structure, for example the Reno mat at Barlow Point and rip rap at County Line Park. Cross waves made the measurement of wakes difficult, as they were often strong enough to disrupt the wave run-up gage. Video footage taken during events captured the nature of these waves. The generation of cross waves may have contributed to fish stranding. Because this phenomenon was unpredictable, it was difficult to measure, though such waves were observed repeatedly by the field crew.

Figure 13 shows a typical wake event. The draw-down and run-up surge generated by the vessel passage are discernable to the left of the plot, as well as the arrival of short-period wake-waves at about the same time as the second surge. In this case, the event lasted about 10 min before the wave action subsided.

For some records, the run-up is followed by a series of evenly spaced wave maxima with periods of about 70 sec. These oscillations extend, with diminishing amplitude, for the entire record length of up to 40 min. The period of oscillation of the wave is consistent with that of a shallow-water wave reflected from bank to bank across the channel. Other investigators have shown records with a few wave cycles that may be indicative of reflections (Maynord 2003). None, however, have lasted as long, nor have others drawn the relationship to cross-channel oscillation. Wake records at all sites show evidence of reflections, but the channel cross-sections at Barlow Point and County Line Park are more complicated by side channels and shallow areas than is the Sauvie Island site, where this pattern is most visible.

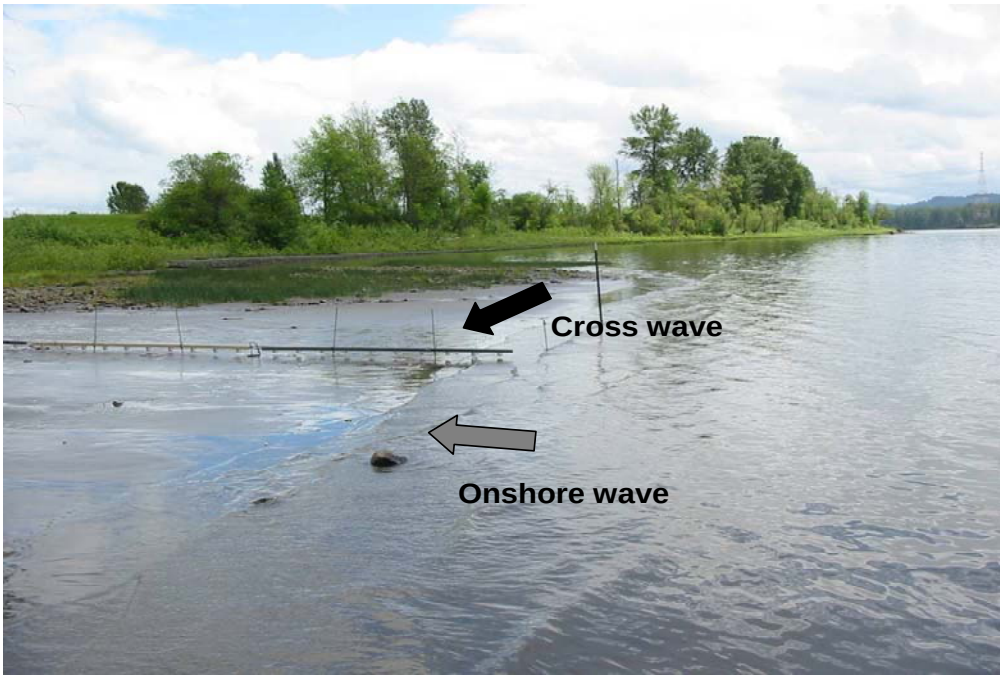


Figure 11. Beach Stretch Showing Direction of Onshore Wave (gray arrow) and Cross Wave (black arrow)



Figure 12. Example of Cross Wave at County Line Park, Coming Across the Beach Rather Than Up the Beach

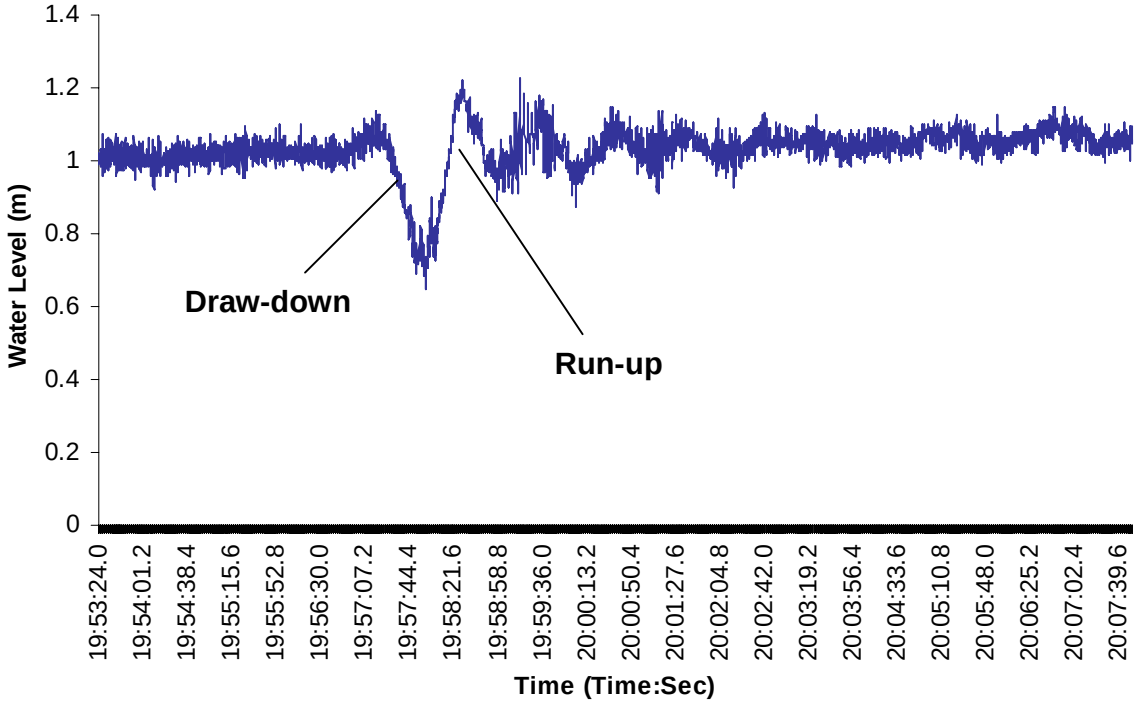


Figure 13. Record From Wave Staff Gage Showing Wake Event Through Time

Figure 14 shows a successful plot of the wave-run up gage. Few records showed the full extent of the event because of the positioning of the instrument on the beach. From the plots, average wave speed was determined. For example, for the initial wake set in the event shown below (Figure 14), the draw-down velocity was 0.51 m/sec (1.67 ft/sec) and the run-up velocity was 0.45 m/sec (1.48 ft/sec). Steeper waves indicate higher velocity, though many wake events resulted in cross waves or confused waves, which interfered with the function of the gage.

For the successful events, distance of the wave excursion could also be measured. However, the run-up and draw-down measurements from the wave run-up gage records differed from those taken in the field using stakes and a tape measure. For example, for the event shown in Figure 14, the apparent distance of the excursion from the wave run-up gage record was 16.1 m. The field measurement for the same event showed a total excursion of 28.7 m. Because the gage is placed several centimeters above the substrate (Section 4.2, Materials and Methods), and the floats are tripped only when there is enough water beneath them (~12 cm), the actual extent of run-up and draw-down as measured in the field by marking the water lines is likely to differ from that recorded by the gage. Therefore, the field measurements are a more reliable and accurate means of measuring wave excursion across the beach.

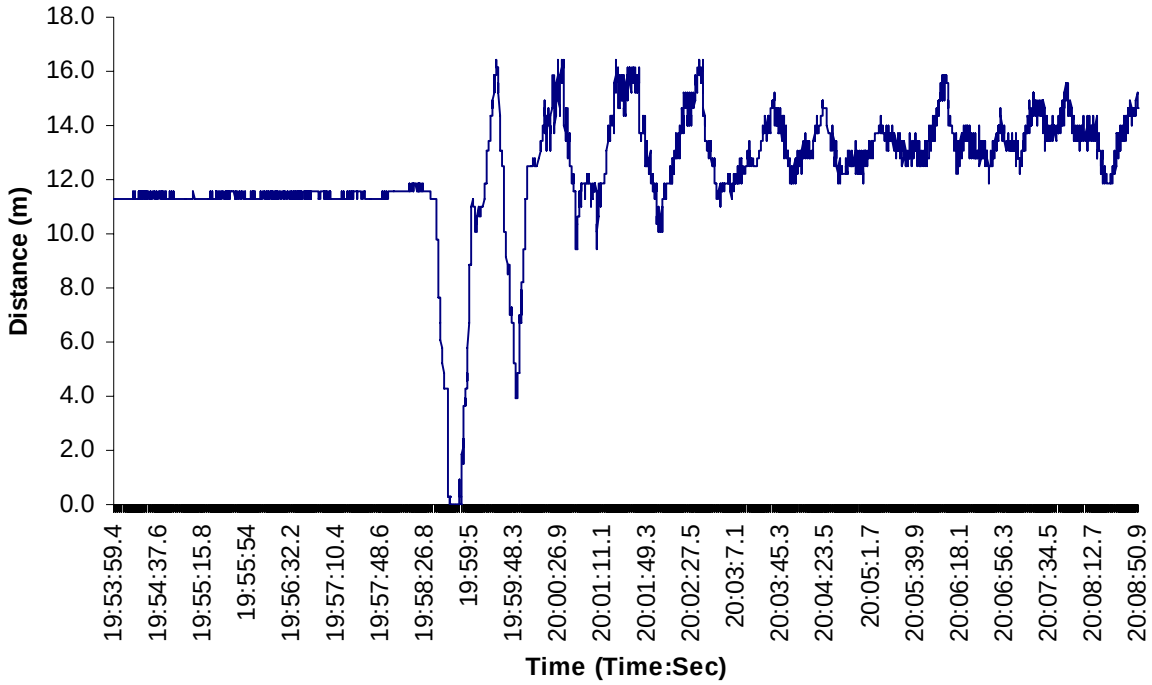


Figure 14. Wave Run-up Gage Plot Showing the Full Extent of Draw-down and Run-up Over the 15-Minute Sampling Event.

4.3.5 Wake Characteristics

A number of variables relating to ship wake were evaluated and are defined in Table 7. These measurements were derived from the wake plots or were measured directly in the field, as noted. Field measurements of the total wave excursion (across the beach face) ranged from 3 m to 78 m. Run-up and draw-down distances tended to be approximately equal, with a mean run-up of 9.3 m and draw-down of 12.6 m. When binned by distance of excursion (Figure 15), distance of total wave excursion appears to be a significant factor ($p = 0.004$, chi-square test).

Similarly, the vertical extent of wave run-up and draw-down was measured and analyzed. The maximum vertical extent ranged from <0.1 m to over 0.7 m, with a mean of 0.25 m. There does not appear to be a clear relationship between vertical extent of ship wakes and fish stranding (Figure 16) and chi-square analysis shows no significant difference in stranding occurrence between ranges of vertical extent ($p = 0.138$, Unknown category removed for analysis).

Table 7. Descriptions of Wake-Related Variables

Variable	Source/Unit of Measurement	Description
Run-up distance	Measured with tape, m	Horizontal distance from normal water line to furthest extent of run-up, measured by flagging the normal water line prior to ship passage and the highest extent of run-up during the vessel passage and measuring the distance between the 2 flags (e.g., 15 m)
Draw-down distance	Measured with tape, m	Horizontal distance from normal water line to furthest extent of draw-down, measured by flagging the normal water line prior to ship passage and the lowest extent of draw-down during the vessel passage and measuring the distance between the 2 flags (e.g., 10 m)
Total Wave Excursion	Measured with tape, m	Maximum distance between run-up and draw-down (sum of 2 measurements, e.g., 25 m)
Run-up Velocity	Camera, m/s	Speed of wave (m/sec) as it crosses between 2 points of known distance from each other (2.5 m, 5 m, or 10 m, depending upon event)
Run-up Velocity	Run-up gage, m/s	Speed of wave (m/sec) during a run-up event using the wave run-up gage. Value was determined by taking a trough and peak of one wave and dividing the maximum distance by the time elapsed.
Wash-back Velocity	Run-up gage, m/s	Speed of wave (m/sec) during a draw-down event using the wave run-up gage. Value was determined by taking a peak and trough of one wave and dividing the maximum distance by the time elapsed.
Vertical draw-down height	Staff gage, m	Vertical distance (-) of wave from the mean
Vertical run-up height	Staff gage, m	Vertical distance (+) of wave from the mean, from the first wave following the draw-down
Maximum Vertical Extent	Staff gage, m	Vertical distance (+) of wave from the mean, from the largest wave of an event

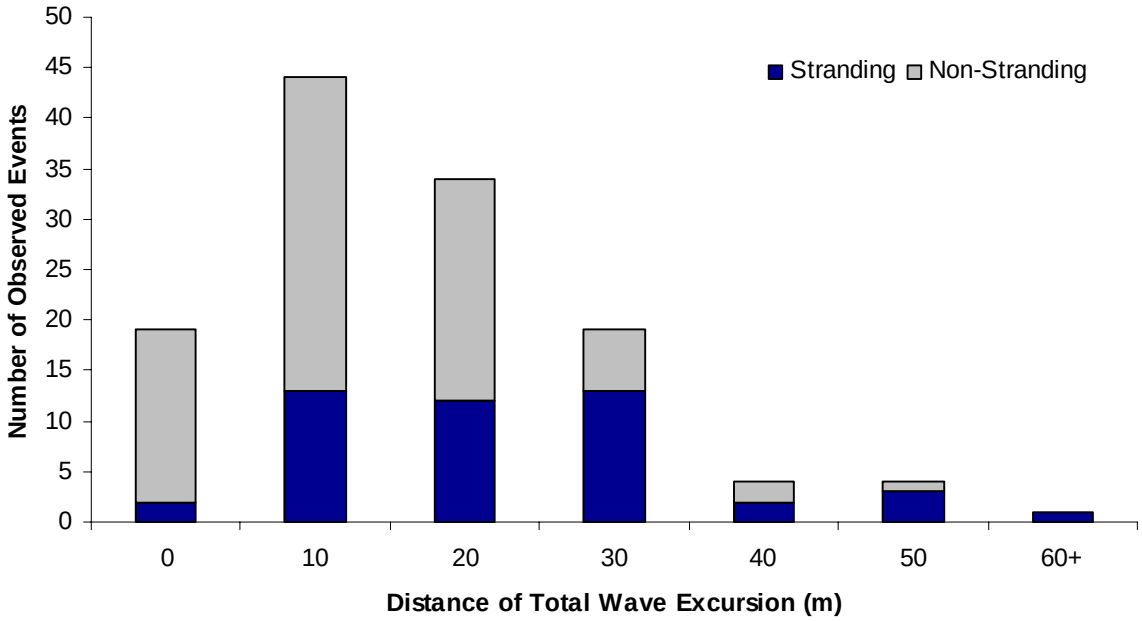


Figure 15. Stranding Events by Distance of Total Wave Excursion Across the Beach Face. Categories refer to a range, e.g., 0 = 0.1 to 9.9; 10 = 10.0 to 19.9; 20 = 20.0 to 29.9.

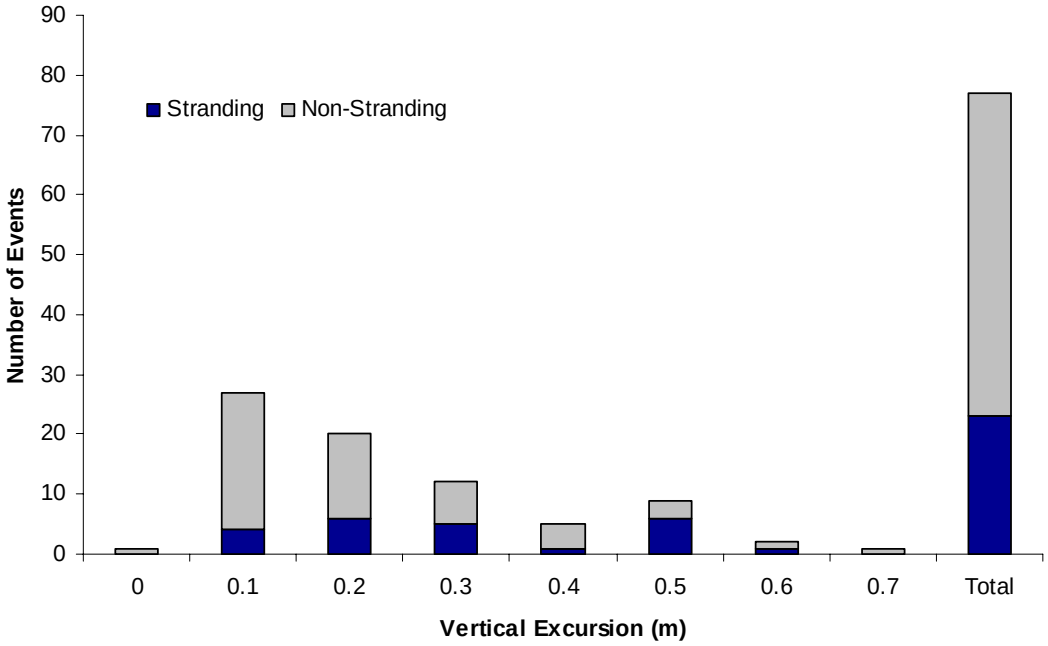


Figure 16. Stranding Events by Vertical Extent of Ship Wakes. Unknown events are those in which gage measurements could not be obtained.

Wave velocity was measured using two methods: run-up gage and camera. The camera was used only during the winter and spring sampling periods. To compare the two methods, regression analysis was used (Figure 17). For events in which acceptable records exist for both methods (n = 12), the run-up speed as captured by the video method is higher (video mean for 12 events is 1.13 m/sec, whereas mean gage speed for same events is 0.95 m/sec). The results of a t-test show this difference to be non-significant (p = 0.407, two-tailed t-test). It is important to note that the wave run-up gage is placed several centimeters above the substrate (Section 4.2, Materials and Methods) and the floats are tripped only when there is enough water beneath them (~12 cm). Therefore, the speed of the approaching wave is measured differently than when the camera is used and may be underestimated.

4.3.6 Water Quality

Water quality was within normal expectation and similar throughout each sampling period at all sites (Table 8).

4.3.7 Fish Availability Index

4.3.7.1 Species Composition

A total of 197 beach seine hauls were made during the "before" study period. With the exception of one seine during the spring sampling period, fish were present in all seines; over 20 species of fish were collected (Table 9). Seven species comprised more than 1% of the total catch (Figure 18); other species were considered rare. Table 10 shows average densities per species for each site and season. It is important to note that observed mortality from beach seines was much lower than predicted at 0.5%.

Chinook salmon were the most abundant species collected, especially during the winter and spring sampling periods when they made up about 85% of the total catch (compared with 9% in the summer). Threespine stickleback and banded killifish were also ubiquitous, being found at all sites during all sampling periods. Threespine stickleback were especially numerous during the summer, comprising almost 40% of the catch. Banded killifish, though more abundant during the summer sampling period, were found in small numbers during all sampling periods. Peamouth chub, American shad, and yellow perch were also common, though were not found during the winter sampling period. During the summer, peamouth chub made up 31% of the total catch. Chum, although comprising 1.6% of the total catch, were only present during the winter and spring sampling periods.

Several of the fish species, including American shad, peamouth chub, banded killifish, threespine stickleback, Chinook, and coho, were represented by more than one age/size class. For salmonids, catch data were separated by two age classes, 0+ and 1+, though only 0+ fish made up a significant proportion of the catch. Mean lengths for prominent species are shown in Figure 19 by season.

As explained in the preliminary analysis (Section 4.3.9, Statistical Analysis of Summer Fish Data) differences in fish composition among sites were evident (Figure 20). The location on the river and geomorphology at each site may contribute to these differences.

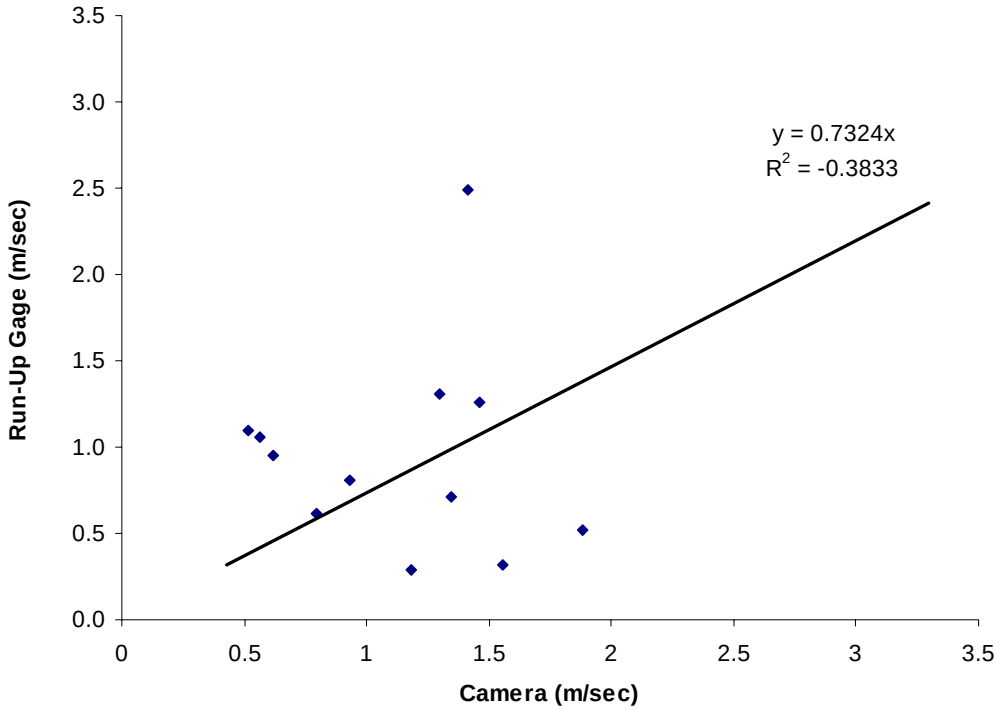


Figure 17. Regression Comparing Events in Which Both the Camera and Run-up Gage Captured Run-up Velocity

Table 8. Summary of Water Quality Data for Sampling Sites During the Three Sampling Periods

	Summer			Winter			Spring		
	BP	**CLP**	**SI**	**BP**	**CLP**	**SI**	**BP**	**CLP**	**SI**
Temperature									
Mean	22.0	21.5	22.0	7.1	6.9	6.6	9.7	11.5	13.0
Min	21.2	19.5	19.5	4.5	4.9	4.5	8.6	9.0	9.8
Max	22.4	23.0	23.7	8.8	8.3	10.4	10.8	15.1	15.7
Dissolved Oxygen									
Mean	7.3	7.3	7.4	11.8	11.7	11.8	10.3	9.5	9.6
Min	6.5	6.1	6.3	10.8	11.1	11.0	9.9	7.3	8.5
Max	7.8	9.0	8.9	12.8	12.7	12.6	10.7	11.1	10.9
Salinity									
Mean	0.06	0.06	0.06	0.07	0.07	0.08	0.06	0.04	0.07
Min	0.06	0.05	0.05	0.07	0.07	0.06	0.05	0.02	0.06
Max	0.06	0.07	0.07	0.08	0.08	0.08	0.07	0.06	0.08
pH									
Mean	6.8	7.4	7.2	7.8	7.8	7.8	8.0	7.9	8.1
Min	6.2	7.1	6.3	7.0	7.7	7.7	7.9	6.6	7.8
Max	7.5	7.8	7.9	8.4	7.8	8.0	8.3	8.2	8.5

Table 9. Species of Fish Collected in Beach Seines for All Sampling Sites and Dates

Common Name	Scientific Name	Total # Caught	% of Total Catch
Chinook (0+)	*Oncorhynchus tshawytscha*	8395	49.1
Threespine Stickleback	*Gasterosteus aculeatus*	3701	21.6
Peamouth Chub	*Mylocheilus caurinus*	2580	15.1
American Shad	*Alosa sapidissima*	1102	6.4
Yellow perch	*Perca flavescens*	388	2.3
Chum	*Oncorhynchus keta*	277	1.6
Banded Killifish	*Fundulus diaphanous*	231	1.4
Chinook (1+)	*Oncorhynchus tshawytscha*	100	0.6
Starry Flounder	*Platichthys stellatus*	75	0.4
Mountain whitefish	*Prosopium williamsoni*	72	0.4
Sculpin	*Cottus* spp.	50	0.3
Coho	*Oncorhynchus kisutch*	38	0.2
Northern Pikeminnow	*Ptychocheilus oregonensis*	25	0.1
UID Trout	*Oncorhynchus* spp.	13	0.1
Bass (fry)	*Micropterus* spp.	11	0.1
Red-sided Shiner	*Richardsonius balteatus*	8	0.0
Large Scale Sucker	*Catostomus macrocheilus*	8	0.0
Lepomis sp.	*Lepomis* spp.	7	0.0
UID salmonid	*Oncorhynchus* spp.	5	0.0
Crappie	*Pomoxis* spp.	5	0.0
Steelhead	*Oncorhynchus mykiss*	3	0.0
Cutthroat	*Oncorhynchus clarkii*	1	0.0
Common carp	*Cyprinus carpio*	1	0.0
Total		17096	

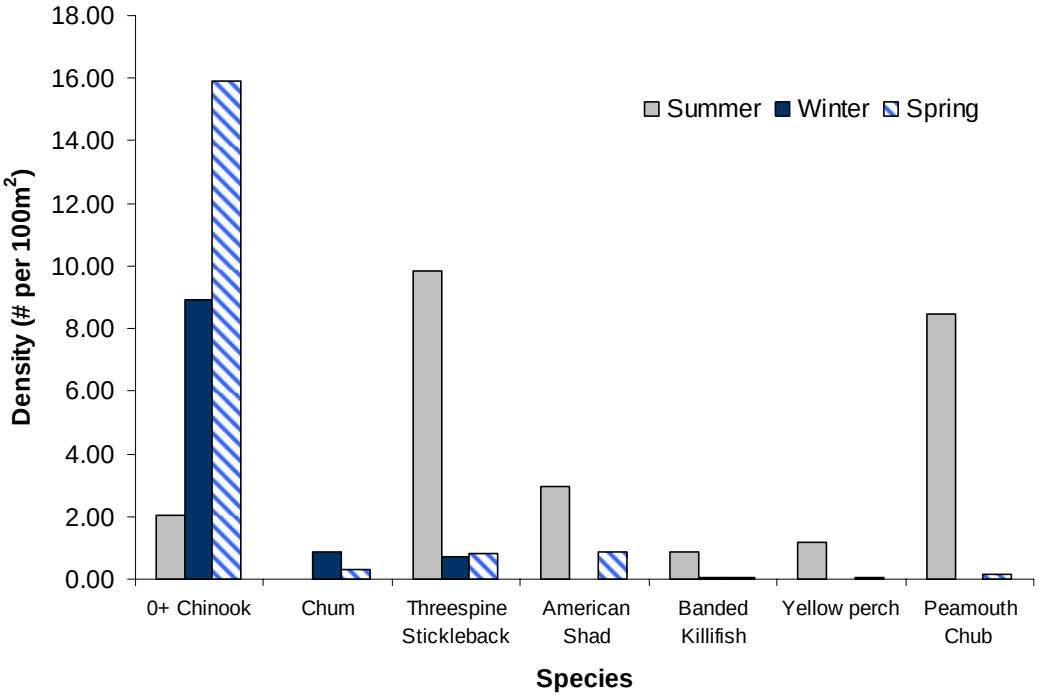


Figure 18. Fish Species Composition (Density) by Season for All Sites. Only species comprising more than 1% of the total catch are shown.

Table 10. Average Densities (# of fish/100 m^2) of Fish Species Found in Beach Seines by Season and Site

	Summer			Winter			Spring		
	BP	**CLP**	**SI**	**BP**	**CLP**	**SI**	**BP**	**CLP**	**SI**
0+ Chinook	2.10	3.02	0.98	17.71	5.91	3.12	14.46	13.85	19.49
1+ Chinook				0.01	0.01	0.08	0.11	0.48	0.35
Chum				0.11	2.13	0.30	0.09	0.69	0.07
Coho					0.66		0.01	0.13	0.01
Cutthroat								0.03	
Steelhead							0.01	0.05	0.01
UID Trout							0.12	0.04	
UID salmonid	0.00	0.01			0.01				0.01
Mountain whitefish		0.03	0.01				0.53		0.10
Threespine Stickleback	4.61	7.52	17.44	0.18	1.64	0.36	1.34	1.01	0.08
American Shad	4.84		1.04				0.88	1.36	0.29
Banded Killifish	0.21	2.40	0.05	0.03	0.05	0.06	0.07	0.02	0.10
Red-sided Shiner			0.01				0.06	0.01	
Common carp			0.01						
Yellow perch	0.00		2.36				0.05		
Bass (fry)		0.01	0.09						
Lepomis sp.	0.01		0.01	0.01			0.01		0.02
Crappie	0.01		0.03						
Peamouth Chub	3.55	4.11	17.73				0.22	0.03	0.21
Large Scale Sucker	0.02		0.02			0.01		0.01	
Northern Pikeminnow	0.01	0.04	0.10				0.01	0.07	0.04
Sculpin	0.02	1.02	0.03			0.01			
Starry Flounder	0.30	0.18	0.03	0.01	0.02		0.06	0.02	0.01

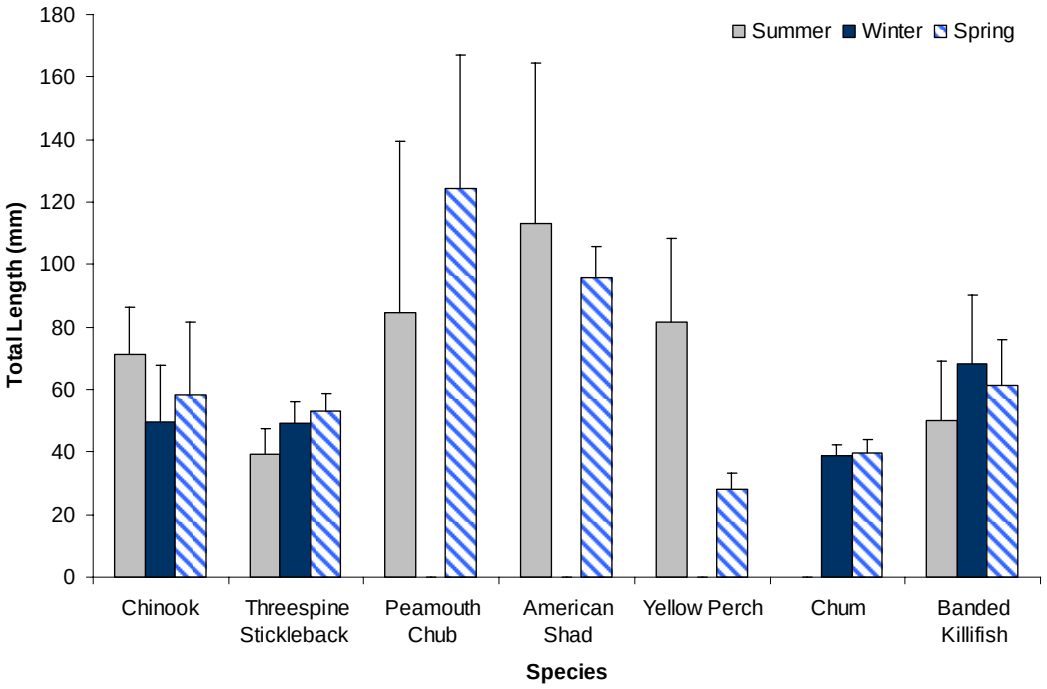


Figure 19. Mean Fish Size (total length) for Common Species by Season. Error bars represent standard deviation of the mean.

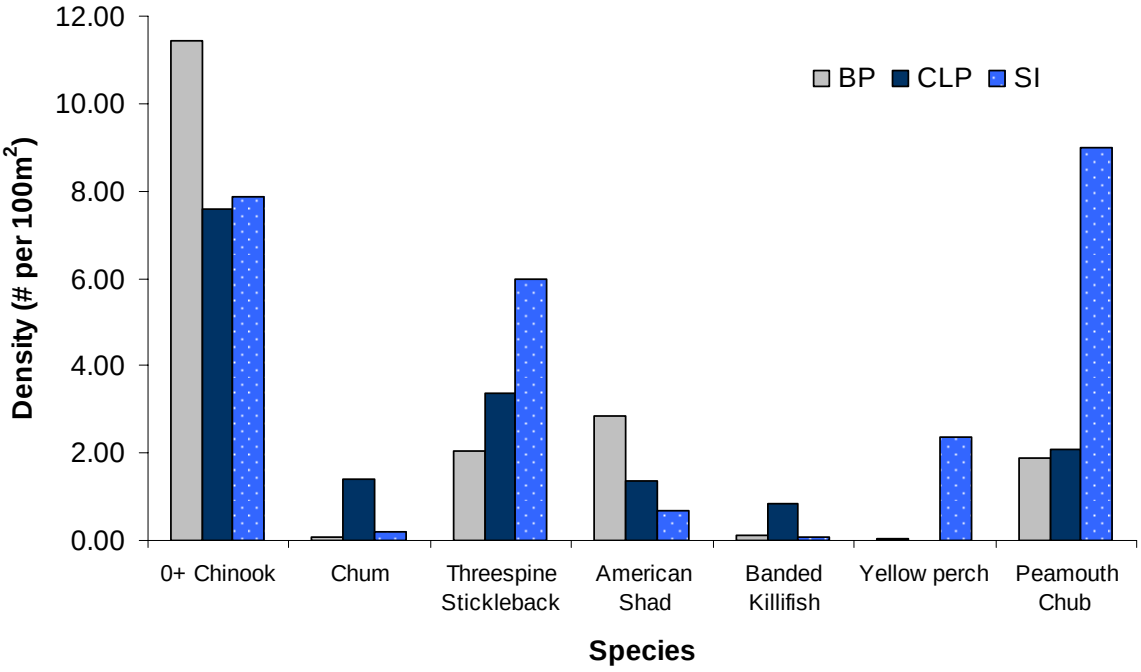


Figure 20. Fish Species Composition (density) by Site for All Seasons

Chinook

Chinook salmon were present in all but 13 seine hauls (10 from the summer, 2 from the winter and 1 from the spring sampling events). Chinook were the only salmon species found in the summer sampling period, though coho, chum, and trout species were found during the winter and spring sampling periods. The spring sampling period had the highest densities of salmonids, especially Chinook in the seines. During the winter sampling period, Barlow Point had substantially more Chinook per seine than did the other sites.

Sampling during the winter and spring periods was done monthly (February through May), allowing for a comparison of Chinook catch over time during peak outmigration. Although February catches were comparable with those from the summer sampling period (average of 18 per haul), the number of Chinook in the beach seines increased substantially in March (average of 65 per haul) and peaked in May with an average of 84 Chinook per seine haul. Additionally, during these two sampling periods, attention was paid to discerning hatchery origin in Chinook (adipose fin clips). Adipose-clipped fish were termed "marked," whereas others were termed "unmarked" (Figure 21). Clipped fish tended to be bigger than unclipped fish and more uniform in size (Figure 22). February Chinook were all unclipped and small in size, some of them still bearing the yolk sac.

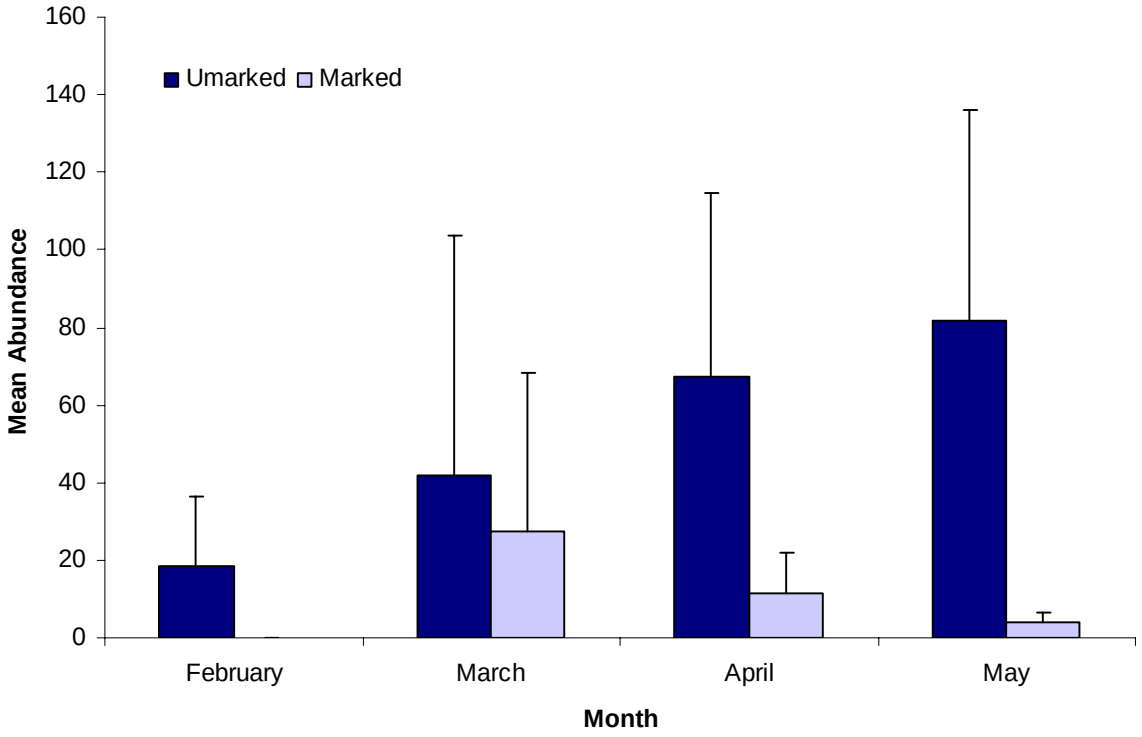


Figure 21. Comparison of Mean Abundance of Marked and Unmarked Chinook by Month for All Sites. Error bars show standard deviation.

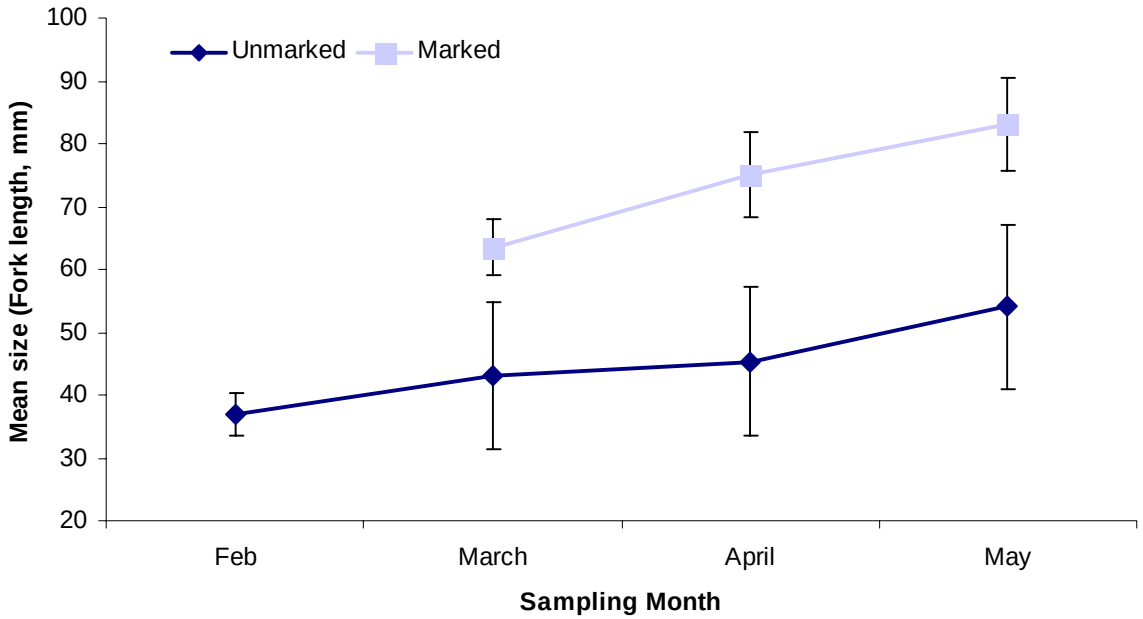


Figure 22. Mean Size of Subyearling Chinook Through Time. Error bars represent standard deviation.

4.3.8 Statistical Analysis of Summer Fish Data

We analyzed fish availability data after one sampling period to ensure the methods would adequately reflect the fish assemblage in the river. This analysis was performed on the summer dataset so that changes for the winter and spring seasons could be implemented, if needed. The seine data were analyzed to a) assess any diel trends (e.g., change in abundance with time during daily sampling), b) estimate sampling variance, c) compare the fish species composition among sites, d) determine whether fish abundance decreased over the sampling period, and e) compare the species composition of the seines for the reference areas versus the "hot spots."

4.3.8.1 Diel Trends

The "start," "middle," and "end" (reference seines 1, 2, and 3, respectively) beach seine data were analyzed for the summer nighttime samples. Ten days of data across the three study locations were analyzed to assess any diel pattern in catch. Counts of subyearling Chinook salmon and total catch (i.e., subyearling Chinook, threespine stickleback, peamouth chub, and banded killifish) were analyzed using a two-way analysis of variance (ANOVA). Blocks were defined by survey day and treatments by time of seining.

There was no significant difference in mean catch between sampling times for either subyearling Chinook ($p = 0.9259$) or total catch ($p = 0.6690$). In addition, an interclass correlation coefficient was calculated to assess whether there was a pattern to the catch numbers across the three sampling times ($\hat{\rho}_I = -0.0321$) .

The estimated correlation is essentially zero, suggesting no consistent diel trend in catches, simply random variation.

The results of the analyses suggest no preferred time to collect the reference beach seine data. The mean catch was not different between sampling times, nor was there a constant diel trend over the 8-hr sampling period. The best characterization of the fish population at risk in this circumstance is the average daily catch.

4.3.8.2 Estimates of Variance of Fish Availability

The ANOVAs also provide estimates of sampling variance, (i.e., the unassignable variance due neither to treatments nor blocks). The average catch for subyearling Chinook was $\overline{x}$ = 1.9943 with a variance of $\hat{\sigma}^2$ = 2.2324 for a coefficient of variation (CV) in catch of $\mathrm{CV}\left(x_i\right) = \hat{\sigma}/\overline{x}$ = 0.7492. The CV for the nightly mean catch is then estimated to be

$$\mathrm{CV}(\overline{x}) = \frac{\sqrt{\frac{\hat{\sigma}^2}{3}}}{\overline{x}} = 0.4325. \tag{3}$$

Hence, for subyearling Chinook, the nightly mean abundance is estimated with an approximate precision of $\pm 86.5\%$ about the true mean, 95% of the time. The average total catch per beach seine was $\overline{x}$ = 11.1827 with a variance of $\hat{\sigma}^2$ = 6140.40. This translates to a CV of 7.0073 for the catch data. Mean nightly catch then has a CV of

$$\frac{\sqrt{\frac{\hat{\sigma}^2}{3}}}{\overline{x}} = 4.0457. \tag{4}$$

In other words, you can expect to be within $\pm 808\%$ of the true abundance, 95% of the time. Hence, with three nightly beach seines, the index of total fish abundance is estimated with great uncertainty. Fortunately, the precision for the salmonid index is much better than the index of total fish availability.

4.3.8.3 Fish Community Comparison

A principal component analysis (PCA) was performed on the beach seine catch data. For each nighttime survey, mean catch by species (i.e., Chinook, threespine stickleback, peamouth chub, and banded killifish) was calculated across the "start," "middle," and "end" seines. The catch data for each species were then standardized across nights and locations by the general equation

$$Z_i = \frac{x_i - x}{\sqrt{s^2}}. \tag{5}$$

Standardization results in PCA focused more on interspecies composition rather than on the absolute abundance of fish species. A bivariate plot of the first two principal components (i.e., PC1 and PC2) was used to graphically depict the species composition at each site and replicate night of sampling (Figure 23).

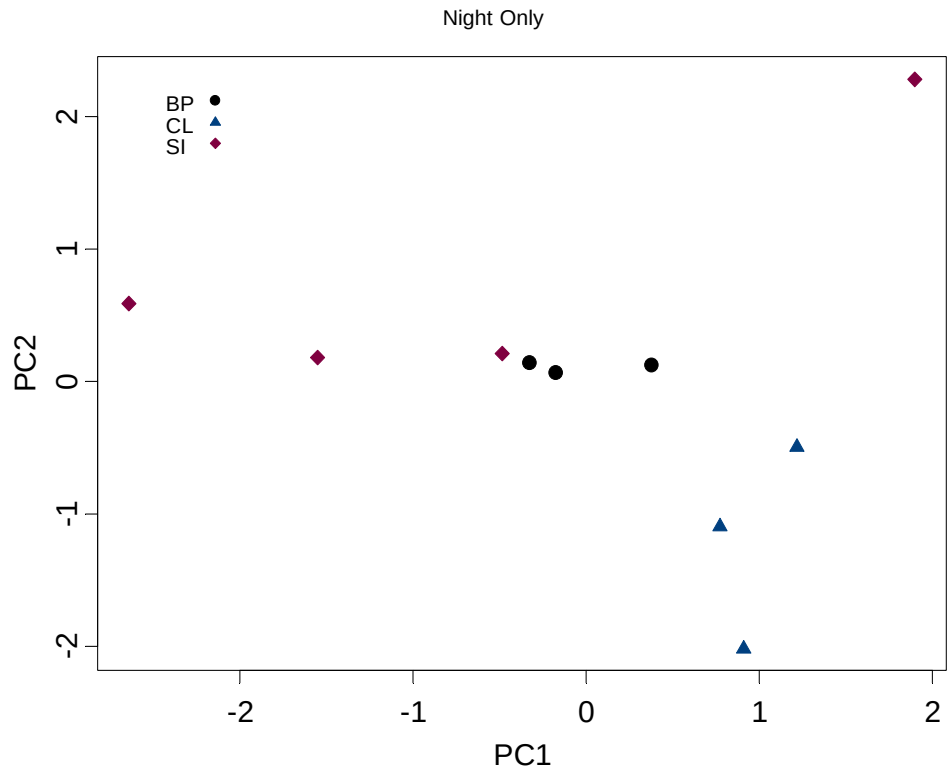


Figure 23. Bivariate Principal Component Plot for Fish Species Composition from Beach Seine Samples at Barlow Point (BP), County Line Park (CL), and Sauvie Island (SI).

Multivariate analysis of variance was subsequently used, based on PC1 and PC2 values to test for significant differences in fish community composition between the three study locations.

The first two principal components of the beach seine fish composition data explained 76.7% of the overall variability in the data. Examination of the PCA bi-plot indicates the replicate catches at a study site tend to be segregated by location. Catches at Barlow Point are located at mid-plot, catches at County Line Park in the lower right corner, and Sauvie Island catches are widely scattered across the top half of the plot. Catches at Barlow Point were the most consistent across replicate nights, whereas Sauvie Island had the greatest variability in species composition. The PC1 contrasts Chinook, peamouth chub, and banded killifish versus threespine stickleback composition. Negative values of PC1 indicate more sticklebacks, whereas positive values show more of the other species present. The PC2 contrasts threespine stickleback and peamouth chub versus banded killifish. Negative values for PC2 indicates more killifish, whereas positive values indicate more of the other two fish species.

The multivariate analyses of variance based on PC1 and PC2 values found a significant difference ($p = 0.0821$) in species composition between the three study areas. Hence, the visual separation seen in Figure 12 is supported by statistical inference.

4.3.8.4 Comparison of Reference Versus Hot spot Seine Samples

Beach seining was conducted at a reference site immediately downstream of the survey reach and after the survey day at two sites within the survey reach. The sites within the survey reach were selected based on observations during the pilot study that revealed that fish stranding tended to be concentrated at these "hot spots."

Two methods were used in comparing fish catch at "hot spots" and reference areas. A PCA was used to compare community composition between reference and "hot spot" areas. Bivariate PCA plots graphically compared community composition (i.e., four primary species) between reference, hot spot 1, and hot spot 2 areas at each location. Multivariate analysis tested whether sampling areas had the same multivariate fish composition. Two-way ANOVAs (night-by-seining locations) were used to compare Chinook-0 and total species abundance between reference, hot spot 1, and hot spot 2 locations at each study site.

A PCA was used to reduce the dimensionality of the species composition data. The first two principal components expand 67.8% of the total variability. Figure 24 presents the bivariate PCA plots for each study site. The first principal component contrasts threespine stickleback abundance versus Chinook-0 and banded killifish abundance. Negative values indicate more stickleback, whereas positive values indicate presence of more of the other two species. The second principal component contrasts peamouth chub abundance versus threespine stickleback and banded killifish abundance. Negative values indicate more peamouth chub, whereas positive values indicate greater abundance of the other two species. Species composition did not differ between reference, hot spot 1, and hot spot 2 areas at any of the study sites ($p = 0.8377$ at Barlow Point, $p = 0.2396$ at County Line Park, $p = 0.9066$ at Sauvie Island).

Analysis of variance found no difference in the number of Chinook-0 caught at reference, hot spot 1, and hot spot 2 locations at any study site ($p = 0.8481$ at Barlow Point, $p = 0.4113$ at County Line Park, $p = 0.2616$ at Sauvie Island). Total fish catch (i.e., four primary species) was not different between seine locations at Barlow Point ($p = 0.7564$) and County Line Park ($p = 0.2139$), but was different at Sauvie Island ($p = 0.0402$). These results indicate that the species compositions in the downstream reference areas are representative of those in the "hot spots" for each site.

4.3.9 Fish Stranding Events

As shown above, we observed a total of 46 stranding events during the study period (all sites, all seasons). Positions of fish strandings are shown at each site in Figures 25-27. Stranding occurred in similar locations for all seasons. County Line Park had the least number of stranding events and stranded fish. At the Barlow Point site, fish tended to strand in an area where strong cross-waves and an eddy occurred. Also at this site, fish were stranded toward the downstream end of the site (upper portion of map) in vegetation patches. Stranding at County Line Park tended to be widespread at the site, but varied by season, possibly as a result of changes in geomorphology with seasonal river conditions. Stranding at Sauvie Island also tended to be widespread, though stranded fish congregated at the far end of the site where ship wakes extended up the beach in a depression.

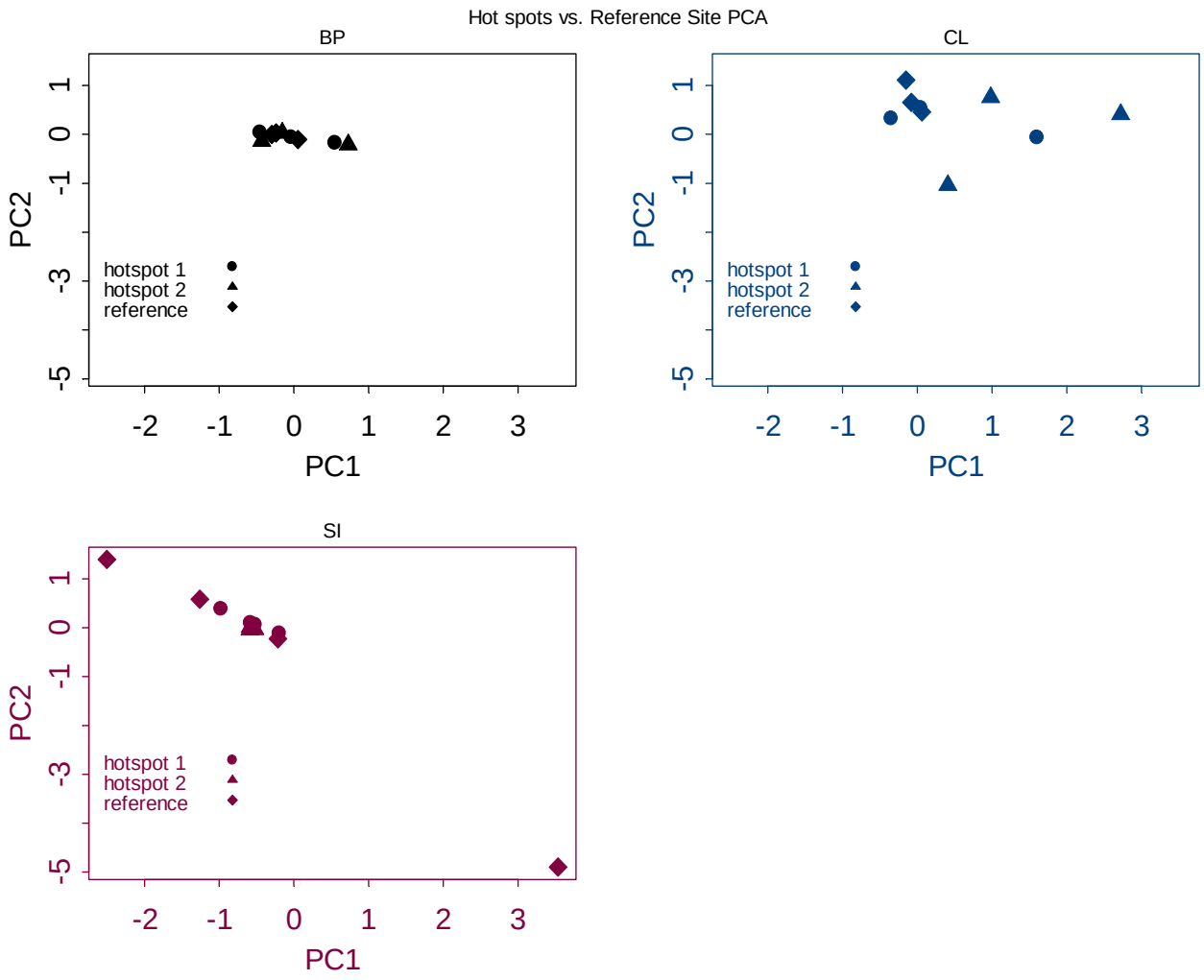


Figure 24. Bivariate PCA Plots for Reference, Hot Spot 1, and Hot Spot 2 Seine Locations at Barlow Point (upper left) County Line Park (upper right), and Sauvie Island (lower left)

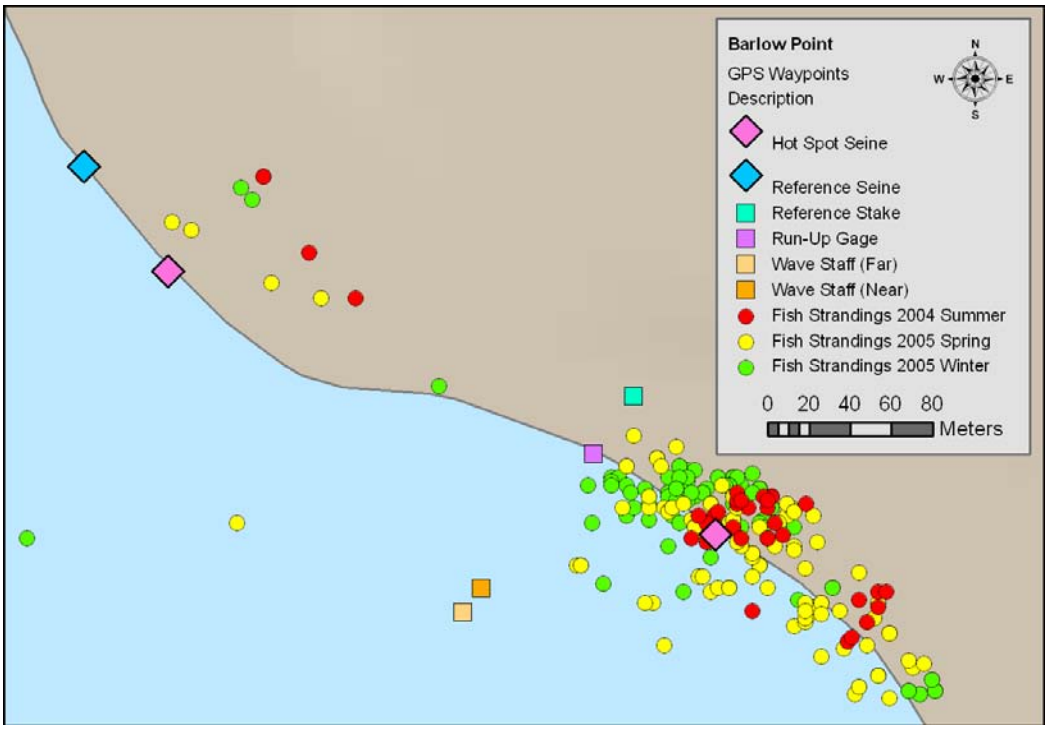


Figure 25. Barlow Point Stranding Locations

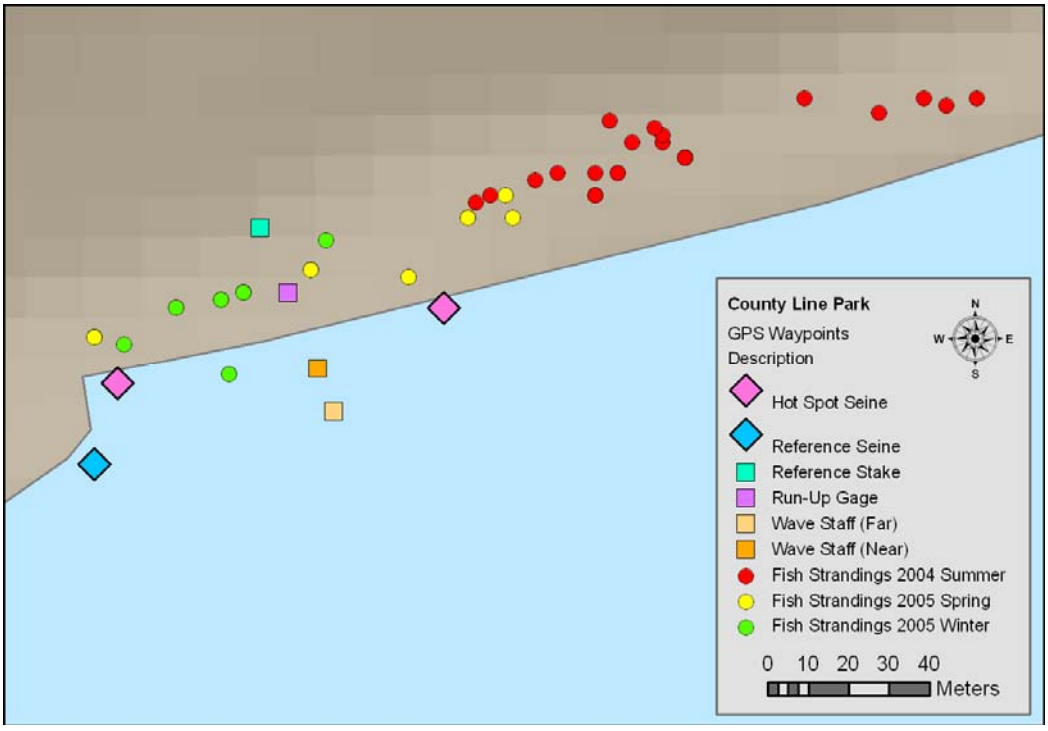


Figure 26. County Line Park Stranding Locations

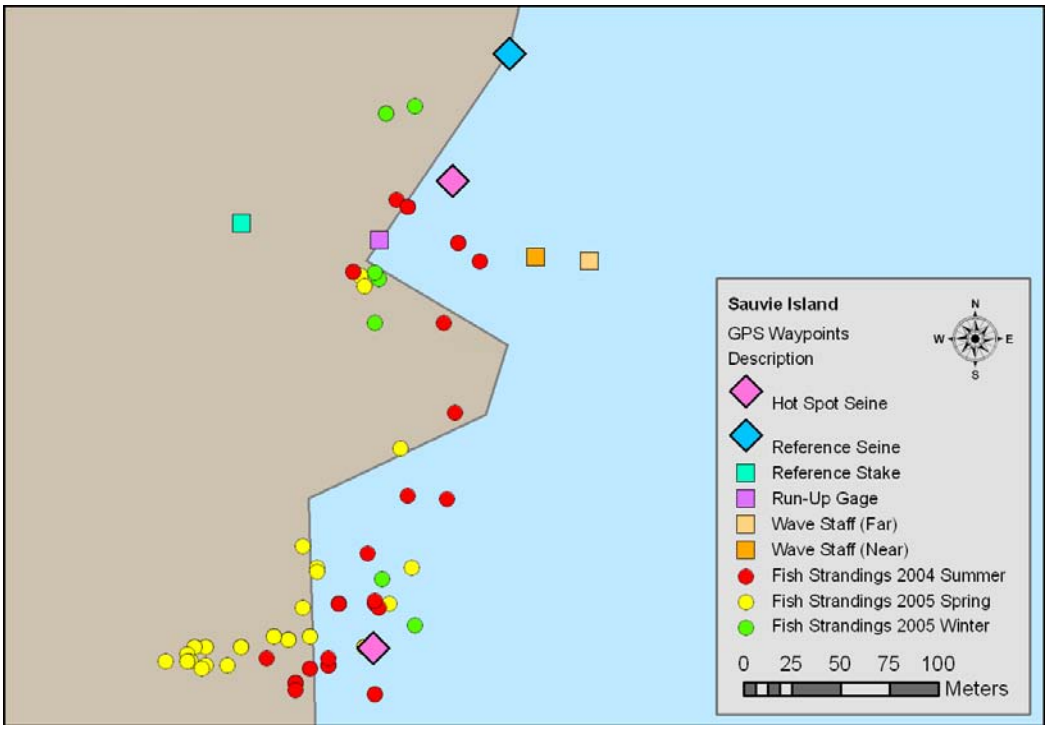


Figure 27. Sauvie Island Stranding Location

Stranding events ranged from 1 to over 100 stranded fish per event, with an average of 11.3 fish stranded per event (only events resulting in stranding were used in this calculation). Data for individual sites are provided in Table 11.

The predominant fish stranded were Chinook salmon subyearlings (Table 12). Threespine stickleback were the only other fish stranded in moderate numbers. Most other fish species were rarely stranded.

4.3.10 Species Composition in Stranded Fish and Available Fish

The hypothesis that the proportion of the seine catch made up of a given species is the same as the proportion of the strandings made up of that species was tested via logistic regression for seven species (Table 13). Trip (i.e., the site-date combination) was used as a blocking factor. Fish comprising <1% of the catch were not examined. It appears that the proportions vary significantly across sampling type (i.e., seine net versus strandings) for Chinook ($p = 0.0121$), American shad ($p = 0.0323$), and possibly for peamouth chub ($p = 0.0866$). Table 14 shows the proportion of each species stranded and caught in seines.

Table 11. Stranding Events and Mean Number of Fish Stranded at Each Site

Site	Number of Events	Mean Number of Stranded Fish
Barlow Point	26	14.9
County Line Park	6	7.3
Sauvie Island	14	5.6

Table 12. Stranded Fish by Species for Each Site

Site	BP		CLP		SI	
Species	**# Stranded**	**%**	**# Stranded**	**%**	**# Stranded**	**%**
0+ Chinook	351	90.7%	30	68.2%	45	50.6%
1+ Chinook	0	0.0%	0	0.0%	0	0.0%
Chum	1	0.3%	4	9.1%	3	3.4%
Coho	3	0.8%	4	9.1%	0	0.0%
UID salmonid	1	0.3%	0	0.0%	0	0.0%
Mountain whitefish	8	2.1%	0	0.0%	0	0.0%
Threespine Stickleback	7	1.8%	0	0.0%	33	37.1%
American Shad	3	0.8%	0	0.0%	1	1.1%
Banded Killifish	3	0.8%	4	9.1%	0	0.0%
Yellow perch	0	0.0%	0	0.0%	2	2.2%
Bass (fry)	1	0.3%	2	4.5%	2	2.2%
Lepomis sp.	1	0.3%	0	0.0%	0	0.0%
Crappie	0	0.0%	0	0.0%	1	1.1%
Peamouth Chub	8	2.1%	0	0.0%	1	1.1%
Starry Flounder	0	0.0%	0	0.0%	1	1.1%
Total	387		44		89	

Note: Percentage refers to the proportion of an individual species to all fish stranded at that site.

Table 13. Results from Species Composition Analyses, Sorted by p-Value

Species	$F_{1,194}$	p-value
Chinook 0+	6.4229	0.0121
American Shad	4.6499	0.0323
Peamouth Chub	2.9671	0.0866
Banded Killifish	1.4822	0.2249
Chum	0.3000	0.5845
Threespine Stickleback	0.0897	0.7649
Yellow Perch	0.0109	0.9168
Note: For each species, the hypothesis tested is that of equal proportions of the catch (seine) and strandings for a given species.		

Table 14. Comparison of Fish Species by Percent of Total Catch and Percent of Total Stranded

Species	% of Stranded	% of Catch
0+ Chinook	81.9	49.1
1+ Chinook	0.0	0.6
Chum	1.5	1.6
Coho	1.3	0.2
UID Trout	0.0	0.1
UID salmonid	0.2	0.0
Mountain whitefish	1.5	0.4
Threespine Stickleback	7.7	21.6
American Shad	0.8	6.4
Banded Killifish	1.3	1.4
Yellow perch	0.4	2.3
Bass (fry)	1.0	0.1
Lepomis sp.	0.2	0.0
Crappie	0.2	0.0
Peamouth Chub	1.7	15.1
Northern Pike Minnow	0.0	0.1
Sculpin	0.0	0.3
Starry Flounder	0.2	0.4
Note: Only Chinook (0+) were stranded at higher rates using logistic regression; American shad were found to strand at lower rates than that at which they were seined.		

Exhibit List 280

5.0 Methods of Ship-Generated Wave Prediction

5.1 Description of Wakes

The wake waves generated by a ship making headway in a channel are of several types. The short-period waves generated at the bow of the vessel along with the transverse stern wave are developed as a result of the near-normal pressure distribution along the hull. The bow wave is formed as the water is accelerated along the flared portion of the bow and elevates the surface above the still-water level. Along the sides of the vessel, the accelerated water is lowered in accordance with Bernoulli's principal, which requires that pressure decrease as velocity increases. The transverse stern wave is formed by the return pressure and separation at the stern of the vessel.

If the vessel is in a channel, long-period waves characterized as draw-down and the following run-up, or surge wave, may also be developed. These waves are observed if the draft of the vessel is greater than about half of the channel depth and a considerable portion of the water in the channel is displaced as the vessel proceeds. A large volume of water is pushed up at the bow of the vessel with an exaggerated lowering of water level along the sides. The wave travels along the shoreline at the speed of the ship and may provide a significant lowering of the water level at the shore followed by an up-rush return flow. Because the draw-down is forced by the ship displacement and the return flow is a free oscillation and is subject to the frictional influences of the shoreline, the draw-down tends to be exaggerated relative to the run-up. Depending on the slope of the channel flanks, the draw-down and up-rush may affect a large portion of the shore perpendicular to the waterline.

The observation and measurement of water-surface-elevation change during a ship passage in a channel are complicated by the superposition of all of the waveforms present, including those formed by the ship as well as the ambient waves due to local wind generation. Because of the importance to channel safety, maintenance, and environmental impacts, ship wakes and their effects have been subjects of a large number of studies. Sorensen (1997) provides an annotated bibliography of studies to 1991; more recent references are found in Maynord (2003).

Sophisticated numerical models based on the Boussinesq or the Navier-Stokes equations have recently been developed and show great promise for accurately representing the wake-wave field, along with animations of the progressive waves generated by ships (Nwogu 1993). These codes are very data intensive, however, requiring detailed information on ship characteristics and bathymetric information to develop a computational grid. They also require large computer resources, such as massive parallel processors or super computers. Because such detailed information is seldom available and is very expensive to gather, empirical methods have been developed that relate ship operating conditions, channel geometry, and vessel hull-form characteristics to estimate short- and long-period waves.

5.2 Prediction of Short-Period Ship Wakes

Because of its importance in channel design and maintenance, and because it is a safety and environmental issue, the generation of ship wakes in channels has received a considerable amount of

attention in the literature. Sorensen (1997) evaluated eight empirical methods of wake-height prediction and recommended a method that was slightly modified from one previously presented in Weggel and Sorensen (1986). Though widely used, the Weggel and Sorensen method was recently shown by Kriebel et al. (2003) to be a relatively poor predictor of ship-generated wave characteristics.

The short-period wave pattern generated by a moving vessel is shown in Figure 28. At the bow of the vessel, a symmetrical set of diverging waves is generated that move obliquely out from the sailing line, and a single set of transverse waves that move in the direction of the sailing line are generated at the stern. The distance from the sailing line is indicated by point y.

The highest waves in the pattern are found along the locus of cusp lines on either side of the vessel where the diverging bow wave constructively interferes with the transverse stern wave. This line forms at an angle of 19°28′ to the sailing line in deep water (e.g., when the water depth is greater than twice the draft [$d/T \geq 2$]) and increases in shallow water.

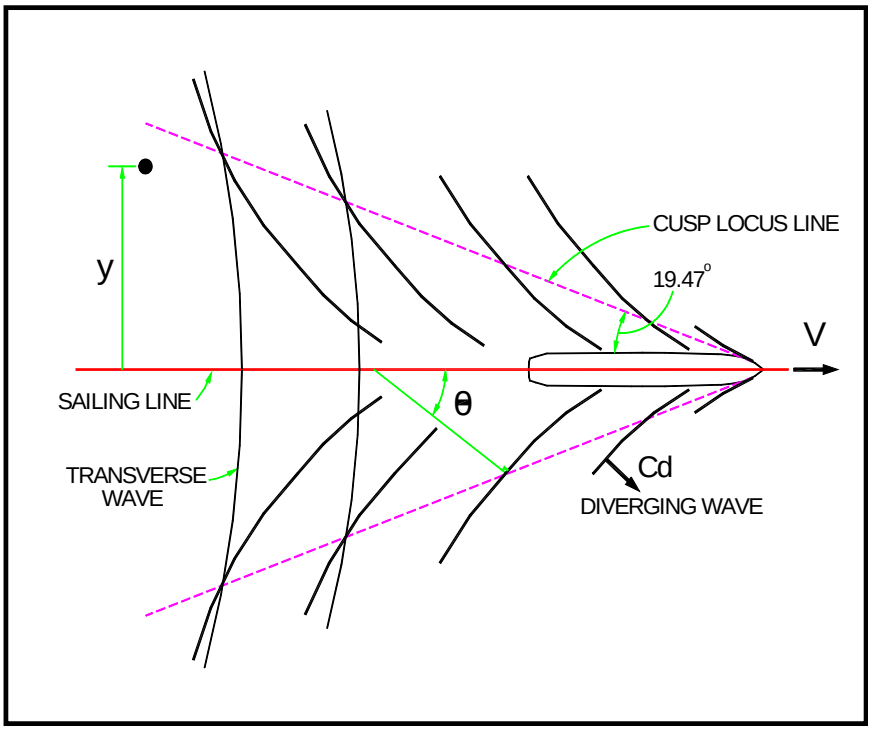


Figure 28. General Short-Period Wake Pattern Produced by a Moving Vessel

The dominant vessel-generated short-period waves, as they travel out from the sailing line, are the diverging waves. These are the waves formed by the constructive interference of the bow wave and the transverse-stern wave. The diverging waves travel at an angle that varies from 35°16′ for deep water to 0°, for a depth-based Froude number (Fd) of unity. Weggel and Sorensen (1986) have shown from experimental data that, for Fd <1, the angle can be expressed as

$$\theta = 35.27(1 - e^{12(F-1)}) \tag{6}$$

where Fd is the depth-based Froude number relating vessel speed (V) to the celerity (e.g., wave speed) of a shallow-water wave.

$$F_d = \frac{V}{\sqrt{gd}} \tag{7}$$

Wave speed is predicted by

$$C = V \cos\theta. \tag{8}$$

Displacement vessels are limited to speeds less than the critical Froude number (e.g., Fd <1.0), because they cannot exceed the speed of the bow wave. Fast ferries and planing hull vessels, however, can span the range from sub- to super-critical speeds. The maximum divergent wave is usually produced at Fd ~0.90 for both displacement and planing hull vessels. In confined navigation channels, displacement vessels typically travel at maximum speeds of 0.7 to 0.9 Fd. For an ~12.2-m (40–ft) channel depth, Equation 8 predicts a speed of 15.1 and 19.4 kts, corresponding to an Fd of 0.7 and 0.9, respectively. If the channel were deepened to ~13 m (43 ft), the *potential* speed could increase to 15.6 and 20.1 knots for the indicated Froude numbers.

For a given hull form, the wave height also varies with ship speed (V), distance from the sailing line (y), and water depth (d). As both the diverging and transverse waves move away from the vessel, their wave energy decreases due to diffraction, with a consequent decrease in height. Theory predicts that the wave height at the cusp point decreases at a rate that is inversely proportional to the cube root of the distance from the bow, whereas the transverse wave heights at the sailing line should decrease at a rate that is inversely proportional to the square root of the distance from the bow (Havelock 1908). These considerations were used by Kriebel et al. (2003) to develop their empirical relationships.

Recordings of wake-waves show that the wave height increases to a maximum in three to four wavelengths followed by a gradual decrease over the remainder of the record. A typical record of short-period wake may last for several minutes before the waves die out completely.

Figure 29 shows the effects of ship speed and water depth on the generated wake wave at increasing distance from the sailing centerline and for the same hull form. The records were made in a laboratory using scale models (1:96). The wave time series on the left is in relatively deep water and with ship speed 1.16 m/sec (3.8 ft/sec). The record shows a wake wave that builds up and decays over time. The records

on the right are for slower ship speed but in much shallower water, and illustrate the draw-down and run-up of the water surface.

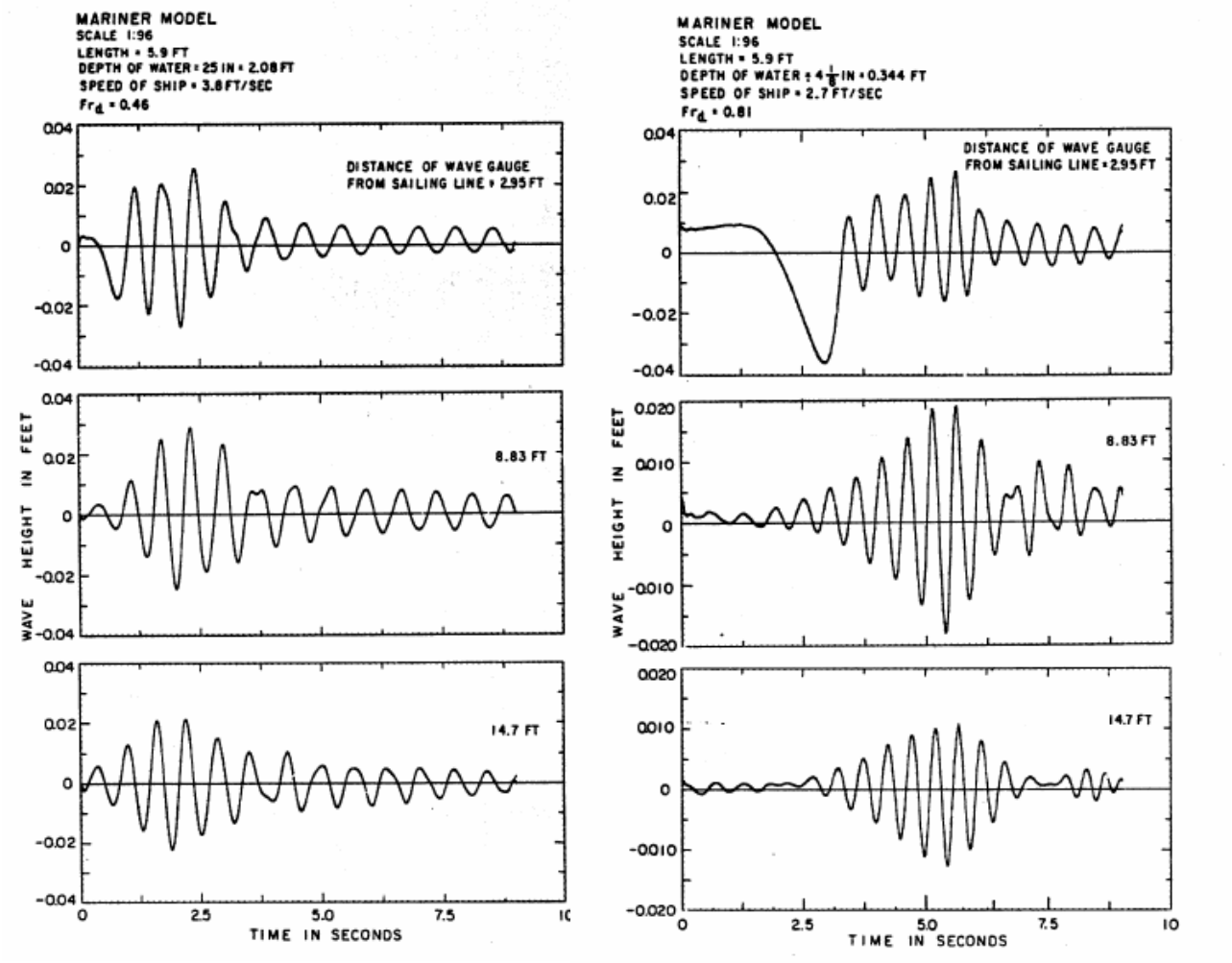


Figure 29. Water Level Records From Scale Model Studies of Ship-Generated Waves (Kriebel et al. 2003)

Kriebel et al. (2003) examined 2100 data records, collected at full and reduced scale from 12 characteristic ship types. Results of the analysis indicate that the variation of wave height, H, with distance from the sailing line, y, is best described by a $-1/3$ power relationship.

$$\frac{gH}{V^2} = C\left(\frac{y}{L}\right)^{-1/3} \tag{9}$$

Where g is gravity, and the coefficient, C, varies with hull form, depth ratio (T/d) and either depth or length Froude number.

Froude depth can be described by the following equation:

$$(F_d = \frac{V}{\sqrt{gd}} \tag{10}$$

Similarly, Froude length can be determined as follows:

$$F_L = \frac{V}{\sqrt{gL}} \tag{11}$$

Of the 2100 records reviewed, Kriebel et al. (2003) selected between 1200 and 1300 that provided sufficient details concerning wave and ship characteristics to be useful in developing a revised empirical equation. Following the relationship suggested above, the equations from Kriebel et al. (2003) are as follows:

$$\frac{gH}{V^2} = \beta(F_* - 0.1)^2\left(\frac{y}{L}\right)^{-1/3} \tag{12}$$

where

$$F_* = F_L \exp\left(\alpha\frac{T}{d}\right) \tag{13}$$

$$\alpha = 2.5(1 - C_b) \tag{14}$$

$$\beta = 1 + 8\tanh^3\left(0.45\left(\frac{L}{L_e} - 2\right)\right). \tag{15}$$

Most of the parameters are defined above but some require further explanation.

The function, F_*, is referred to by Kriebel et al. (2003) as a "Universal Froude Number," which is closely related to the variability of $\frac{gH}{V^2}$. The single empirical coefficient, α, is dependent on ship hull form; α is large for slender hulls and small for blocky hulls. Two parameters appear to be most significant in determining the variation of α: the entry length, L_e, defined as the length of the curved bow section to the start of the parallel middle body, and the block coefficient, C_b, defined as the ship volume relative to a block with volume L x B x T. Evaluation of the available data showed a linear relationship between α and C_b (Figure 30).

Experimental data for a given ship indicated that $\frac{gH}{V^2}$ increased with F_*, and the shape of the curve indicated that the relationship was quadratic or higher. Distinct variations were observed for different hull forms, and trial and error led to a best-fit relationship between β and $\frac{L}{L_e}$, as shown in Figure 31 and described by the relationship above.

The equations provided in Kriebel et al. (2003), referred to as KSJ equations, are considered preliminary, because there are plans to further investigate the relationship of the variables with additional data. The predictive skill of Equation 12 is shown in Figure 32, which displays the evaluated data relative to the line of perfect agreement. Comparison with the large data set obtained by Kriebel et al., this relationship has much greater predictive capability than that proposed by Sorensen (1997). Later studies by Sorensen attempted to include an empirical hull-shape factor into the wave-height calculation but results were not compelling.

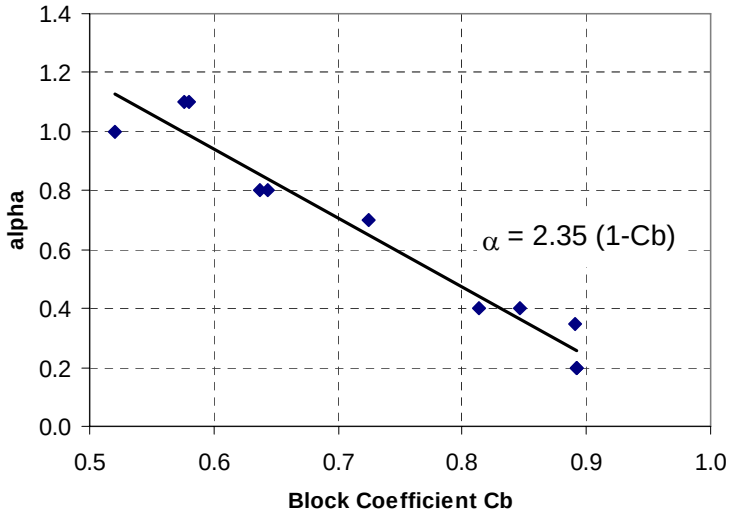


Figure 30. Relationship Between α and C_b Determined From Regression of Available Data (Kriebel et al. 2003). Fast ships with "fine form" have block coefficients <0.65; slow ships with "full form" have block coefficients greater than 0.75.

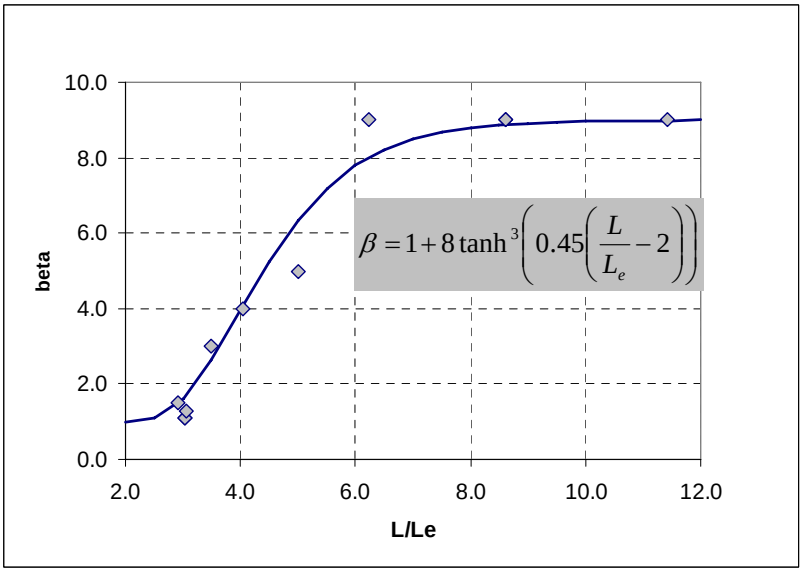


Figure 31. Empirical Shape Factor Related to Hull Form, in This Case, the Ratio Between Entrance Length to Total Waterline Length

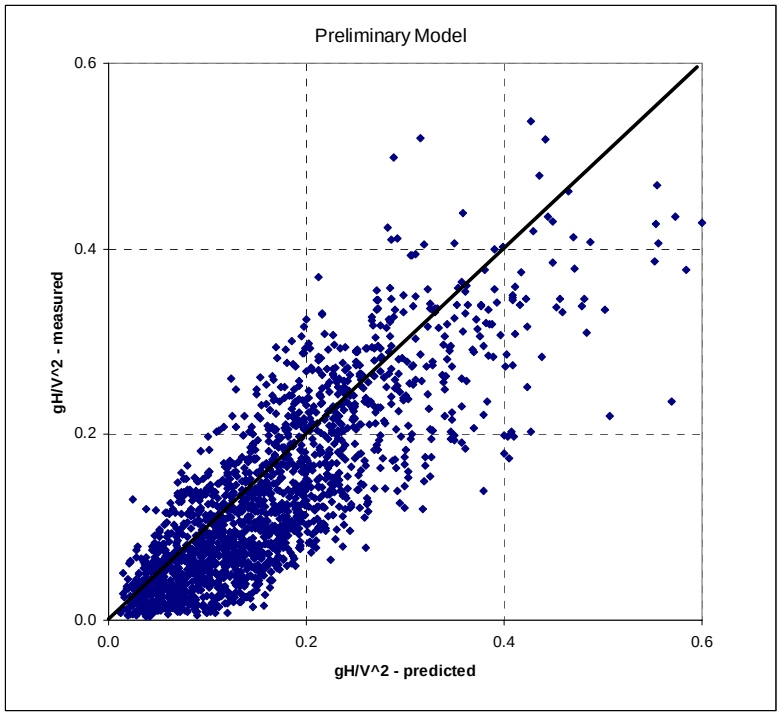


Figure 32. Comparison of Predicted Non-dimensional Wake Height to Measured Values (Laboratory and Field) Using Equations of Kriebel et al. (2003). The solid line indicates perfect agreement.

Equation 12 can be rearranged to solve for wake-wave height to evaluate the importance of the various terms.

$$H = \frac{V^2}{g}\left[\frac{V}{\sqrt{gL}}\exp\left(\alpha\frac{T}{d}\right) - 0.1\right]^2 \beta\left(\frac{y}{L}\right)^{1/3} \tag{16}$$

Equation 16 shows that velocity is very important in controlling wake wave height since it enters the predictive equation to greater the second power.

5.3 Implications of the KSJ Development

A spreadsheet was developed using the KSJ equations to predict short-period wake-wave height at selected distances from the ship sailing line.

The magnitude of entry length (L_e) is often not readily available and must be assigned an estimated value based on characteristics of the ship class or by observation. Most streamlined ships have β values of 1 to 2, whereas more blunt vessels, such as tankers, have β up to 9. The former corresponds to an entry length extending over ~30% of the total ship length, whereas the latter corresponds to an entry length of ~7.5% of total length.

The value of α may also be problematical, because the block coefficient (C_b) is not often known. As shown in Figure 30, blunt hulls, typical of cargo ships have lower values of α, on the order of 0.2 to 0.4. Once α and β are determined, the calculation of F_* and H are straightforward. The lack of accurate information, however, may introduce scatter into the wave estimate.

As an example, the predicted wake heights are shown in Table 15 for a 575-ft (175.3-m) long ship with a 23.5-m (77-ft) beam traveling at 14 knots. The height of the wake wave is determined at y = 300 ft (e.g., at the edge of the maintained channel) for three conditions, as shown, with all other parameters held constant.

If the first condition is considered the "base case" using a nominal channel depth of 40 ft (12.2 m), increasing channel depth and vessel draft each by 3 feet (0.9 m) while operating at the same speed (14 kts) will increase the expected wake wave by 0.3%. Increasing channel depth by 3 ft (0.9 m), from 40 to 43 ft, while maintaining the same draft and operating speed will reduce the wake by nearly 10% relative to the base case. The final line shows the effect of ship speed *reduction* from 14 kts to 12 kts, which results in prediction of nearly a 60% decrease in wake height. The results in Table 15 show trends and sensitivity of predicted wave height based on the adjustment of selected parameters in the KSJ equations. The predicted wave under actual operating conditions should be compared with measured data to test the accuracy of the method for the prototype conditions. Table 15 summarizes the wave estimates based on a few conditions of variable speed, draft, and channel depth. A large number of such sensitivity experiments were conducted using the spreadsheet program but are not shown here.

Table 15. Sensitivity Analysis Comparing Wake-Wave Height for Indicated Combined Values of Vessel Draft, Channel Depth and Vessel Speed

Variables	Wake Height, *H*, at *y* = 300 ft	Percent Change in Wake Height
T = 38 ft, *D* = 40 ft, *V* = 14 kts	3.59 ft	-
T = 41 ft, *D* = 43 ft, *V* = 14 kts	3.60 ft	0.3 % Increase
T = 38 ft, *D* = 43 ft, *V* = 14 kts	3.28 ft	8.6 % Decrease
T = 38 ft, *D* = 40 ft, *V* = 12 kts	1.53 ft	57.3% Decrease

5.4 Evaluation of Ship Generated Draw-down and Run-up

The method of wake wave prediction proposed by Kriebel et al. (2003) applies only to the short-period waves generated by a moving large displacement vessel. Based on primarily laboratory data, it predicts that speed is the most important variable in controlling wake-wave height. In confined channels, large vessels also generate long waves with periods of more than a minute, which are characterized by a draw-down and subsequent run-up.

As large displacement vessels pass through confined channels, they may displace a significant portion of the volume of water within the channel. This displacement creates a mound of water ahead of the vessel and a draw-down of water along its sides. At the shoreline, the draw-down is seen as a drop in the water level to some minimum below the still-water level. The following surge or run-up onto the shore is the rise to the maximum water level as the water returns following vessel passage. Both draw-down and surge are measured from the average ambient or still-water level. The draw-down is a forced wave that moves along the shore at the speed of the vessel, whereas the surge is a return-flow event. The magnitude of the draw-down and surge depend on the channel and beach geometry, the speed of the vessel, distance from the sailing line, and the size (beam, draft, length) of the vessel relative to the channel cross-section, e.g., the blocking ratio. In some channels, the long-period wave persists for a considerable time (e.g., more than 30 min) after ship passage due to reflection from the channel sides.

Empirical methods for calculating the draw-down and surge (run-up) in confined navigational channels have been developed by Maynord and others at the Army Engineer, Engineering Research and Development Center (ERDC), Vicksburg, Mississippi, and are documented in a number of Coastal and Hydraulics Laboratory technical reports. Much of the model development and documentation was conducted for the Rock Island District for the Upper Mississippi River-Illinois Waterway and are available in a series of environmental reports. The primary references used here are Maynord (1996) and Maynord (2003).

The draw-down observed at the shoreline can be calculated using the Navigation Effects (NAVEFF) numerical model developed by Maynord (1996). The program was translated from the QuickBASIC 4.5 to VisualBASIC and adapted to an EXCEL spreadsheet. The example file inputs were tested to confirm that the program returned the expected output. The program was then run to evaluate the predicted draw-down under various speeds and sailing locations relative to the channel centerline. Initial program testing

to evaluate the sensitivity of draw-down to various parameters was made for the Sauvie Island (Willow Bar) site. Later, the program was applied to the other sites.

The Willow Bar study location is on the left bank of the LCR at river mile 119 (RM 119). General characteristics are shown in Figure 33. Sediment characteristics, ground water stage, beach vegetation cover and type, and local beach morphology features may also be important in predicting local draw-down and surge.

A series of NAVEFF input files was generated to examine the predicted effect of ship speed on draw-down. The lowering of the water surface below the still-water level is shown in the dark blue line of Figure 34 as a function of ship speed. The effect of ship speed indicates that, for a given ship, speed is the dominant factor influencing draw-down. The model predicts that draw-down increases from about -0.5 ft at 14 kts to about -2 ft at 18 kts.



Figure 33. Willow Bar, Sauvie Island Survey Site. The channel cross-section A-A' was used in the NAVEFF calculations.

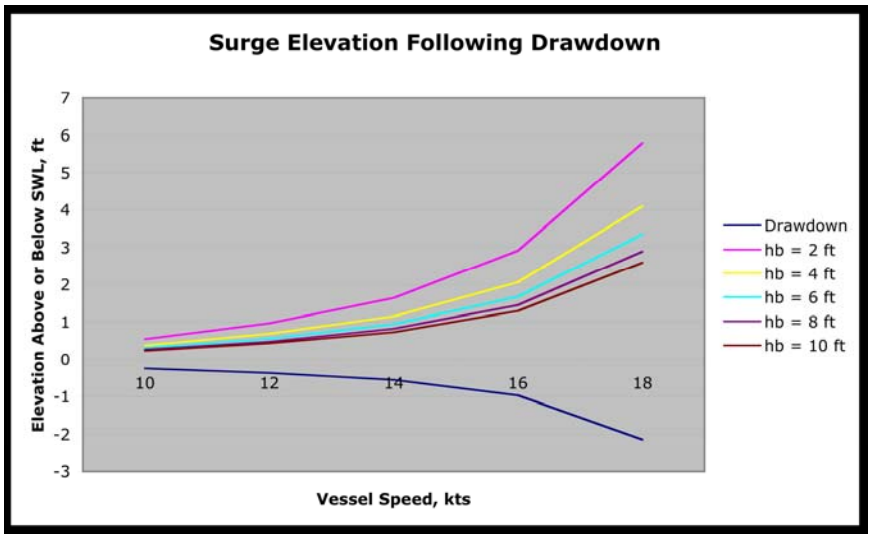


Figure 34. Predicted Draw-down and Run-up at the Shore for Indicated Speed and Berm Depth

The surge elevation following draw-down is calculated using the following empirical relationship (Maynord 2003):

$$\frac{H_s}{h_b} = 0.26\left(\frac{d}{h_b}\right)^{0.6}\left(\frac{V}{\sqrt{gh_b}}\right)^{1.8} \tag{17}$$

where H_s = surge height (run-up) above the still-water level
h_b = berm depth – depth at the channel edge
d = draw-down determined from NAVEFF
V = ship speed
g = gravity.

The surge height, H_s is seen to be proportional to ship speed, V, to the 1.8 power. Small changes in speed can be expected to generate large changes in surge elevation.

The berm depth, h_b, in the Sabine-Neches Waterway is constant and relatively well-defined, because the channel was dredged in the river bottom to form a sort of groove along which the barges and ships pass. The berm depth is relatively easy to distinguish under these conditions. In the LCR, the determination of berm depth is more problematical. A number of berm depths were used in the numerical experiments to examine the effect it has on surge. Figure 34 shows the run-up estimates for the indicated values of speed and berm depth. The nearly exponential change in draw-down and surge with speed is evident. Figure 34 also shows that, as a first estimate, the surge elevation is nearly the same as the preceding draw-down. The values of the predicted water-level changes are likely to be different from those that would be measured in the field, because the estimation method makes many simplifying assumptions, but the

model results can be used to show the sensitivity of the parameters of interest to the relative magnitude of the water-level change.

Figure 35 shows the change in predicted draw-down at the shoreline for a ship sailing off the channel centerline toward the left side of the channel. A 1-kt current was used in the calculation. The red lines on the right and left represent the channel centerline and left side (300 ft from center) respectively. At a given location in the channel, the draw-down increases rapidly with speed, as expected. At speeds under 14 kts, however, the predicted draw-down is relatively small and does not change appreciably with position in the channel.

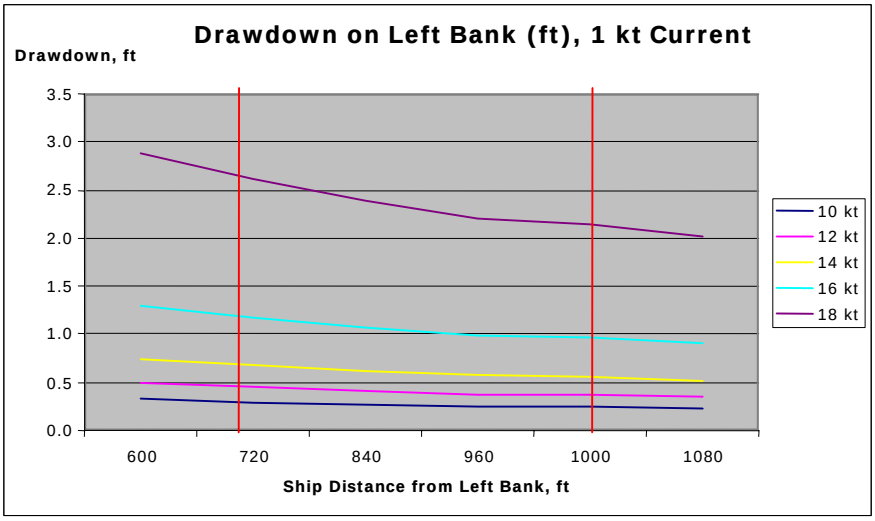


Figure 35. Predicted Draw-down at the Shoreline for Off-centerline Courses and for Various Ship Speeds

5.5 Conclusions From Modeling

The following conclusions can be reached from the preceding analysis of the ship-wave generation near the Willow Bar site:

- The empirical method of Kriebel et al. (2003) for predicting the short waves generated by ships provides a better fit to the available laboratory and the limited field data than do previous estimation techniques.
- Channel deepening from 40 to 43 ft will have little effect on individual ship-wave generation, all else remaining equal.
- Increased ship draft in the deeper channel to a bottom clearance in the existing channel will have little effect on ship-wave generation, all else remaining equal.

- Ship speed is expected to have the greatest effect on ship-wave generation, including short-period waves, draw-down, and run-up.

The empirical methods of ship-wave prediction were developed by assessing the important variables that influence wave generation and by fitting the curves to measured data. They are applicable only within the limits of the verification data and should not be applied outside of those limits. Additional field data that can be used to evaluate the appropriateness of the method for the proposed site and ship conditions should be collected to determine the confidence to be placed in the empirical estimates. The following sections evaluate the wave-height data that were collected at the three study sites along the Columbia River.

5.6 Wake-wave Record-Processing Procedure

For most field deployments, two wave staffs were placed perpendicular to the shoreline, with one about 5 m (15 ft) farther offshore. The field crew tried to place the staff in water of sufficient depth and at such a tidal stage such that the variation caused by wave passage occurred in the center two-thirds of the staff. Each staff was attached by mounting brackets to a metal rod firmly driven into the sandy bottom. To determine the deployment depth, the distance from the bottom of the staff to the sediment-water interface was measured and added to the mean still-water level recorded by the staff gage. The staff was connected to a computer at the shore station through a fixed cable and RS232 connection and was set to record at a data rate of 10 Hz. The voltage signal was converted to water level and arrayed on an Excel spreadsheet; plots were made of the signals from both staffs to evaluate differences between water levels. A typical row wave height recording from both wave staffs is shown in Figure 36.

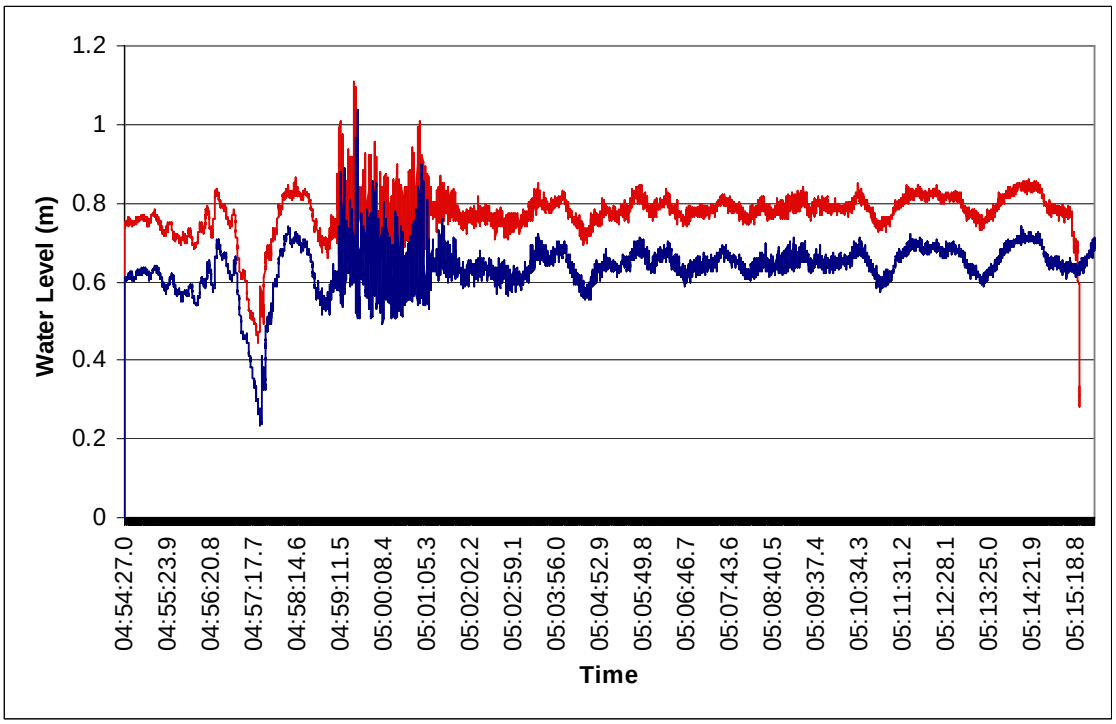


Figure 36. Raw Data Record of Waves From an Oil Tanker Recorded on Two Wave Staffs at Sauvie Island On 16 August 2004

A review of the raw water-level record indicates that when both staffs operated normally, the outputs were essentially identical in amplitude, with only a small phase lag between staffs related to the 15-ft separation. If both wave gages recorded a complete data record, the deeper one was selected for further processing because the shallower staff was more likely to "bottom out" during the draw-down coinciding with the deep-draft ship passage. If only one staff recorded data, as happened on only a few occasions, the data from that staff were used. For a few deployments, only one staff was used to save time setting up the equipment.

Other environmental and physical information collected on site or obtained to assist in the analysis included the following:

- Ship dimensions – The ship name and time of passage was noted by the field crew. Following their return, the compiled list was submitted by e-mail to the Columbia River Pilots Association, who supplied the length, beam, and draft of the vessels. Because Pilots bill the ship operators based on draft, both the pilots and the ship's crew corroborate this information. The type of ship (oil tanker, car carrier, bulk carrier, container vessel, other) was also noted by the field crew and confirmed by the Pilots.
- Ship speed – Ship speed over the ground was determined by timing the passage of the vessel between two fixed points a known distance apart along a straight portion of the study reach.
- Tide, water level. and current – Water level was obtained from the tide prediction tables and from the USGS river gage at the Beaver Army Terminal, Quincy, Oregon, at RM 53.8. The gaging station also supplies floe velocity and river volume. Flow velocity was used to compute ship speed through the water.
- Water depth and channel cross-section – Information on the channel depth and cross-sections at the survey sites was obtained from Portland District hydrographic channel surveys. Bathymetry for County Line Park, near RM 51 was obtained from soundings along the Eureka Bar Reach; Barlow Point, near RM 61 from the Walker Island Reach; and Sauvie Island, near RM 96 from the Willow Bar Reach.

5.7 Wave Data Processing

The record shown in Figure 36 clearly shows a draw-down of the water level, a run-up above the mean water level, and the arrival of short-period wake-waves following passage of the ship. Short-period waves of relatively low amplitude can be seen before the draw-down event and, following the arrival of the pulse of short-period waves, the water surface returns to small amplitude waves.

The deeper wave staff, in this case the pink (upper) record, was selected for processing. It was "demeaned" by averaging the entire record and subtracting the average from each individual measurement to determine the water fluctuation around the still-water level; and filtered using a 60-point moving average to better show the long-period wave. The record that results from this processing is shown in Figure 37, which shows a 12-minute record from the wave staff, beginning 2 min before the draw-down minimum, and continuing for an additional 10 min.

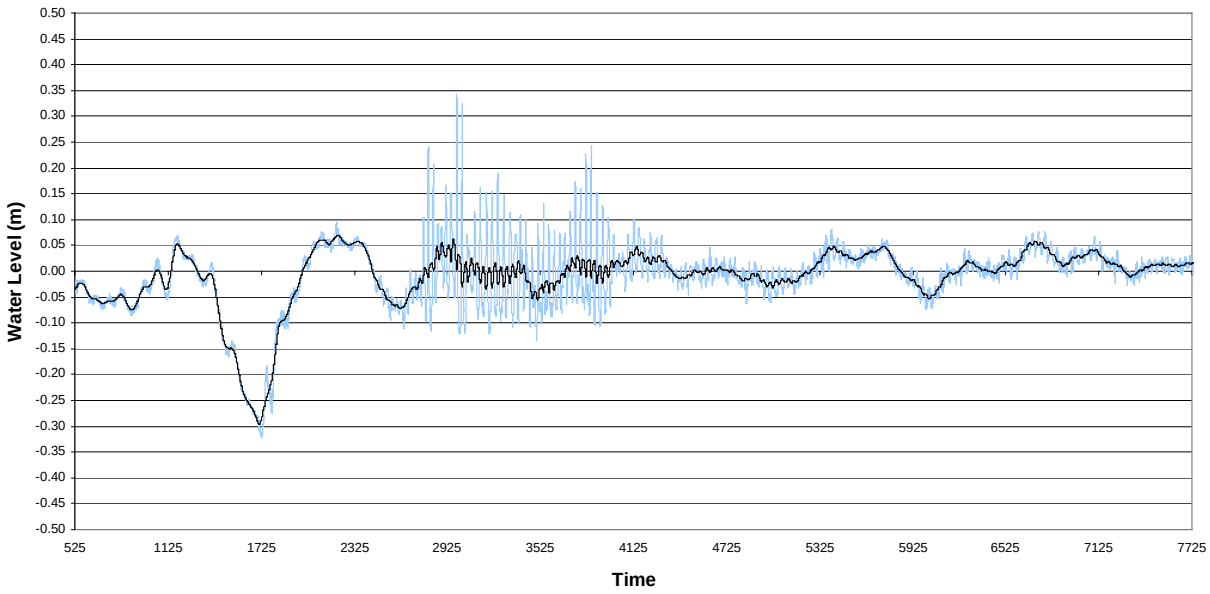


Figure 37. Processed Wave Record for Passage of an Oil Tanker Ship at Sauvie Island. Time line is recorded each 1/10 second and shows a 12-minute record.

The dark line is the filtered record showing the long-period draw-down and run-up, whereas the lighter line is short-period wave height. Most large displacement vessels generate a draw-down and following run-up with a pattern similar to that shown in Figure 37, though the degree of draw-down and run-up varies by ship, operating conditions, and site. When the draw-down pattern is observed, the depression of the water level below the still-water level during the long-period event is always greater than the following run-up above the still-water level. The draw-down may be three to five times the run-up height. The initial long-period surge is almost always of greatest trough-to-crest distance compared with subsequent long-period oscillations. In the record selected, the long-period wave shows only one surge but, in some records, a long-period oscillation is evident at decreasing amplitude for as long as 30 min when the recorder was turned off. The period of oscillation corresponds to that of a shallow-water wave oscillating across the navigation channel.

The periods of the long-period waves generated by the vessels are between ~40 sec to as long as ~116 sec between the first and second trough. The longest periods were observed at Barlow Point where the slope of the beach is small.

The arrival of the short-period bow and transverse-stern waves are clearly visible in the lighter lines of the record in Figure 37, which have not been filtered and are recorded at a frequency of 10 Hz. Though the short-period waves in this record appear to arrive for about 2 min duration, other records have a more abbreviated signal with as few as five large, short-period waves before returning to nearly background conditions.

During the study, 75 wave records were obtained from the three sites; Sauvie Island (22), Barlow Point (26), and County Line Park (27). Each of the raw wave records was processed as described above. The short-period wave height and period were obtained by locating the arrival of the wake-wave and measuring and averaging the total wave height (trough to crest) of the five largest waves in the record. These were usually, but not always, successive waves in the record. The average wave period was determined by measuring the time for 10 successive wave crests. Wave gages were deployed in various water depths, which affects the wave height as a result of shoaling. All waves were transformed to the corresponding height in water depth of 1.5 m (4.9 ft) using linear wave theory (Dally et al. 1984).

The NAVEFF program of Maynord (1996) was used to determine the draw-down for each of the sites, and the method of Maynord (2003) was used to estimate the run-up. The total long-period wave height (trough to crest) was obtained by summing the measured draw-down and run-up and comparing it with the modeled values. Ship speed used in the computation was corrected for river flow velocity and ship direction; it was, therefore, speed through the water. The regression relationship between measured and modeled values had an r^2 of ~0.15, indicating a very poor prediction. A comparison between the predicted short-period wake-wave using KSJ equations and the measured short-period wave gave a similar r^2. It seems apparent that these models do not perform well for predicting draw-down and run-up or for short-period wake-waves for ships passing the measurement sites on the LCR. Both methods depend heavily on empirical coefficients to combine physical factors that are important in the wave generation and propagation. Such empirical relationships often work well under the conditions for which they were developed (e.g., Mississippi River, Sabine-Neches Waterway, unrestricted channels) but often do not perform well outside of that environment.

Alternative regression relationships between independent variables (or combinations of variables) are considered to be important to wave generation and the observed short- and long-period wave heights. The independent variables selected to compare with wave height were as follows:

- Relative draft equal to total depth divided by vessel draft (d/T) – A non-dimensional factor used by Kriebel et al. (2003), representing the area of channel taken by the vessel
- Draft Froude number (V/(gT)1/2) – A non-dimensional relationship that incorporates speed as well as draft
- Block volume (LxBxT) – The total submerged volume displaced by the block of the vessel
- Keel clearance Froude number (V/[g(d-T)]1/2) – A non-dimensional number that uses the vessel keel clearance as the length scale.

Measured values of both long-period wave height (draw-down plus run-up) and short-period wake-wave height were used to develop regression equations and r^2 values using data at each site. The most favorable relationship was obtained between wave and block volume for long-period waves at the Sauvie Island site (Figure 38).

The r^2 values for the other regression relationships for all long- and short-wave measurements are given in Tables 16 and 17 respectively.

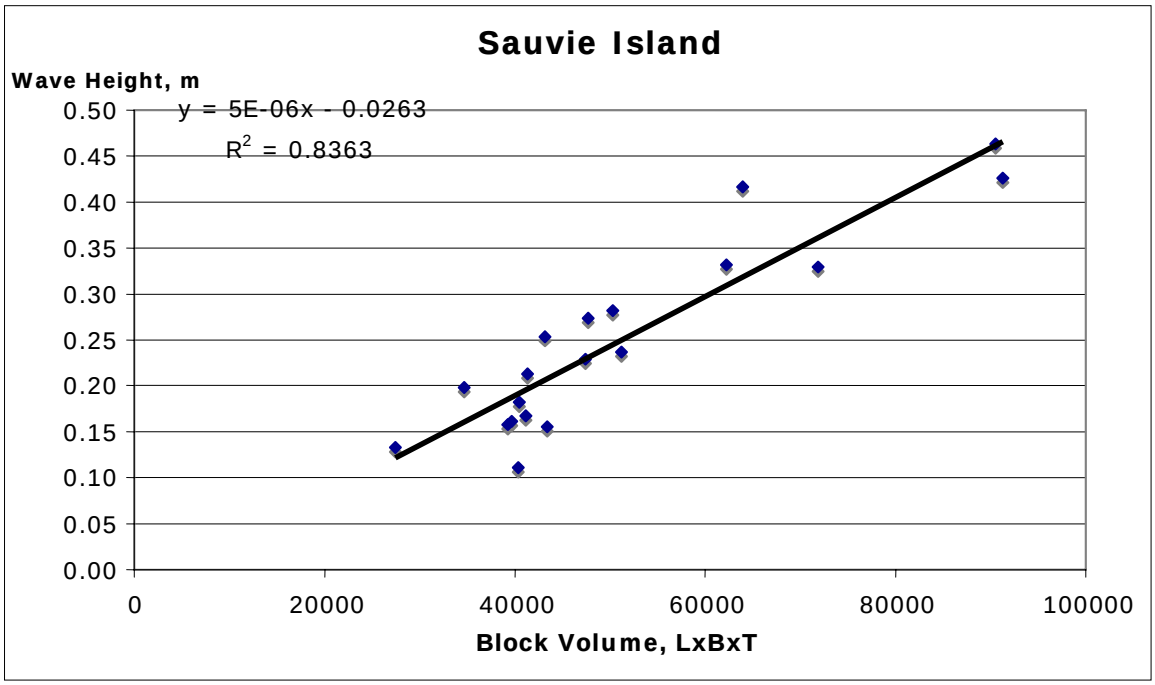


Figure 38. Linear Regression Relationship Between Long Wave Height (Draw-Down Plus Run-Up) and Vessel Block Volume at the Sauvie Island Study Site

Table 16. r^2 Values Resulting From Regression of the Indicated Value Against Long-Period, Vessel-Generated Surge-Wave Height at the Site Indicated

	Relative Draft d/T	Draft Froude Number $V/(gT)^{1/2}$	Block Volume LxBxT	Keel Clearance Froude Number $V/[g(d-T)]^{1/2}$
Sauvie Island	0.38	0	0.84	0.44
Barlow Point	0.01	0	0.10	0.02
County Line Park	0.15	0.05	0.19	0.28

Table 17. r^2 Values Resulting From Regression of the Indicated Value Against Short-Period Vessel-Generated Wake-Wave Height at the Site Indicated

	Relative Draft d/T	Draft Froude Number $V/(gT)^{1/2}$	Block Volume LxBxT	Keel Clearance Froude Number $V/[g(d-T)]^{1/2}$
Sauvie Island	0.19	0	0.26	0.18
Barlow Point	0	0.03	0.11	0.05
County Line Park	0	0.09	0.18	0.18

.

The results displayed in Tables 16 and 17 indicate that ship variables and differences between sites play large roles in the generation and propagation of surge and wake-waves. It may be possible to reduce some of the variability by using other parameters or by combining parameters, but it is apparent that the physical process is not captured by these relationships.

There were 15 occurrences when the same ship was observed multiple times, but only 8 of these provided measured data that allowed comparison of wave conditions for the passage. These results are provided in Table 18. Only one vessel was observed three times. The multiple observations do not provide sufficient data for a statistical evaluation. Considerable variability can be observed between passages at various sites, further emphasizing that site characteristics may be controlling factors.

Table 18. Comparison of Vessel Wake for Multiple Observations of the Same Ship

Ship	Date	Site	Direction	L	B	D	Vessel speed	Surge wave height in 1.5 m water depth	Surge wave period	Wake-wave height in 1.5 m water depth	Wake-wave period
Units				**ft**	**ft**	**ft**	**m/s**	**m**	**s**	**m**	**s**
A	08/09/04	CLP	Downstream	558	89	33.3	5.07	0.216	80	0.372	4.01
A	02/10/05	BP	Downstream	558	89	n/a	6.35	0.27	97.7	0.159	3.26
B	**08/16/04**	**SI**	**Upstream**	**650**	**96**	**35.2**	**5.05**	**0.332**	**92.4**	**0.345**	**3.31**
B	**08/30/04**	**BP**	**Downstream**	**650**	**96**	**27**	**7.28**	**0.218**	**81.4**	**0.191**	**2.21**
B	**05/16/05**	**SI**	**Downstream**	**650**	**96**	**27**	**5.52**	**0.273**	**71.1**	**0.32**	**2.85**
C	06/29/04	CLP	Upstream	568	90	28	6.36	0.295	80.1	0.151	4.05
C	06/30/04	BP	Downstream	568	90	27	7.29	0.121	110.7	0.164	3.59
D	07/20/04	SI	Upstream	950	106	32	6.87	0.426	97.7	0.551	3.68
D	**07/21/04**	**CLP**	**Downstream**	**950**	**106**	**33.4**	**8.85**	**0.418**	**62**	**0.375**	**3.53**
E	02/08/05	SI	Downstream	623	106	21	6.14	0.158	46.2	0.261	3.72
E	**02/11/05**	**BP**	**Downstream**	**623**	**106**	**39**	**4.65**	**0.145**	**116.8**	**0.206**	**3.96**
F	08/10/04	CLP	Upstream	640	106	26.1	6.69	0.503	39.3	0.304	1.97
F	**08/13/04**	**SI**	**Downstream**	**640**	**106**	**37.4**	**5.1**	**0.329**	**56**	**0.204**	**3.26**
G	**03/21/05**	**CLP**	**Downstream**	**599**	**106**	**25**	**7.22**	**0.336**	**73.8**	**0.284**	**3.71**
G	**05/18/05**	**SI**	**Downstream**	**599**	**106**	**24**	**5.35**	**0.254**	**59.3**	**0.319**	**2.78**
H	08/15/04	SI	Downstream	650	102	25.3	3.99	0.229	71.2	0.126	2.95
H	**02/11/05**	**BP**	**Upstream**	**650**	**102**	**25**	**6.4**	**0.423**	**104.7**	**0.391**	**3.88**

Bold = stranding events.

5.8 Conclusions

Methods for predicting the magnitudes of ship-generated wake-waves, consisting of long-period draw-down and run-up, have been developed for confined channels. Additional methods for predicting the short-period bow and transverse-stern wake have been developed primarily from scale model tests. Though these methods show promise for the conditions under which they were developed, they do not accurately predict the components of ship wake observed at the three study sites along the Columbia River. Both prediction methods rely heavily on empirical relationships, which combine physical parameters into non-dimensional numbers with coefficients and exponents determined from observation. Neither of the methods adequately accounts for factors that are likely to be important during wave propagation, such as bottom slope, distance from the site, bottom friction, and possible non-linear wave effects, to name a few.

Exhibit List 300

6.0 Multivariate Analysis of Covariance

6.1 Introduction

The before-and-after comparison needs to account for covariates so that any changes in the covariates between before and after time periods will not later confound analysis. One obvious covariate during the design phase was fish availability, which received attention during design and before-phase sampling. Other potential covariates were expected to be among the ambient conditions (e.g., tidal height, river flow) and among the ship and wake characteristics. However, precisely which of the several ambient conditions and ship and wake characteristics would be appropriate covariates was not evident during design or even during the pilot-phase sampling.

Single-variable and multivariate regression analyses were used to discern which ambient conditions and ship or wake characteristics would be appropriate covariates. First, we examined the incidence of stranding events versus the ambient conditions and ship characteristics. Second, we examined the incidence of stranding events versus ambient conditions and wave characteristics. Third, we examined wave characteristics versus ambient conditions and ship characteristics.

6.2 Incidence of Stranding Versus Ambient Conditions and Ship Characteristics

Nineteen independent variables were considered as potential factors affecting the incidence of smolt stranding. Four variables reflecting ambient conditions were considered:

- tidal stage: ebbing, flooding, low slack, and high slack
- tidal height
- river flow
- current velocity (knots)

Current velocity measured in m/sec was also available, but mirrored the values of current velocity in knots, so only the velocity measured in knots was used. Eleven variables reflecting ship characteristics were considered, including several constructed from other variables:

- ship type: five types of vessels (car carrier, bulk carrier, oil tanker, container vessel, and other)
- ship direction: upstream or downstream
- ship condition: unloaded, partially loaded, and loaded
- ship distance: five levels of distance of the vessel from shore (near, near-middle, middle, middle-far, and far)
- ship time: duration of vessel passage (sec)
- ship speed over ground (knots)
- ship draft
- ship beam
- ship length
- ship block coefficient: draft×beam×length
- kinetic energy proxy: block × (ship speed)2/1 × 10−8

Two measures of ship speed over ground were available: one measured in knots and the other in m/sec. Because the difference in speed measures was only one of units, only the measurement in knots was used. The derived variable kinetic energy proxy was scaled by 10^{-8} to facilitate interpretation of model parameters.

In addition to the ambient and ship characteristics listed above, site, season, and fish density were also considered. Site (i.e., "location") was included as an indicator variable for the three study sites (BP, CL, and SI). Season was included as an indicator variable for the three seasons studied (summer, winter, and spring). Both a Chinook seine index and a more inclusive salmonid seine index were considered as measures of fish density.

Not all variables were measured for each passage trial. Thus, the degrees of freedom in the following models vary more than expected simply due to the type of covariates.

6.2.1 Single-variable Regressions

Single-variable logit regression models were analyzed to identify factors that may be related to stranding incidence. The results are summarized in Table 19 (also see Appendix B-1). Table 19 suggests that season ($p = 0.2192$), tidal stage ($p = 0.2947$), and ship distance ($p = 0.5277$) are not significantly related to stranding incidence, and that the remaining variables may be related to incidence. Tidal height ($p = 0.0045$), location ($p = 0.0055$), and ship time ($p = 0.0071$) are particularly indicated. Multivariate analyses considering the effects of these and other variables are explained below. Graphs showing the relationship between incidence of stranding and location (Figure 39), tidal height (Figure 40), ship time (Figure 41), kinetic energy (Figure 42), and salmonid density index (Figure 43) are shown below. Figure 39 shows a plot of the proportion of the stranding at the three different locations.

6.2.2 Multivariate Regressions

Several multiple regressions using combinations of ambient factors, ship characteristics, and fish density were considered. Because of the differing beach morphology and hydrology at the three locations, the location variable is included in all the following analyses.

With the location effect accounted for, the significance of each of the other variables was tested; the resulting p-values are shown in Table 20, with the individual analysis of deviance tables in Appendix B-2. It appears from Table 20 that most of the ship covariates (ship time, force or kinetic energy proxy, speed, beam, block coefficient, type, length, direction, and draft) may be related to the incidence of stranding, even when location is accounted for. Figures 44 through 47 show the fitted single-logistic curves, together with a non-parametric moving-average curve showing the proportion of the stranding versus the covariate. As previously described, the variable kinetic energy (which is rather a proxy for kinetic energy) is a function of the variables ship speed, and block coefficient (beam, length, and draft) and it is reasonable to expect that inclusion of kinetic energy in the model will obviate the need for these other ship variables. This is shown to be the case in Table 21, which gives the p-values for alternative variables when both location and kinetic energy are accounted for.

Table 19. Summary of Single-Variable Logit-Regression Analyses, With Covariates Ranked by Their p-Value

Independent Variable	p-value
Tidal Height	0.0045
Location	0.0055
Ship Time	0.0071
Ship Beam	0.0138
Kinetic Energy Proxy	0.0141
Ship Speed	0.0166
Current Velocity	0.0206
Ship Block	0.0262
Ship Direction	0.0364
Chinook Seine Index Count	0.0529
River Flow	0.0700
Ship Condition	0.0731
Ship Type	0.0782
Salmonid Seine Index Count	0.0821
Ship Length	0.0948
Ship Draft	0.1026
Season	0.2192
Tidal Stage	0.2947
Ship Distance	0.5277

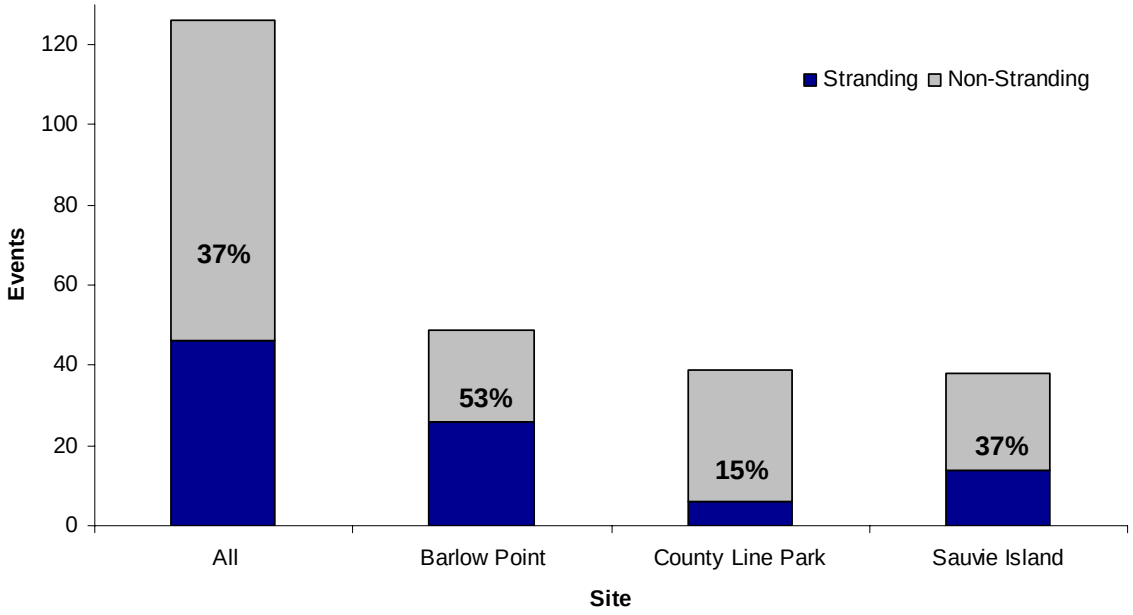


Figure 39. Proportion of Stranding Events by Site, for All Seasons

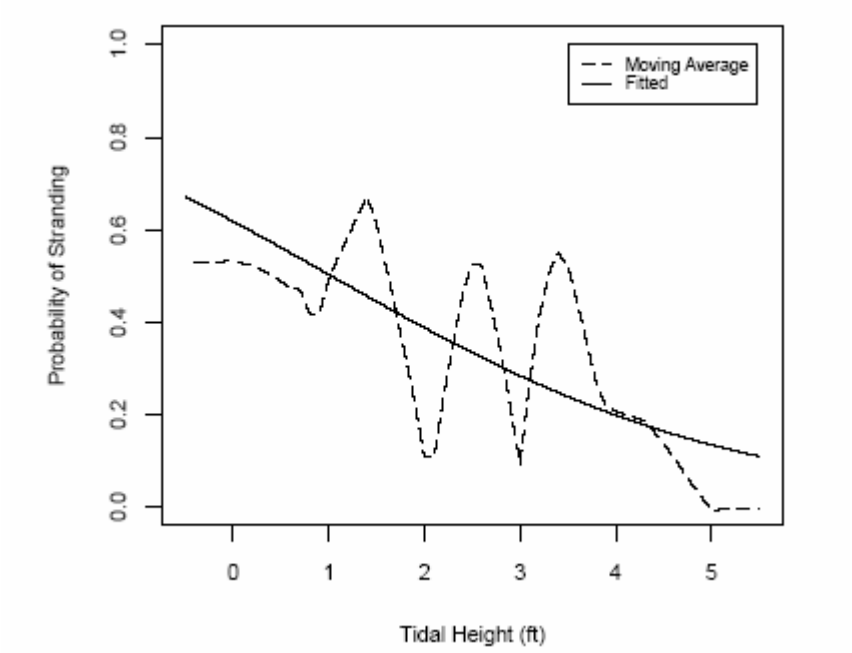


Figure 40. The Fitted Logistic Curve (solid line) of the Probability of Stranding Versus Tidal Height, and a Non-Parametric Moving Average Curve (dotted line) of the Proportion of Strandings Versus Tidal Height

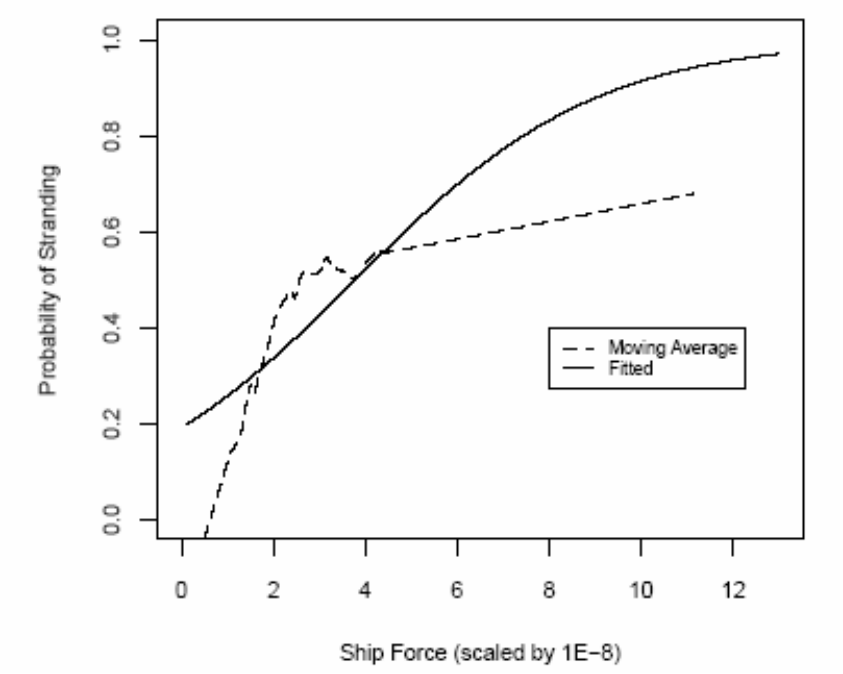


Figure 41. The Fitted Logistic Curve (solid line) of the Probability of Stranding Versus a Proxy for Ship Kinetic Energy (scaled by 10^{-8}), and a Non-Parametric Moving Average Curve (dotted line) of the Proportion of Strandings Versus Ship Time

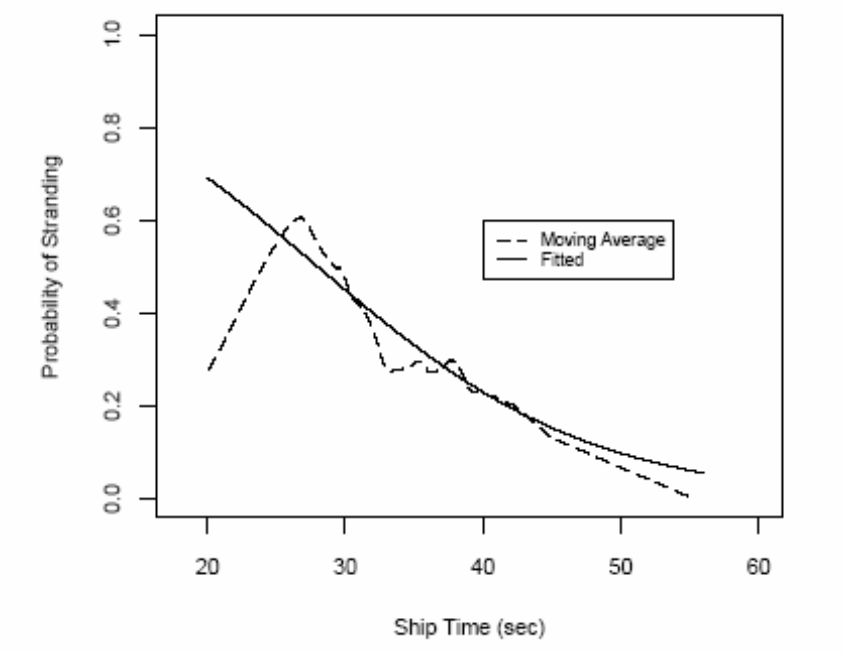


Figure 42. The Fitted Logistic Curve (solid line) of the Probability of Stranding Versus Ship Time, and a Non-Parametric Moving Average Curve (dotted line) of the Proportion of Stranding Versus Kinetic Energy

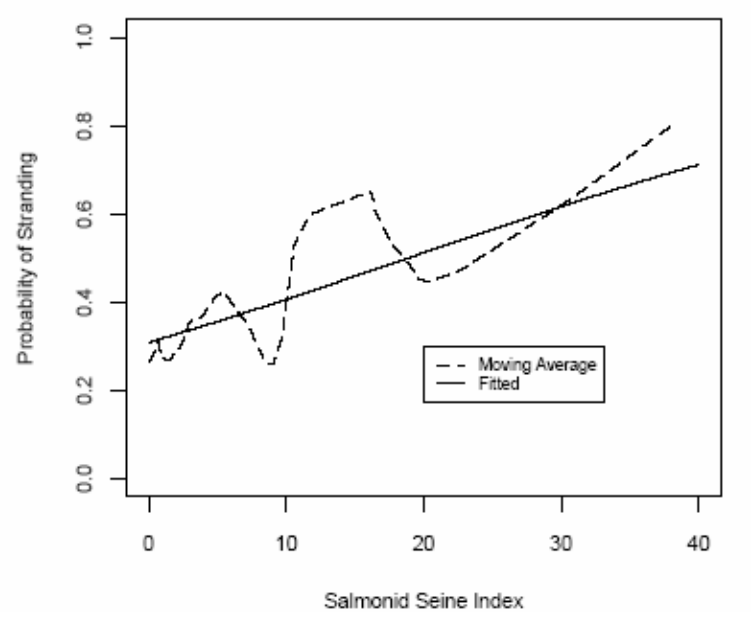


Figure 43. The Fitted Logistic Curve (solid line) of the Probability of Stranding Versus Salmonid Seine Index, and a Non-Parametric Moving Average Curve (dotted line) of the Proportion of Strandings Versus Salmonid Seine Index

Table 20. Summary of Added Significance of Individual Covariates in Two-Variable Logit-Regression Analyses With Location Accounted For

Independent Variable	p-value
Ship Time	0.0004
Kinetic Energy Proxy	0.0008
Ship Speed	0.0009
Ship Beam	0.0020
Ship Block	0.0074
Ship Type	0.0146
Tidal Height	0.0267
Ship Length	0.0268
Ship Direction	0.0281
Current Velocity	0.0363
Ship Draft	0.0399
Salmonid Seine Index Count	0.0420
Chinook Seine Index Count	0.0441
Ship Condition	0.0661
River Flow	0.1260
Season	0.1488
Ship Distance	0.2750
Tidal Stage	0.6944
Note: The covariates are ranked by their p-values.	

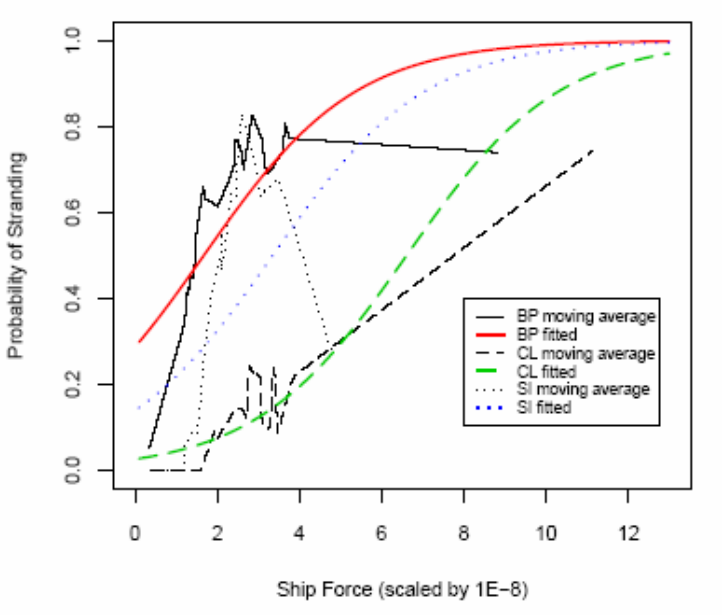


Figure 44. The Fitted Logistic Curves of the Probability of Stranding Versus Kinetic Energy (scaled by 10^{-8}), and Non-Parametric Moving Average Curves of the Proportion of Strandings Versus Kinetic Energy (scaled), Each for the Three Locations. The logistic curves vary significantly with location (p-value for equal lines: $p[F_{2,95} \geq 8.1798] = 0.0005$).

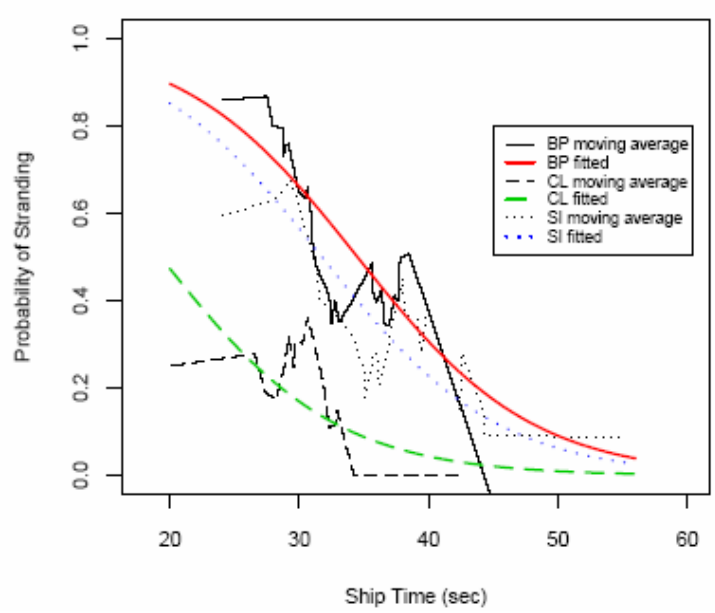


Figure 45. The Fitted Logistic Curves of the Probability of Stranding Versus Ship Time, and Non-Parametric Moving Average Curves of the Proportion of Strandings Versus Ship Time, Each for the Three Locations. The logistic curves vary significantly with location (p-value for equal lines: $p[F_{2,109} \geq 7.6829] = 0.0008$).

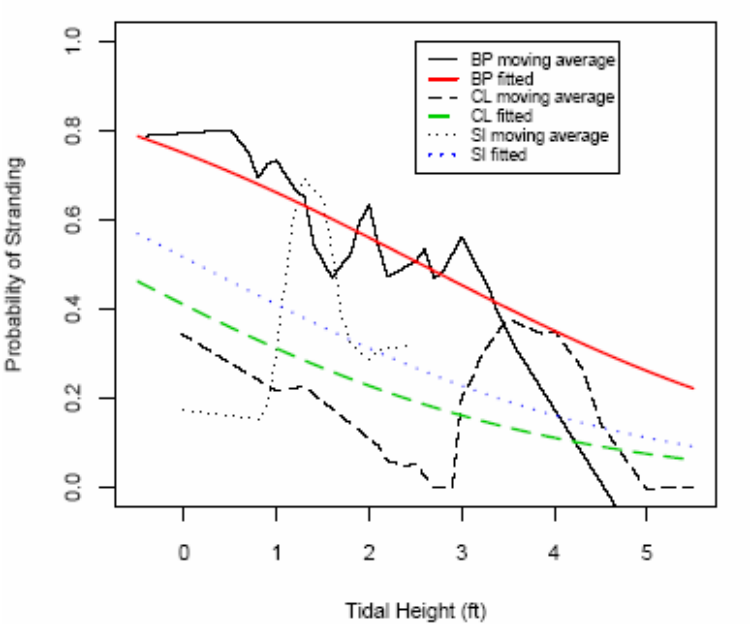


Figure 46. The Fitted Logistic Curves of the Probability of Stranding Versus Tidal Height, and Non-Parametric Moving Average Curves of the Proportion of Strandings Versus Tidal Height, Each for the Three Locations. The logistic curves vary significantly with location (p-value for equal lines: $p[F_{2,114} \geq 3.7640] = 0.0261$).

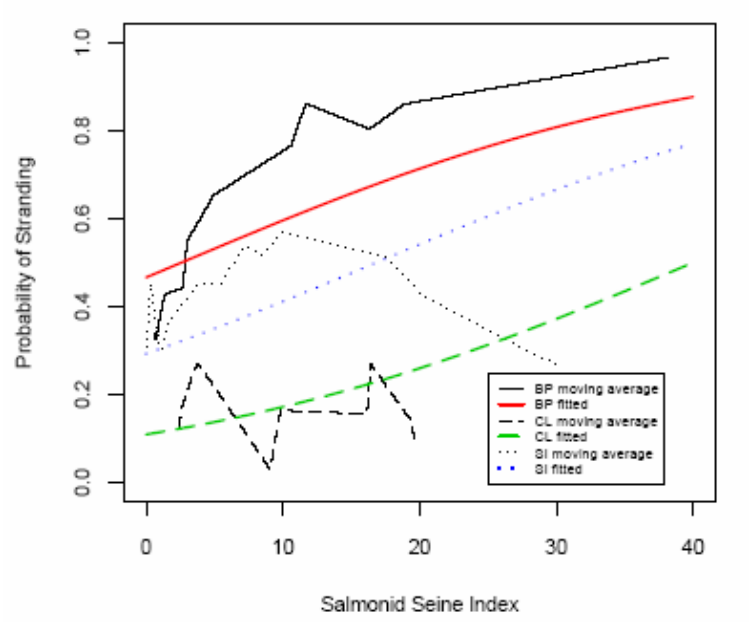


Figure 47. The Fitted Logistic Curves of the Probability of Stranding Versus Salmonid Seine Index, and Non-Parametric Moving Average Curves of the Proportion of Strandings Versus Salmonid Index, Each for the Three Locations. The logistic curves vary significantly with location [p-value for equal lines: $p[F_{2,114} \geq 6.0485] = 0.0032$).

Table 21. Summary of Trivariate Logit-Regression Analyses, With Covariates Ranked By Their p-Value, Given That Location and Kinetic Energy Are Accounted For

Independent Variable	p-value
Tidal Height	0.0729
Salmonid Seine Index	0.0806
Chinook Seine Index	0.0979
Season	0.1108
Ship Time	0.1285
Ship Type	0.1512
Ship Speed	0.1730
Ship Direction	0.9247
Ship Beam	0.2955
Current Velocity (Knots)	0.4484
Ship Condition	0.5321
River Flow	0.5905
Ship Distance From Shore	0.6657
Ship Block Coefficient	0.6835
Ship Length	0.6891
Tidal Stage	0.7823
Ship Draft	0.8307

From Table 21, it is apparent that with both location and kinetic energy accounted for, the remaining variables that may be related to the incidence of smolt stranding are tidal height ($p = 0.0729$), the salmonid density index ($p = 0.0806$), and the Chinook seine index ($p = 0.0979$).

There is some evidence that season, ship time, ship type, and ship speed may be related to smolt stranding, as well. The significance of added contributions of the different variables when location, kinetic energy proxy, and tidal height were already accounted for was examined, and the associated p-values are listed in Table 22.

Table 22 suggests that with location, kinetic energy proxy, and tidal height accounted for, no other variables may be sufficiently related to smolt stranding incidence to warrant inclusion in the model. Although ship time is weakly indicated ($p = 0.1288$), because it is closely related to the derived variable kinetic energy, it is not included as a fourth variable. Ship speed is not considered for a similar reason. The contribution of the salmonid index of fish density is considered below.

Table 22. Summary of Multivariate Logit-Regression Analyses, With Covariates Ranked by Their p-Value Given That Location, Kinetic Energy, and Tidal Height Are Accounted For

Independent Variable	p-value
Ship Time	0.1288
Ship Speed	0.1742
Salmonid Seine Index	0.1748
Ship Type	0.1845
Chinook Seine Index	0.2070
Ship Direction	0.2321
Season	0.2421
Ship Beam	0.2917
Tidal Stage	0.5094
Ship Condition	0.6399
Ship Distance From Shore	0.6539
River Flow	0.7352
Ship Length	0.7455
Ship Block Coefficient	0.7596
Ship Draft	0.8193
Current Velocity (knots)	0.8572

6.2.3 Interaction Effects

Possible interaction effects between location and either kinetic energy, tidal height, or salmonid index were considered. For each, it was concluded that the interaction effect of location with the other variable was non-significant, implying that although the effect of the amplitude of the values of the three variables varies with site, a change in these variables has the same effect on stranding incidence at each of the three sites ($p = 0.8000$, $p = 0.1103$, and $p = 0.3084$, respectively, for the interaction effect between location and kinetic energy, tidal height, and salmonid density) (Tables 23 through 25). The analysis of deviance tables that follow show the added contributions of each term (variable), given that the variables listed above it in the table are already in the model. Thus, the listed F-statistics test the significance of the variable relative to the model that includes the previously listed variables, rather than to the model with all terms listed in the table.

Interaction effects between kinetic energy and tidal height were also considered (Table 26). It appears that there is a significant interaction effect between kinetic energy and tidal height ($F_{1,92} = 3.2555$, $p = 0.0745$). This indicates that the effect of a given increase in kinetic energy varies with tidal height, although the effect of the increase is the same at the three different locations.

Table 23. Analysis of Deviance Table Examining the Effect of the Interaction Between Location and Kinetic Energy

Source	DF	DEV	MDEV	F	P
Total $_{Corr}$	98	132.775			
Location	2	12.870	6.435		
Kinetic energy proxy	1	13.489	13.489		
Tidal Height	1	3.597	3.597		
Salmonid Density	1	2.026	2.026	$F_{1,93}$ = 1.8697	0.1748
Location X Kinetic energy	2	0.493	0.247	$F_{2,91}$ = 0.2237	0.8000
Error	91	100.280	1.102		

Notes:
- The F1,93 statistic for salmonid density tests the significance of the added contribution of salmonid density when location, kinetic energy proxy, and tidal height are accounted for.
- The $F_{2,91}$ statistic for the interaction term (location × kinetic energy) tests the significance of the added contribution of the interaction term when the preceding four variables are accounted for.
- Overall Model $p(F_{7,91}) \geq 4.2100 = 0.0005$, $r^2 = 0.2446$.

Table 24. Analysis of Deviance Table Examining Effect of Interaction Between Location and Tidal Height

Source	DF	DEV	MDEV	F	P
Total $_{Corr}$	98	132.775			
Location	2	12.870	6.435		
Kinetic energy	1	13.489	13.489		
Tidal Height	1	3.597	3.597		
Salmonid Density	1	2.026	2.026	$F_{1,93}$ = 1.8697	0.1748
Location X Tidal Height	2	4.767	2.384	$F_{2,91}$ = 2.2592	0.1103
Error	91	96.006	16.001		

Note: Overall Model $p(F_{7,91}) \geq 4.9761 = 0.000085$, $r^2 = 0.2768$.

Table 25. Analysis of Deviance Table Examining Effect of Interaction Between Location and Salmonid Density

Source	DF	DEV	MDEV	F	P
Total $_{Corr}$	98	132.775			
Location	2	12.870	6.435		
Kinetic energy	1	13.489	13.489		
Tidal Height	1	3.597	3.597		
Salmonid Density	1	2.026	2.026	$F_{1,93}$ = 1.8697	0.1748
Location X Salmonid Density	2	2.572	1.286	$F_{2,91}$ = 1.1917	0.3084
Error	91	98.201	1.079		

Note: Overall Model p(F7,91) ≥4.5743 = 0.00021, $r^2 = 0.2603$.

Table 26. Analysis of Deviance Table Examining Effect of Interaction Between Kinetic Energy and Tidal Height

Source	DF	DEV	MDEV	F	P
Total $_{Corr}$	98	132.775			
Location	2	12.870	6.435		
Kinetic energy	1	13.489	13.489		
Tidal Height	1	3.597	3.597		
Salmonid Density	1	2.026	2.026	$F_{1,93}$ = 1.8697	0.1748
Kinetic Energy Proxy x Tidal Height	1	3.444	3.444	$F_{2,91}$ = 3.2555	0.0745
Error	91	97.328	1.058		
Note: Overall Model p($F_{6,92}$) ≥5.5813) = 0.000057, r^2 = 0.2669.					

A possible interaction effect between kinetic energy and salmonid density (instead of tidal height) was also considered; the interaction effect between kinetic energy and salmonid density was found to be insignificant (p[$F_{1,92}$ ≥1.1658] = 0.2831, r^2 = 0.2504). Also, a possible interaction between tidal height and salmonid density was considered, in addition to the interaction between kinetic energy and tidal height; the interaction effect between tidal height and salmonid density was found to be significant (p = 0.0297). The analysis of deviance table for this model is below (Table 27).

The model in Table 27 accounts for the largest amount of variation in incidence of stranding (r^2 = 0.3042) among the models considered, and is biologically reasonable. Because of these considerations and the significance of the interaction between tidal height and salmonid density, this model was selected as the final model.

Table 27. Analysis of Deviance Table Examining Effect of Interaction Between Tidal Height and Salmonid Density

Source	DF	DEV	MDEV	F	P
Total $_{Corr}$	98	132.775			
Location	2	12.870	6.435		
Kinetic Energy Proxy	1	13.489	13.489		
Tidal Height	1	3.597	3.597		
Salmonid Density	1	2.026	2.026	$F_{1,93}$ = 1.8697	0.1748
Kinetic Energy Proxy X Tidal Height	1	3.444	3.444	$F_{1,92}$ = 3.2555	0.0745
Tidal Height X Salmonid Density	1	4.954	4.954	$F_{1,91}$ = 4.8803	0.0745
Error	91	97.374	1.015		
Note: Overall Model p($F_{7,91}$) ≥5.6783) = 0.000018, r^2 = 0.3042.					

In summary, the final model has the following form:

Stranding~ Location + Kinetic Energy Proxy + Tidal Height + Salmonid Density + Kinetic Energy Proxy × Tidal Height + Tidal Height × Salmonid Density.

The coefficients of the terms in the final model are given in Table 28.

Table 28. Coefficients from Final Logistic Model of Regression 1: Stranding~ Location + Kinetic Energy Proxy + Tidal Height + Salmonid Density + Kinetic Energy Proxy×Tidal Height + Tidal Height×Salmonid Density

Independent Variable	Coefficient	S.E.
Intercept	-1.0945	1.1843
Location 2 (CL)	-3.1547	0.9856
Location 3 (CL)	-1.3672	0.6063
Kinetic Energy Proxy (scaled)	1.2334	0.4011
Tidal Height	-0.2310	0.4828
Salmonid Density	-0.0714	0.0589
Kinetic Energy Proxy (scaled) x Tidal Height	-0.2554	0.1357
Tidal Height x Salmonid Density	0.0736	0.0358

6.3 Incidence of Stranding Versus Ambient Conditions and Wave Characteristics

6.3.1 Single-Variable Regressions

Seventeen single-variable regressions were analyzed independently to identify potential factors affecting incidence of stranding. Four variables reflecting ambient conditions were considered:

- Tidal Stage: indicator variable for four tidal stages (ebbing, flooding, low slack, and high slack)
- Tidal Height
- River Flow
- Current Velocity (knots)

Current velocity measured in m/sec was also available, but mirrored the values of current velocity in knots, so only the velocity measured in knots was used. Nine variables reflecting wave characteristics were considered, including several constructed from other variables:

- Run-up Distance
- Draw-down Distance
- Total Wave Excursion: run-up distance plus draw-down distance (horizontal)
- Maximum Run-up Height
- Maximum Draw-down Height
- Maximum Water Level
- Run-up Velocity (measured with gage)
- Run-up Velocity (measured with camera)
- Wash-back Velocity (measured with gage)

The two measures of run-up velocity do not appear related, so both measures were considered. Some measures of wave characteristics were unavailable for a large number of records, in particular run-up velocity and washback velocity, and to a lesser extent, maximum run-up and draw-down heights. In addition to the ambient and wave characteristics listed above, site, season, and fish density were also considered. Site (i.e., "location") was included as an indicator variable for the three study sites (BP, CL, and SI). Season was included as an indicator variable for the three seasons studied (summer, winter, and spring). Both a Chinook seine index and a more inclusive salmonid seine index were considered as measures of fish density. The results for the 17 single-variable regressions are shown in Table 29.

Table 29. Summary of Single-Variable Logit-Regression Analyses, With Covariates Ranked by Their p-Value

Independent Variable	p-value
Total Wave Distance	0.0004
Draw-Down Distance	0.0006
Run-Up Distance	0.0016
Tidal Height	0.0045
Location	0.0055
River Flow	0.0700
Current Velocity (knots)	0.0206
Maximum Draw-down Height	0.0393
Chinook Seine Index	0.0529
Salmonid Seine Index	0.0821
Maximum Run-up Height	0.0956
Run-up Velocity	0.1509
Season	0.2192
Tidal Stage	0.2947
Maximum Water Level	0.3368
Washback Velocity	0.7118
Run-up velocity (camera)	0.9943

Several factors appear unrelated to incidence of stranding from Table 29: season, tidal stage, maximum water level, wash-back velocity, and run-up velocity (camera). Run-up velocity (gage) is not strongly indicated, but is considered further. Of the remaining nine covariates, five had p-values <0.01: total wave distance ($p = 0.0004$), draw-down distance ($p = 0.0006$), run-up distance ($p = 0.0016$), tidal height ($p = 0.0045$), and location (i.e., site; $p = 0.0055$). The remaining variables are indicated at slightly lower levels of significance (Table 19; Appendix B-3). The three measures of wave velocity (run-up velocity with camera, run-up velocity with gage, and wash-back velocity) may appear insignificant because of the large number of missing values among these data. A graph showing the fitted logistic curve relating incidence of stranding to total wave distance is given below (Figure 48). The fitted single-variable logistic curve is shown, together with a non-parametric moving average curve showing the proportion of the stranding versus the covariate. Figures 39 and 40 show the relationship between stranding incidence and location and tidal height, respectively.

6.3.2 Multivariate Regressions

Based on the results shown in Table 29, certain factors were considered in multivariate regressions. Because of varying topography and hydrology across sites, location was included in all multivariate regressions. With the location effect accounted for, the significance of each of the other variables was examined; the resulting p-values are shown in Table 30.

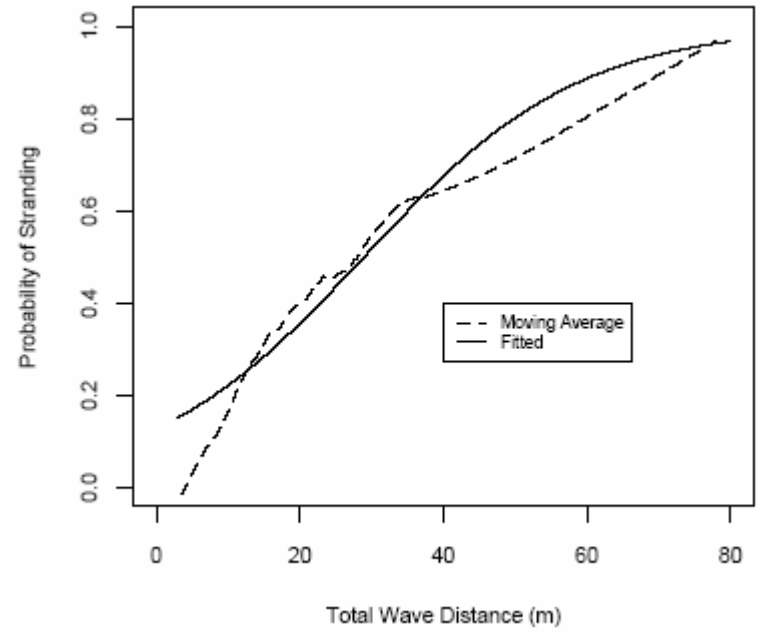


Figure 48. The Fitted Logistic Curve (solid line) of the Probability of Stranding Versus Total Wave Distance, and a Non-Parametric Moving Average Curve (dotted line) of the Proportion of Strandings Versus Total Wave Distance (horizontal)

Table 30. Summary of Added Significance of Individual Covariates in Two-Variable Logit-Regression Analyses With Location Accounted For

Independent Variable	p-value
Total Wave Distance	0.0003
Draw-down distance	0.0005
Run-up distance	0.0008
Maximum draw-down Height	0.0023
Maximum Run-up Height	0.0041
Tidal Height	0.0267
Current Velocity (knots)	0.0363
Salmonid Seine Index	0.0420
Chinook Seine Index	0.0441
Run-up Velocity (gage)	0.1158
River Flow	0.1260
Season	0.1488
Maximum Water Level	0.2073
Run-up Velocity (camera)	0.4778
Washback Velocity	0.6015
Tidal Stage	0.6994
Note: The covariates are ranked by their p-values.	

Table 30 indicates that measures of both horizontal wave distance (total wave distance, draw-down distance, and run-up distance) and (vertical) wave height (maximum draw-down height and maximum run-up height) are significant ($p < 0.01$ for each factor individually), even when location is accounted for. Additionally, tidal height ($p = 0.0267$), current velocity ($p = 0.0363$), and both fish density measures ($p < 0.05$ for each individually) are also significant when location is accounted for. Run-up velocity (gage), river flow, and season may be significant factors.

Because total wave distance is just the sum of the run-up distance and the draw-down distance, total wave distance was considered in future models, with both run-up distance and draw-down distance omitted. Similarly, because the two measures of fish density are closely related (Figure 49) and because the salmonid index ($p = 0.0420$) is slightly more significant than the Chinook index ($p = 0.0441$), only the salmonid index is used in future regressions. Figures 47 and 50 show graphs of the fitted logistic models that include both location and either total wave distance or salmonid index, respectively. The plots show the fitted logistic curves for the three locations, together with a non-parametric moving average curve showing the proportion of stranding versus the covariate, again for each of the three locations.

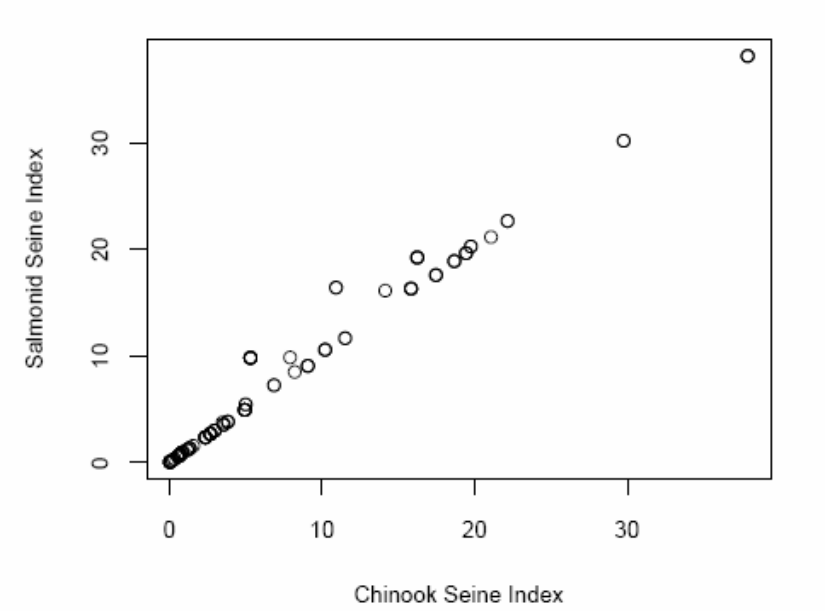


Figure 49. Scatterplot of the Two Measures of Fish Density, Across All Locations

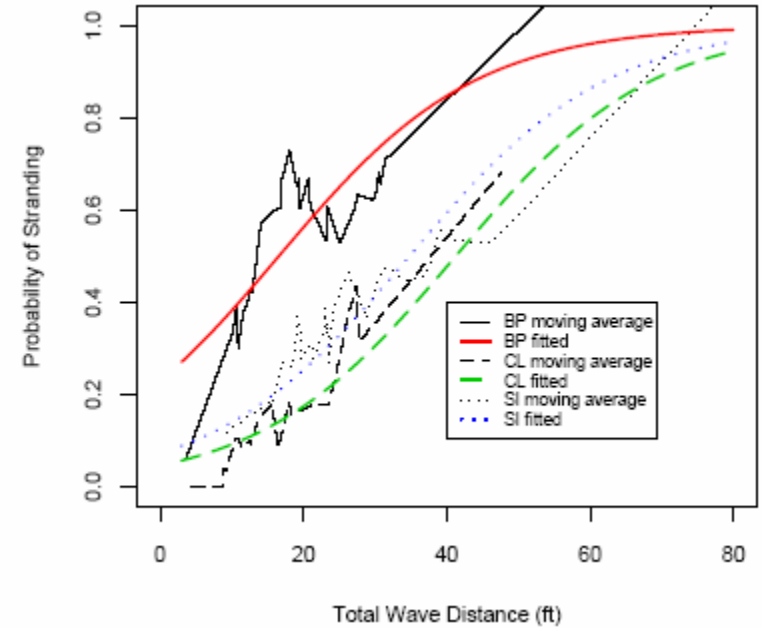


Figure 50. Fitted Logistic Curves of the Probability of Stranding Versus Total Wave Distance, and a Non-Parametric Moving Average Curve of the Proportion of Strandings Versus Total Wave Distance, Each for the Three Locations. The logistic curves vary significantly with location (p-value for equal lines: $p[F_{2,113} \geq 6.0208] = 0.0033$).

Total wave distance appears to be a key factor, and models that include location, total wave distance, and other variables were considered. With both total wave distance and location included, salmonid index ($p = 0.0013$), season ($p = 0.0082$), tidal height ($p = 0.0327$), and river flow ($p = 0.0397$) were all indicated as significant (Appendix B-4). With location, total wave distance, and salmonid index all included ($r^2 = 0.2616$), no other factor was found to be significant at the 10% level. Run-up velocity (gage) was found to be marginally related to stranding incidence ($p = 0.1735$) when location, total wave distance, and salmonid index were accounted for. However, inclusion of run-up velocity in the model decreased the amount of variation explained ($r^2 = 0.2436$), possibly a result of the large number of missing values in the run-up velocity data. Thus, neither run-up velocity nor other variables were considered further.

6.3.3 Interaction Effects

Several models examining possible interaction effects among location, total wave distance, and salmonid index were considered (Tables 31 and 32). In an analysis of the interaction between location and total wave distance (accounting for salmonid density), it was concluded that although the effect on stranding by the absolute value of the total wave distance varied across sites ($p = 0.0003$), the effect of a given increase in total wave distance was the same at each location ($p = 0.7777$) (Table 31). Similarly, in examining the interaction between location and salmonid density (accounting for wave distance), it was concluded that although the effect on stranding at different sites varied with fish density ($p = 0.0013$), a given change in fish density also had the same effect at each location ($p = 0.3354$) (Table 32). A possible interaction between total wave distance and salmonid density was considered, and found to be insignificant ($p[F_{1,111} \geq 0.1238] = 0.7256$).

After examining alternative models, the model selected includes the main effects of location, total wave distance, and salmonid density, with no interaction effects:

Stranding ~ Location + Total Wave Distance + Salmonid Density Index.

This main effect, trivariate model is significant ($p[F_{4,112} \geq 9.922] = 6.57 \times 10^{-7}$ for the overall model), and explains 26.2% of the variability in smolt stranding incidence ($r^2 = 0.2616$). Both total wave distance and salmonid density appear to be related to smolt stranding, but the relationship varies at the different sites. Parameters of the logistic model are listed in Table 33.

Table 31. Analysis of Deviance Table Examining Effect of Interaction Between Location and Total Wave Distance When Salmonid Density Is Accounted For

Source	DF	DEV	MDEV	F	P
Total $_{Corr}$	116	156.813			
Location	2	13.644	6.822		
Total Wave Distance	1	16.087	16.087	$F_{1,113} = 14.3045$	0.0003
Salmonid Density	1	11.297	11.297	$F_{1,113} = 10.9278$	0.0013
Location X Total Wave Distance	2	0.528	0.264	$F_{2,110} = 0.2520$	0.7777
Error	110	115.256	1.048		

Notes:
- The F-statistic for total wave distance tests the significance of the effect of total wave distance given that location is already accounted for, but without salmonid density in the model.
- Overall Model $p(F6,110) \geq 6.6103 = 5.47 \times 10^{-6}$, $r^2 = 0.2650$.

Table 32. Analysis of Deviance Table Examining Effect of Interaction Between Location and Salmonid Density When Total Wave Distance Is Accounted For

Source	DF	DEV	MDEV	F	P
Total $_{Corr}$	116	156.813			
Location	2	13.644	6.822		
Total Wave Distance	1	16.087	16.087	$F_{1,113} = 14.3045$	0.0003
Salmonid Density	1	11.297	11.297	$F_{1,113} = 10.9278$	0.0013
Location X Salmonid Density	2	2.277	1.139	$F_{2,110} = 1.1033$	0.3354
Error	110	113.506	1.032		
Note: Overall Model p(F6,110) ≥6.9949) = 2.55×10^{-6}, $r^2 = 0.2762$.					

Table 33. Coefficients from Final Logistic Model of Regression 2: Stranding _ Location + Total Wave Distance + Salmonid Density.

Independent Variable	Coefficient	S.E.
Intercept	-2.2883	0.6506
Location 2 (CL)	-2.0106	0.6129
Location 3 (SI)	-1.5336	0.5668
Total Wave Distance	0.0933	0.0227
Salmonid Density Index	0.0879	0.0289

6.4 Wave Height Versus Ship Characteristics and Ambient Conditions

Wave height (maximum run-up height plus maximum draw-down height) was used as a descriptor of wave characteristics. Relationships between wave height and several measures of ship characteristics and ambient conditions were examined using both simple linear regression and multivariate normal regression. Wave height was analyzed on the log scale to better fit regression assumptions. Eighteen independent variables were considered as potential factors affecting wave height. Five variables reflecting ambient conditions were considered:

- Tidal Stage (4 levels): ebbing, flooding, low slack, and high slack
- Tidal Stage (2 levels): ebbing or low slack, and flooding or high slack
- Tidal Height
- River Flow
- Current Velocity (knots)

Two forms of tidal stage indicator variables were considered because wave height appeared to be similar for ebbing and low slack tides, and also for flooding and high slack tides. Current velocity measured in m/sec was also available, but mirrored the values of current velocity in knots, so only the velocity measured in knots was used. Eleven variables reflecting ship characteristics were considered, including several constructed from other variables:

- Ship Type: indicator variable for five types of vessel (car carrier, bulk carrier, oil tanker, container vessel, and other)
- Ship Direction: indicator variable for upstream or downstream
- Ship Condition: indicator variable for unloaded, partially loaded, and loaded
- Ship Distance: indicator variable for five levels of distance of the vessel from shore (near, near-middle, middle, middle-far, and far)
- Ship Time: duration of vessel passage (sec)
- Ship Speed over ground (knots)
- Ship Draft
- Ship Beam
- Ship Length
- Ship Block Coefficient: Draft × Beam × Length
- Kinetic Energy Proxy: Block × (Speed)2 /1 × 10^{-8}

Two measures of ship speed over ground were available: one measured in knots and the other in m/sec. Because the difference in speed measures was only one of units, only the measurement in knots was used. The derived variable kinetic energy proxy was scaled by 10^{-8} to facilitate interpretation of model parameters.

In addition to the ambient and ship characteristics listed above, site (i.e., location) and season were also considered. Location was included as an indicator variable for the three study sites (BP, CL, and SI). Season was included as an indicator variable for the three seasons studied (summer, winter, and spring). Not all variables were measured for each passage trial. Thus, the degrees of freedom in the following models vary more than expected simply due to the type of covariates.

6.4.1 Single-Variate Regressions

It appears that season ($p = 0.2585$), ship direction ($p = 0.3196$), and the four-level measure of tidal stage ($p = 0.4188$) were not significant. There is marginal evidence that tidal height ($p = 0.1178$) and river flow ($p = 0.1235$) are related to wave height. The other variables considered are all indicated as being related to wave height, in particular the ship block coefficient ($p = 1 \times 10^{-5}$), kinetic energy ($p = 0.0001$), ship length ($p = 0.0002$), and ship type ($p = 0.0006$).

Figure 51 shows the pattern of wave heights across location. Figures 52 through 54 show the relationship between wave height and ship block coefficient, tidal height, and ship speed, respectively. The curves are fitted values from simple linear regressions summarized in Table 34. Figures 55 through 57 show the observed and predicted wave height values for the three different study sites versus ship block, tidal height, and ship speed, respectively.

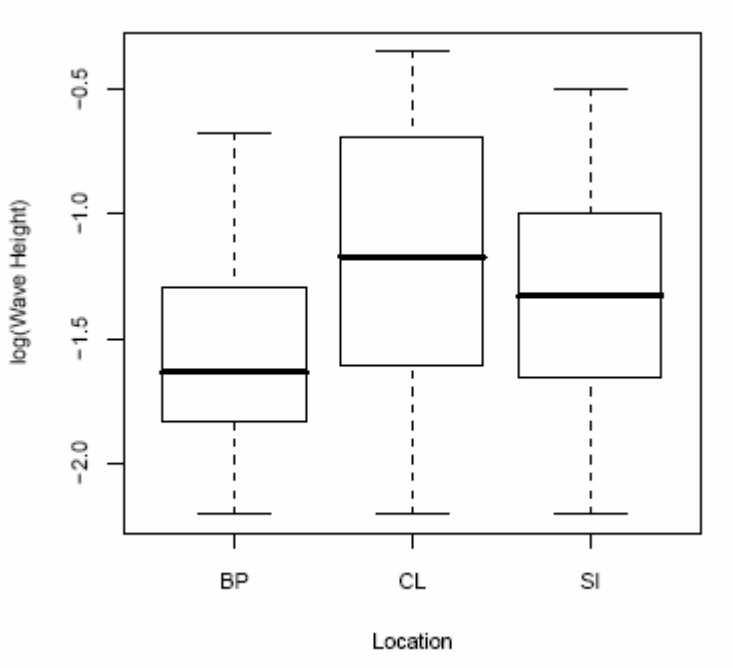


Figure 51. Wave Height (Log Scale) by Location

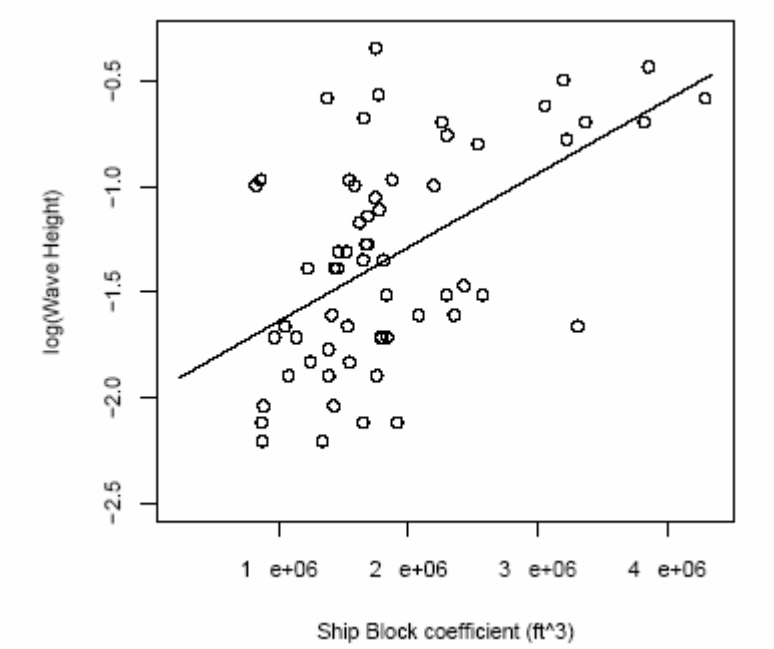


Figure 52. The Observed Values (points) and Fitted Values (line) of Wave Height (log scale) Versus Ship Block Coefficient

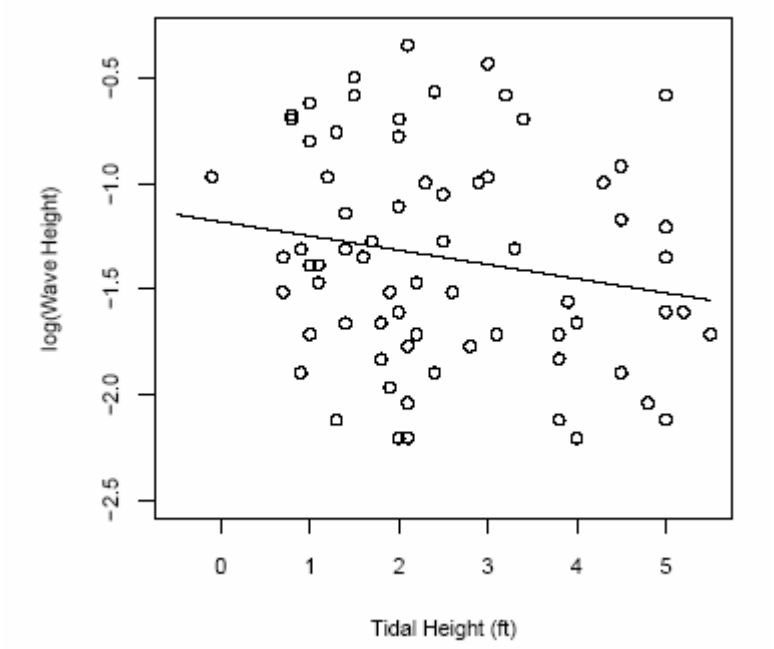


Figure 53. The Observed Values (points) and Fitted Values (line) of Wave Height (log scale) Versus Tidal Height

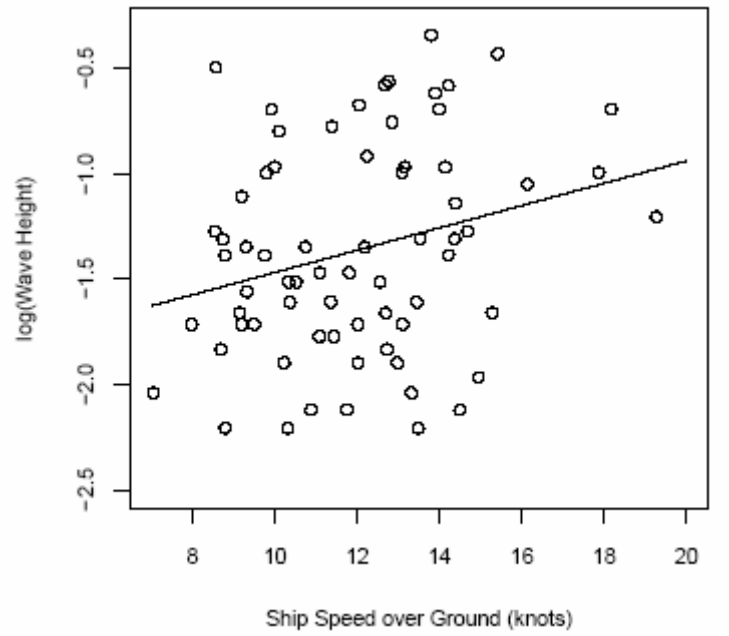


Figure 54. The Observed Values (points) and Fitted Values (line) of Wave Height (log scale) Versus Ship Speed Over Ground (in knots)

Table 34. Summary of Significance of Individual Covariates in Single-Variable Regression Analyses.

Independent Variable	p-value
Ship Block Coefficient	1e-05
Kinetic energy	0.0001
Ship Length	0.0002
Ship Type	0.0006
Ship Beam	0.0023
Ship Draft	0.0027
Ship Distance	0.0242
Ship Speed	0.0278
Ship Time	0.0350
Ship Condition	0.0398
Location	0.0433
Current Velocity (knots)	0.0486
Tidal Stage (2 levels)	0.0932
Tidal Height	0.1178
River Flow	0.1235
Season	0.2585
Ship Direction	0.3196
Tidal Stage	0.4188
Note: The covariates are ranked by their p-values.	

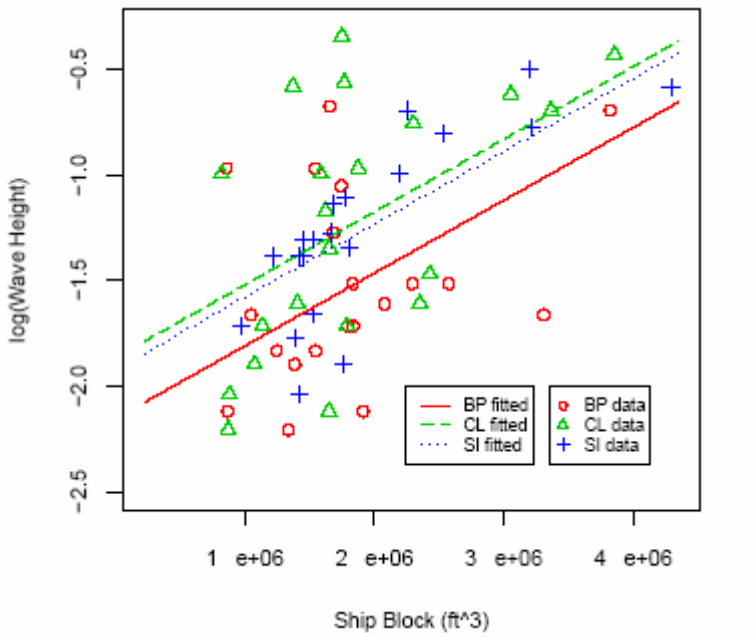


Figure 55. The Observed Values (points) and Fitted Values (line) of Wave Height (log scale) Versus Ship Block Coefficient for the Three Different Study Sites. The fitted curves vary with location (p-value for equal lines: $p[F_{2,57} \geq 2.635] = 0.0804$).

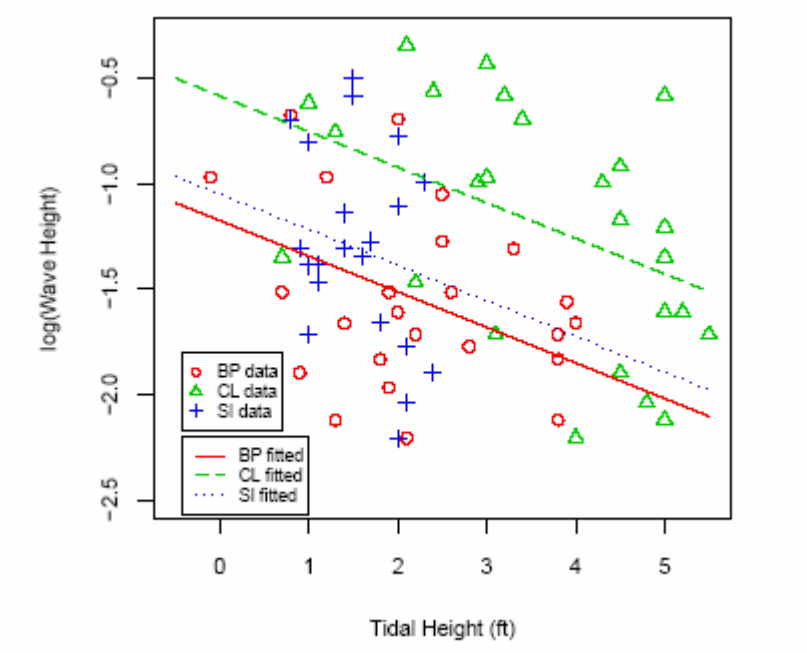


Figure 56. The Observed Values (points) and Fitted Values (line) of Wave Height (log scale) Versus Tidal Height for the Three Different Study Sites. The fitted curves vary with location (p-value for equal lines: $p[F_{2,67} \geq 8.0014] = 0.0008$).

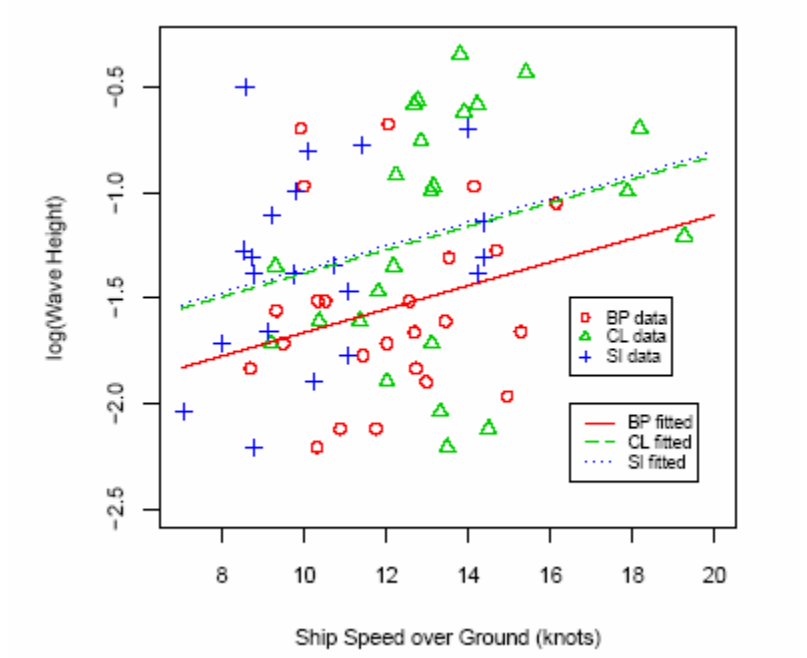


Figure 57. The Observed Values (points) and Fitted Values (line) of Wave Height (log scale) Versus Ship Speed Over Ground (in knots) for the Three Different Study Sites. The fitted curves vary with location (p-value for equal lines: $p[F_{2,65} \geq 2.9186] = 0.0611$).

6.4.2 Multivariate Regressions

The block coefficient appears to be the most significant single variable (Table 34), so it is included in the multivariate regressions. Beam, length, draft, and kinetic energy are all related to the block coefficient, so no multivariate model includes both block and one of these other four variables. The significance of the added contribution of the remaining variables, given that block coefficient is accounted for, is summarized in Table 35.

With block coefficient accounted for, it appears that tidal height ($p = 0.0360$), ship speed ($p = 0.0455$), current velocity ($p = 0.0615$), river flow ($p = 0.0779$), location ($p = 0.0804$), and ship time ($p = 0.0870$) are all possibly significantly related to wave height. Season ($p = 0.1657$) may be slightly related to wave height, but such a relationship may occur through the relationship between season and current velocity or river flow. Ship type ($p = 0.4549$) and condition ($p = 0.6616$) no longer appear related to wave height when block coefficient is accounted for; nor does the two-level measure of tidal stage ($p = 0.9562$), possibly because most trials occurred at ebbing or low slack tides.

Tidal height appears to be the most significant factor in affecting wave height, once the ship block coefficient is taken into account. However, because of the differing tidal regimes at the three study sites, inclusion of tidal height should be accompanied by location, as well. The added contribution of location, given block and tidal height, is significant ($p[F_{2,56} \geq 9.9860] = 0.0002$); all future models considered included ship block coefficient, tidal height, and location. The significance of the added contribution of the remaining variables is summarized in Table 36.

With block, tidal height, and location all accounted for, only ship speed ($p = 0.0532$) and ship time ($p = 0.0683$) appear significant. Ship speed is inversely related to ship time, so only one of these factors should be considered. Because ship speed appears slightly more significant, it is included. No other variable had a significant effect on wave height, when block, tidal height, location, and ship speed were all accounted for (Table 37).

Table 35. Summary of Significance of Individual Covariates in Bivariate Regression Analyses, With Ship Block Coefficient Accounted For

Independent Variable	**p-value**
Tidal Height	0.0360
Ship Speed	0.0455
Current Velocity (knots)	0.0615
River Flow	0.0779
Location	0.0804
Ship Time	0.0870
Season	0.1657
Ship Direction	0.3686
Ship Type	0.4549
Ship Distance	0.5653
Ship Condition	0.6616
Tidal Stage (4 levels)	0.8934
Tidal Stage (2 levels)	0.9562
Note: The covariates are ranked by their p-values.	

Table 36. Summary of Significance of Individual Covariates in Multivariate Regression Analyses, With Ship Block Coefficient, Tidal Height, and Location Accounted For

Independent Variable	p-value
Ship Speed	0.0532
Ship Time	0.0683
Ship Direction	0.3010
Ship Distance	0.3680
Ship Type	0.4052
Ship Condition	0.5919
Current velocity (knots)	0.6282
River Flow	0.6610
Season	0.6799
Tidal Stage (4 levels)	0.8003
Tidal Stage (2 levels)	0.9430
Note: The covariates are ranked by their p-values.	

Table 37. Summary of Significance of Individual Covariates in Multivariate Regression Analyses, With Ship Block Coefficient, Tidal Height, Location, and Ship Speed Accounted For

Independent Variable	p-value
Ship Type	0.4684
Ship Direction	0.6933
Ship Condition	0.5617
Ship Distance	0.5143
River Flow	0.9743
Tidal Stage (4 levels)	0.6502
Current Velocity (knots)	0.9047
Season	0.8129
Tidal Stage (2 levels)	0.8153
Note: The covariates are ranked by their p-values.	

6.4.3 Interaction Effects

Possible interaction effects among block, tidal height, location, and speed were considered; the results from these analyses are summarized in Table 38.

It appears from Table 38 that no interaction effect is significant. Thus, the final model has the form:

Log(Wave Height) ~ Ship Block + Tidal Height + Location + Ship Speed.

The coefficients for the model are given in Table 39.

Table 38. Summary of Analyses of Interaction Effects Among Ship Block Coefficient, Tidal Height, Location, and Speed, With All Four Main Effects Included in Each Model.

Interaction Effect	F-statistic	P-Value
Ship Block x Location	$F_{2,51} = 1.7773$	0.1794
Ship Block x Ship Speed	$F_{1,52} = 1.5616$	0.2170
Ship Block x Tidal Height	$F_{1,52} = 0.1931$	0.6622
Tidal Height x Location	$F_{2,51} = 0.3249$	0.7241
Tidal Height x Ship Speed	$F_{1,52} = 0.0606$	0.8066
Location x Ship Speed	$F_{2,51} = 0.0891$	0.9149
Note: The covariates are ranked by their p-values.		

Table 39. Coefficients From Final Model of Regression 3: Log(Wave Height) ~ Ship Block + Tidal Height + Location + Ship Speed

Independent Variable	Coefficient	S.E.
Intercept	-2.281	0.3325
Ship Block	3.276e-07	6.642e-08
Tidal Height	-0.1886	0.0456
Location 2 (CL)	0.5214	0.1415
Location 3 (SI)	0.2122	0.1260
Ship Speed	0.0454	0.0230

Notes:
- Ship Speed is measured in knots.
- Overall model $p(F_{5,53} \geq 12.1079) = 7.6 \times 10^{-8}$, $r^2 = 0.5332$.

6.5 Wave Excursion vs. Ship Characteristics and Ambient Conditions

Wave excursion (maximum run-up distance plus maximum draw-down distance across the beach) was used as a descriptor of wave characteristics. Relationships between wave excursion and several measures of ship characteristics and ambient conditions were examined using both simple linear regression and multivariate normal regression. Wave excursion was analyzed on the log scale to better fit regression assumptions (Table 40).

The resulting model has the form:

Log(Wave Excursion) ~ Kinetic Energy + Tidal Height + Site.

Table 40. Coefficients From the Model of Regression 4: Log(Wave Excursion) ~ Kinetic Energy + Tidal Height + Site, $r^2 = 0.415$.

Independent Variable	Coefficient	S.E.	p-value
Intercept	1.289	0.0514	<0.001
Kinetic Energy Proxy	0.000714	0.000117	<0.001
Tidal Height	-0.0341	0.0168	0.046
BP	-0.153	0.0500	0.003
CL	-0.259	0.0614	<0.001

Exhibit List 328

7.0 Discussion

The pilot study and extended pre-deepening field sampling proved the value of the experimental design and generally confirmed the appropriateness of the approaches and equipment in evaluating the complexities associated with ship wakes and fish stranding.

7.1 Sites

The study observed stranding at all three sites. This observation validates their selection under the criterion for a before-and-after study that the variable of interest must be known to occur at the sampling locations. Physically, the three sites were also selected based on their low slope, and all have an average slope of <5%. Although the sites represent low-slope beaches on the river scale, each has distinct differences at the fine scale of local beaches.

Barlow Point has the lowest slope and the finest sand with slowest infiltration rate. In fact, the infiltration rate is so low at Barrow Point that little or no infiltration may occur during the time it takes for a wave to run-up and wash-back. In contrast, County Line has the highest slope with the coarsest sand and highest infiltration. At County Line, infiltration rate may be high enough that infiltration could affect the speed of wash-back. Sauvie Island is between the other two sites but is closer to County Line in many respects.

Perhaps more important than infiltration is the local-scale shoreline structure at each site. The differential GPS (dGPS) waypoints taken at the location of each stranded fish enabled the critical observation that fish were consistently stranded at one or two specific locations and not evenly distributed over the beach (Figures 25 through 27). Also, these “hot spot” locations are characterized by distinct beach morphologies that interact with onshore waves in dynamic and complex ways. Field observations and video records validated that these "hot spots" were indeed areas where complex waves occurred. At Barlow Point, for example, the area at the upstream end of the site where the majority of stranding occurred was heavily influenced by complex waves. Onshore waves from ship wakes interacted with the shoreline structure (Reno mat) upstream of the site. These waves propagated along the Reno mat as cross waves, and finally broke at the end of the Reno mat, where the shoreline structure had a berm. It is in this area where stranding occurrence was the highest. This effect was observed at both Sauvie Island and County Line Park, though not to the same extent as at Barlow Point.

7.2 Fish Availability Index

Biologically, the sites differed in the fish species composition. However, the species of interest, Chinook salmon and other salmonids, were found at all sites during all seasons. The FAI based on beach seining in downstream reference areas immediately adjacent to the survey areas proved appropriate.

The DIDSON camera and narrow-beam sonar are known to work well elsewhere but did not reliably discern fish in the extremely shallow (<1 m) areas that were surveyed in this study. The observed sensitivity of the seines to change among the sites and over time indicated that the seines were an

appropriate approach to indexing fish availability in the before-and-after design of the overall project. Also, limited mortality to Chinook salmon occurred during seining and catch-processing.

The beach seine and resulting FAI provided adequate quantitative data. Although fish composition changed over time and with each location, salmon (specifically Chinook) were present in all sampling seasons and the FAI (salmonid density) was found to be a significant factor in stranding. Additionally, a comparison of seined fish with stranded fish showed Chinook were stranded more often than seined. Other fish were stranded at equal or lower frequencies than seined. Wolter and Arlinghaus (2003) concluded from studies of wake impacts along European rivers that impacts on fish communities occurred when the run-up velocity exceeded the swimming abilities of fish. The differences between seined and stranded fish may be related to differences in swimming ability or behavior or some combination of both. The finding that total wave excursion across the beach is a significant factor in probability of stranding also suggests swimming ability and behavior may play a role. For example, a rheotactic response by Chinook salmon during draw-down may aggregate the fish at the water's edge, and the aggregation may then be carried up the beach by the run-up wave. Investigation of swimming speed and other behavioral factors is warranted to further understand the increased predisposition to stranding among Chinook.

7.3 Wake Characteristics and Instrumentation

For measurement of wake characteristics, the wave staff gages proved adequate, whereas the wave run-up gage proved to have some difficulties. The addition of the video recording helped offset some of the problems associated with the wave run-up gage and provided additional information otherwise not possible. First, the two wave staff gages deployed 5 m apart adequately captured the wave height dynamics; for cases in which only a single gage was used, the nature of the wave was still characterized successfully, given that only a slight phase shift was evident between the two gages (attributable to the 5-m difference in placement location). The wave staff-gage records were of fine enough detail to detect the long-period oscillations not seen elsewhere in studies of this nature. At beaches with low slope, such as Sauvie Island and Barlow Point, the width of the beach at low tide created difficulty in placing the gages for maximum effect while also ensuring the electronics stayed dry. The cable length (~95 m) and water depth proved somewhat limiting and resulted in several events in which the gages were dry at draw-down or low tide; a longer cable may alleviate some of the problems; however, the shore-based installation precluded placement in water depths greater than 1.5 m, which is less than the mean tide range at some sites.

The best use of the run-up gage was that of estimating the speed of run-up and wash-back, which were obtained when the wave crests of the onshore wave were parallel to the shoreline and the gage was in optimal position. To maximize such sampling, the wave run-up gage needed to be placed at the water line; however, as the tidal height changed, the gage would be in a sub-optimal location, limiting its ability to capture the full extent of the wave. Reinstalling the gage as the tide moved was impractical, because during installation, passage and stranding observations would be missed.

When the wave climate became complex, the run-up gage did not yield speed measurements. Waves moving across (rather than onto) the beach occurred during certain wake events (see Figure 10 and discussion of cross waves in Section 4.3.4). Such cross waves lifted all the wave run-up gage floats

simultaneously and disrupted the ability of the data record to support speed calculations. The lack of reliability with the wave run-up gage led to modification of methods for measuring run-up velocity.

Video observations were included to augment measurements of wave velocity. The video camera proved reliable and logistically sound. Unlike the wave run-up gage, the camera could be moved with the tide to be in optimal position for each event; thus, the number of unsuccessful recordings was fewer with the camera than with the run-up gage. Error in the interpretation of video records was minimized by using software intended for quantitative analysis. Although the video camera captured cross waves for qualitative description, the ability to quantify cross waves was limited due to angle of view. Additionally, the use of the camera at night has not been tested, though portable or infrared lights may enable night-video observations.

Wake measurement was augmented by staking the points of maximum draw-down and maximum run-up, thereby capturing the full across-beach extent of these end points.

7.4 Multivariate Regression Equations and Conceptual Models

One overall objective of the study was to determine the relationships among factors that influence the probability of stranding. This analysis would have two outcomes: 1) a determination of factors that need to be considered in the before-and-after comparison, and 2) an increased understanding of the mechanisms that produce stranding. During the design phase, the need to address fish availability was obvious, but the roles and linkages among other potential factors were not. Figure 58 is the original conceptual model the study team conceived after the summer field season. The indicated factors were derived from the literature, the pilot study, the summer field season, and other field observations. The strength of each component was unknown, though all factors were suggested to have some causal relationship to stranding.

Single factor and multivariate regression analyses of the full set of before data were undertaken to assess statistically those roles and linkages and to discern which ambient conditions and ship or wake characteristics would be appropriate covariates. It is now clear that no single factor appears to be the cause for juvenile salmon stranding. Statistical analyses of the covariates resulted in the following multivariate equations:

- Stranding Probability ~ Location + Kinetic Energy Proxy + Tidal Height + Salmonid Density Index + Kinetic Energy Proxy × Tidal Height + Tidal Height × Salmonid Density Index.
- Stranding Probability ~ Location + Total Wave Excursion + Salmonid Density Index.
- Log(Wave Height) ~ Ship Block Coefficient + Tidal Height + Location + Ship Speed.
- Log(Wave Excursion) ~ Kinetic Energy Proxy + Tidal Height + Location

These equations indicate that location, a proxy for ship kinetic energy (which accounts for ship size and speed), tidal height, total wave excursion, and an index of salmon density along the beach are the primary factors in stranding occurrences. Figure 59 is the conceptual model developed as a result of our complete “before” field study and the statistical analyses.

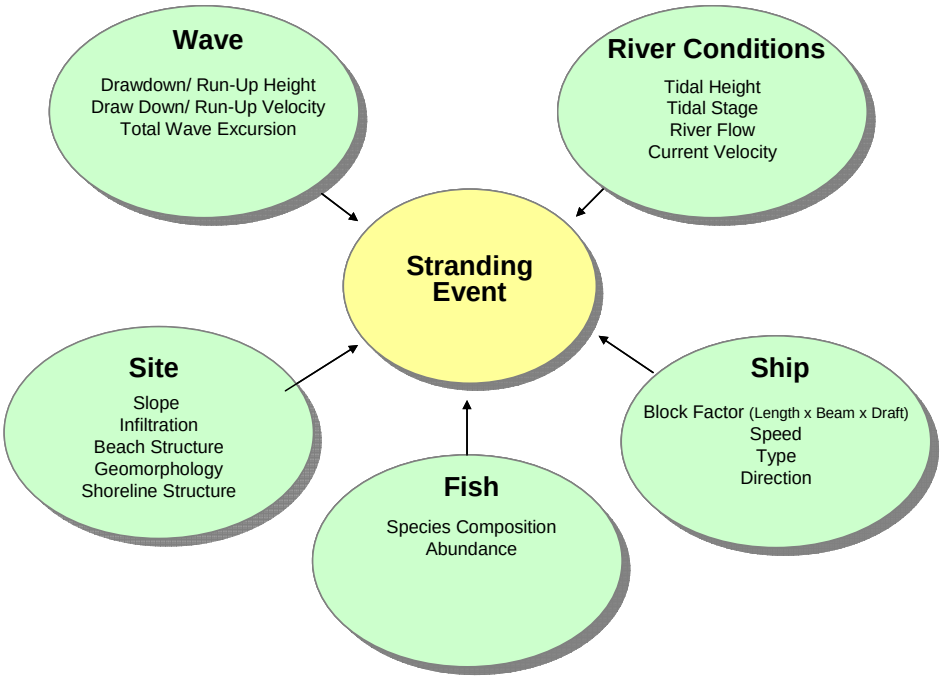


Figure 58. Original Conceptual Model of Stranding

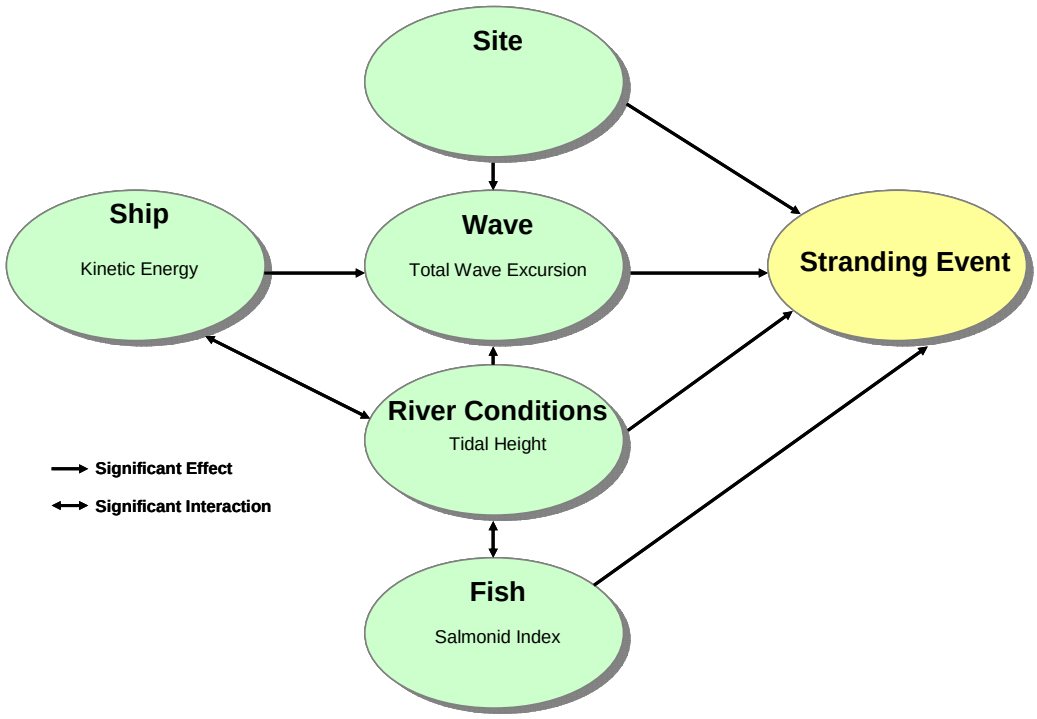


Figure 59. Current Conceptual Model, With Statistically Significant Factors and Linkages

Although the mechanisms of stranding are still not completely understood, the linkages in this model are all statistically significant, are consistent with what is known about biological and physical processes, and represent a substantial advance in our understanding of fish stranding by ship wakes. Rather than any single factor, a series of interlinked factors act together to produce stranding during a ship passage. The kinetic energy proxy derived from the size and speed of the vessel provides the energy producing the wake. Tidal height influences both the fish availability and the interaction of the wake with the beach at each site. Increasing total distance from draw-down to run-up is the wake characteristic that increases the probability of stranding. Increasing juvenile salmonid density in the nearshore increases the probability of stranding and remains a significant factor even after the location is taken into account. The multivariate regression equations, the video observations of waves, and the presence of stranding hot spots all indicate that fine-scale site characteristics at a specific location play a dominant role in structuring the processes that produce the onshore wave and subsequent fish stranding.

7.5 Assessment of Impacts of Channel Deepening

The purpose of the before-and-after impact assessment is to determine whether the probability of juvenile salmon stranding will increase once the LCR is deepened ("post-dredging"). There are two questions to be examined:

1. For similar ambient river conditions, fish availability, and vessel conditions, does the probability of stranding relative to pre-deepening conditions increase after channel deepening?
2. If yes to the above question, then do the patterns of use by deeper-draft vessels change after deepening and, holding other factors equal, is there a greater probability of stranding associated with such changes compared with pre-deepening conditions?

The post-deepening impact assessment will examine both questions using the above multivariate regression equations derived from the before data. For juvenile salmon stranding by ship wakes, we recommend the impact assessment decision process outlined in Figure 60 and described below.

7.5.1 Test of the Physical Effects of Channel Deepening on the Incidence of Juvenile Salmon Stranding (Test 1)

A logistic regression model was constructed using the pre-deepening surveys of the form

$$\ln\left(\frac{\hat{p}_i}{1-\hat{p}_i}\right) = \underset{\sim}{\beta}'\underset{\sim}{x}_i \tag{19}$$

or

$$\hat{p}_i = \frac{e^{\underset{\sim}{\beta}'\underset{\sim}{x}_i}}{1+e^{\underset{\sim}{\beta}'\underset{\sim}{x}_i}} \quad \text{(Model 1)} \tag{20}$$

where $\hat{p}_i$ is the estimated probability of smolt stranding for the *i*th trial, $\underset{\sim}{x}_i$ is the vector of covariates for the *i*th trial, and $\underset{\sim}{\beta}$ is the vector of regression coefficients.

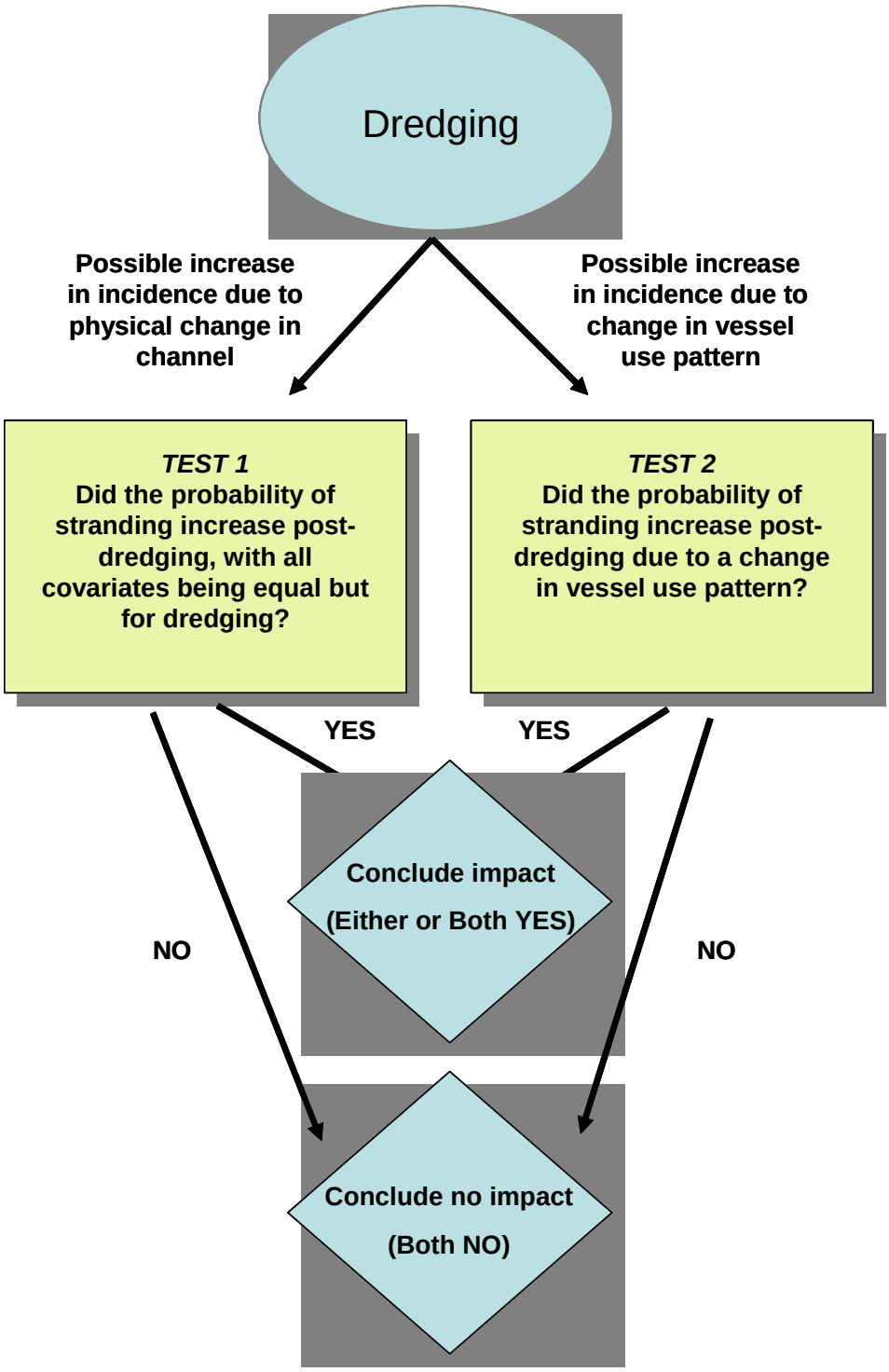


Figure 60. Schematic of the Decision Rules for Assessing Impact of Channel Deepening on the Incidence of Smolt Stranding

The incidence of stranding post-dredging will be compared with the predictions based on the pre-deepening Model 1. Correcting for the specific covariate values observed during a post-deepening trial, the probability of stranding will be calculated using the pre-deepening model. The test of impact is based on assessing whether the incidence of stranding actually observed post-deepening is greater than that predicted by the pre-deepening logistic Model 1. The null hypotheses can be written as

$$\mathrm{H_o}: \quad E\left(I_{\mathrm{Post},i}\right) \le E\left(I_{\mathrm{Pre},i}\right) \tag{21}$$

versus

$$\mathrm{H_a}: \quad E\left(I_{\mathrm{Post},i}\right) > E\left(I_{\mathrm{Pre},i}\right), \tag{22}$$

where

$$I_i = \begin{cases} 1 & \text{if stranding occured in the } i\text{th trial} \\ 0 & \text{otherwise.} \end{cases}$$

The test statistic comparing observed and expected outcomes can be written as a *Z*-statistic for a single trial, where

$$Z_i = \frac{I_{\mathrm{Post},i} - \hat{p}_i}{\sqrt{\mathrm{Var}\left(\hat{p}_i\right)}} \quad \text{(Model 2)} \tag{23}$$

A similar test will be computed for each post-deepening trial. The overall test results will be compiled as a chi-square statistic, where

$$\chi^2_{2k} = \sum_{i=1}^{k}\left(-2\ln P_i\right) \quad \text{(Model 3)} \tag{24}$$

for $P_i = P\left(Z \ge Z_i\right); i = 1,\ldots,k$. The test statistic is a chi-square random variable with 2*k* degrees of freedom. The null hypotheses of no impact will be rejected if

$$P\left(\chi^2 > \chi^2_{2k}\right) \le 0.10 \tag{25}$$

for an α = 0.10, one-tailed test of impact.

Note:

$$\mathrm{Var}\left(\hat{p}_i\right) = \mathrm{Var}\left(\frac{e^{\beta' \underset{\sim}{x}_i}}{1+e^{\beta' \underset{\sim}{x}_i}}\right) \quad \text{(Model 4)} \quad (26)$$
$$\approx \left(\frac{1}{1+e^{\beta' \underset{\sim}{x}_i}}\right)^2 \left(e^{\underset{\sim}{x}_i' \underset{\sim}{\Sigma} \underset{\sim}{x}_i} - 1\right)$$

and where $\underset{\sim}{\Sigma}$ is the variance-covariance matrix of the logistic regression parameters.

This logistic regression analysis is necessary because neither the pre-deepening nor the post-deepening trials were randomly selected. The regression model is used instead to correct for extraneous factors that were not eliminated by a process of randomization affecting stranding.

An alternative assessment approach might include a comparison of the multiple regression models constructed separately for the pre-dredging and post-dredging periods. However, large complex multiple regression models may make direct comparisons difficult or impractical to interpret.

7.5.2 Test of the Effect of Changes in Vessel Use Pattern on the Frequency of Juvenile Salmon Stranding (Test 2)

A change in the frequency or size class of the vessels post-dredging would have an effect on the incidence of stranding in and of itself. This source of impact will be assessed in two fashions:

1. Comparison of the size frequency of vessels pre- and post-dredging (i.e. draft, displacement, length, etc.).
2. Comparison of the predicted frequency of stranding events pre- and post-dredging.

7.5.3 Comparison of Size Frequency of Vessels

Using Port of Portland and Port of Longview records, data on vessel type, displacement, and other factors, will be compared on an annual basis for the years 2004 (pre-dredging) and 2007 (post-dredging). Kolmogorov-Smirnov (Conover 1980, pp. 373-376) tests of equal distributions will be performed comparing pre- and post-dredging vessel distributions.

This test alone will not determine a change in the frequency of stranding events, only a change in vessel-use pattern between phases of the study. However, these results may provide some explanation for a change in stranding frequency, should it occur.

7.5.4 Comparison of Predicted Frequency of Stranding Pre- Versus Post-Dredging

During each of the pre- and post-dredging phases of the monitoring program, a logistic regression model (Model 1, Equation 20) will be developed to describe the incidence of stranding as a function of ambient river conditions, fish availability, and vessel characteristics. If *TEST 1* rejects the null hypothesis of no impact, two separate models will be developed—one for each phase of the monitoring. If *TEST 1* does

not reject the null hypothesis of no impact, a common logistic model will be used to describe both monitoring phases.

Using the distribution of vessel characteristics compiled in Section 4.3, the predicted incidence of stranding events at the three monitoring sites will be calculated under pre- and post-dredging vessel-use patterns. The total number of stranding events predicted per monitoring phase will be calculated as follows:

$$\hat{I}_{Total} = \sum_{j=1}^{3}\sum_{i=1}^{k} f(\underset{\sim}{x}_i)\, p_{ij}(\underset{\sim}{x}_i) \quad \text{(Model 5)} \tag{27}$$

where $\underset{\sim}{x}_i$ is the vector of vessel characteristics for the ith vessel (i = 1,…, k), $f(\underset{\sim}{x}_i)$ is the frequency of vessels with characteristics ($\underset{\sim}{x}_i$), and $p_{ij}(\underset{\sim}{x}_i)$ is the predicted probability of a stranding event for a vessel with characteristics ($\underset{\sim}{x}_i$) at the jth location (j = 1, 2, 3).

The set of one-tailed hypotheses will be tests of the form

$$H_o : I_{Total-Post} \le I_{Total-Pre} \tag{28}$$

versus

$$H_a : I_{Total-Post} > I_{Total-Pre} \tag{29}$$

using an asymptote Z-statistic of the form

$$\hat{Z} = \frac{\hat{I}_{Total-Post} - \hat{I}_{Total-Pre}}{\sqrt{\widehat{\mathrm{Var}}(\hat{I}_{Total-Post}) + \widehat{\mathrm{Var}}(\hat{I}_{Total-Pre})}} \quad \text{(Model 6)} \tag{30}$$

where H_o will be rejected if $P(Z > \hat{Z}) \le 0.10$

The variance of $\hat{I}_{Total}$ can be expressed as

$$\mathrm{Var}(\hat{I}_{Total}) = \sum_{j=1}^{3}\sum_{i=1}^{k} f(\underset{\sim}{x}_i)^2 \mathrm{Var}(\hat{p}_{ij}) + 2\sum_{j=1}^{3}\sum_{i>j}^{k} f(\underset{\sim}{x}_i)\, f(\underset{\sim}{x}_i')\mathrm{Cov}(\hat{p}_{ij}, \hat{p}_{ij}') . \tag{31}$$

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8.0 Conclusions and Recommendations

The results of the design phase, the pilot study, and the pre-deepening sampling lead us to several conclusions and recommendations concerning the design and conduct of the overall study:

- The three sites chosen during the design remained appropriate for the before-deepening sampling and should be retained for the after-deepening sampling. Stranding occurred at all three sites. Location proved to a major factor in the probability of stranding.

- Beach seining proved effective in providing an index of fish availability, and we recommend that three seines in the downstream reference area continue as the basis for the FAI. The present seining approach should be applied in the same way during the after-deepening phase. The DIDSON camera and narrow-beam sonar are known to work well elsewhere but did not reliably discern fish in the extremely shallow (<1-m) areas surveyed in this study.

- The wave staff gage performed adequately and should be employed in the after-deepening measurements. The two wave staff gages deployed 5 m apart captured the wave-height dynamics that a single gage would have missed. We recommend continuing with two gages.

- The video monitoring approach performed more reliably and provided more kinds of information than did the wave run-up gage. When complex waves were generated, along-shore waves lifted all the floats simultaneously and disrupted the ability of the data recorder to support speed calculations. We recommend consideration be given to discontinuing the use of the wave run-up gage in favor of increasing the use of video monitoring. The current stake approach to measuring maximum wave excursion across the beach should be continued.

- For surveys of stranded fish, the field crew was able to perform 100% surveys of stranded fish at all sites at all samplings, day and night. The statistical sub-sampling design developed for stranded fish surveys did not need to be implemented. Taking the dGPS positions of stranded fish enables the discernment of fine-scale patterns in fish stranding that suggest that fine-scale interactions of wake characteristics with beach morphology may contribute to stranding. We recommend that 100% beach surveys along with dGPS positioning of stranded fish continue.

Concerning characterization of the study sites, the major findings of the before sampling include the following:

- The three study sites all have beach slopes of <5% but differ in beach morphology, grain size, and infiltration rate.

- County Line has the highest slope (about 4%), predominantly coarse sand, and the highest infiltration rate.

- Barrow Point has the lowest slope (about 2%), predominantly fine and very fine sand, and the lowest infiltration rate.

- Sauvie Island is between the other two sites with a low slope (almost 3%), predominantly medium sand, and moderate infiltration rate.

- The water-quality values for temperature, salinity, dissolved oxygen, and pH did not vary among the sites and were all with normal expectation.

- The beach characteristics varied only slightly with seasons. We recommend continued collection of data on slope, grain size, and infiltration rate at a rate of one assessment per seasonal sampling period.

Concerning the fish fauna and FAI, the major findings of the before sampling were as follows:

- Fish were captured in almost all seines at all sites both day and night.

- The four most abundant fish in the seines in order from most to least were juvenile Chinook salmon, threespine sticklebacks, peamouth chub, and American shad. Juvenile Chinook salmon were almost 50% of the total catch of seined fish for all seasons. In winter and spring, juvenile Chinook were over 85% of the seined catch. Juvenile Chinook salmon observed in this study were predominantly unmarked.

- Fish species composition in the reference area seines varied among the sites and among seasons.

- The density of subyearling Chinook decreased significantly over the summer with the rate of decrease differing among the sites. The over-summer decline in Chinook density is consistent with the 2004 timing of outmigration of fall Chinook at the Bonneville Dam.

- The lack of a diel trend in Chinook and total fish abundance among the times of sampling within a sampling day indicates that the three sampling times (start, middle, and end) are appropriate.

- Neither fish species composition in seines nor subyearling Chinook density differed significantly among the reference and two hot spots within the survey areas at any site. Total fish density did not differ significantly among reference and two hot spots within the survey areas at Barrow Point and County Line but did at Sauvie Island.

- The differences in fish species composition at the river scale but not at the site scale are of great advantage in a before-and-after study. The ability to detect change in Chinook density at different sites over time is also of great advantage in a before-and-after study.

Concerning wake and wave run-up characteristics, the major findings of the pre-deepening field sampling were as follows:

- Four types of deep-draft vessels (bulk carriers, container ships, oil tankers, and car carriers) produced wakes leading to both draw-down and run-up on the beach. Tugs and small passenger vessels did not produce wakes leading to any significant draw-down and little run-up.

- Different types of deep-draft vessels produce wakes leading to different patterns of draw-down and run-up.

- The sustained presence of long-period waves following the initial draw-down and run-up was documented for probably the first time in these types of studies.

- Average draw-down distance was 12.6 m; average run-up distance, 9.4 m; and average maximum excursion across the beach was 21.9 m.

Concerning fish stranding events, the major findings of the pre-deepening field sampling were as follows:

- Of 126 observed passages of deep-draft vessels, 46, or 36%, led to fish stranding.

- Fish stranding occurrence varied significantly with site. Barlow Point had the highest number of observed vessel passages (49) and the highest proportion of stranding events (26 of 49, or 53% of passages). County Line Park and Sauvie Island had a similar number of observed passages (39 and 38, respectively), but Sauvie Island had a higher incidence of stranding with 14 events (37% of passages). We observed only six stranding events at County Line Park (15% of passages).

- Fish stranding occurrence did not vary with season at Sauvie Island or County Line Park but did at Barlow Point.

- During summer 2004, all stranding events occurred during night passages and none occurred during day passages. This finding is consistent with other studies for the summer period (Bauersfeld 1977, Hinton and Emmett 1994, Ackerman 2002).

- Fish stranding was observed with four vessel types (bulk carriers, container ships, oil tankers, and car carriers but not tugs). The frequency of stranding events differed significantly by vessel type. The order from highest frequency was tanker, container ship, car carrier, and bulk carrier.

- Fish stranding was localized in one or two hot spots at the three study sites. Such localization appeared to be related to interactions between the incoming wakes and the particular beach morphology at a site.

- The observations suggest two scales for stranding events: a river scale governed by low slope and proximity to the navigation channel, and a beach or site scale governed by a complex set of

fine-scale interactions between wake properties, beach morphology, and tidal height, along with fish distribution and behavior.

- Some fish, including juvenile Chinook salmon, occurred among the stranded fish at a significantly higher percentage of total fish than they occurred among the available fish as a percentage of total fish captured in the seines. This difference may be related to swimming abilities and behavior of the different fish species.

Concerning the factors analyses to determine the relationships among the factors that influence the probability of stranding, the major findings of the pre-deepening study were as follows:

- Based on single factor and multivariate regression analyses of the full set of before-deepening data, clearly there is no single factor for juvenile salmon stranding. Several factors interlinked together to produce stranding.

- Statistical analyses of the covariates resulted in the following multivariate equations:

  1. Stranding Probability ~ Location + Kinetic Energy Proxy + Tidal Height + Salmonid Density Index + Kinetic Energy Proxy × Tidal Height + Tidal Height × Salmonid Density Index.
  2. Stranding Probability ~ Location + Total Wave Excursion + Salmonid Density Index.
  3. Log(Wave Height) ~ Ship Block Coefficient + Tidal Height + Location + Ship Speed.
  4. Log(Wave Excursion) ~ Kinetic Energy Proxy + Tidal Height + Location

- Location, a proxy for ship kinetic energy (which accounts for ship size and speed), tidal height, total wave excursion, and an index of salmon density along the beach are the primary factors in stranding occurrences.

  The kinetic energy proxy derived from the size and speed of the vessel provides the energy producing the wake.

  Tidal height influences both the fish availability and the interaction of the wake with the beach at each site.

  Longer total distance from draw-down to run-up is the wake characteristic that increases the probability of stranding.

  Higher juvenile salmonid density in the nearshore increases the probability of stranding and remains a significant factor even after the location is taken into account.

- The multivariate regression equations, the video observations of waves, and presence of stranding "hot spots" all indicate that fine-scale site characteristics at a specific location play a dominant role in structuring the processes that produce the onshore wave and subsequent fish stranding.

Concerning the impact assessment to be accomplished following the post-deepening sampling, we offer the following:

- The decision rules for the before-and-after impact assessment need to be specified before the data are collected post-deepening.

- A detailed analysis and decision procedure should be followed that addresses two questions:

  Does the probability of stranding increase post-deepening, holding constant all relevant factors other than dredging?

  Do the patterns of use by deeper-draft vessels change after deepening and, holding other factors equal, is there greater probability of stranding associated with such changes compared with pre-deepening conditions?

The multivariate equations from the before-deepening phase will be used with the after-deepening data to address these two questions.

Exhibit List 344

9.0 Literature Cited

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Appendix A

Photographs



Figure A-1. County Line Park looking upstream. In addition to the large root wad, there are numerous local scour features around sloughed rip-rap.



Figure A-2. Barlow Point survey reach.



Figure A-3. Barlow Point, upstream end of site. The upper part of the beach is protected by a gabion structure known as “Reno mat.”



Figure A-4. Sand Flats at Barlow Point. Ripples on the beach are characteristic of a tidal flat. The pencil and footprints indicate scale.



Figure A-5. Sauvie Island survey reach, looking upstream.



Figure A-6. Sauvie Island, downstream termination of the survey reach.

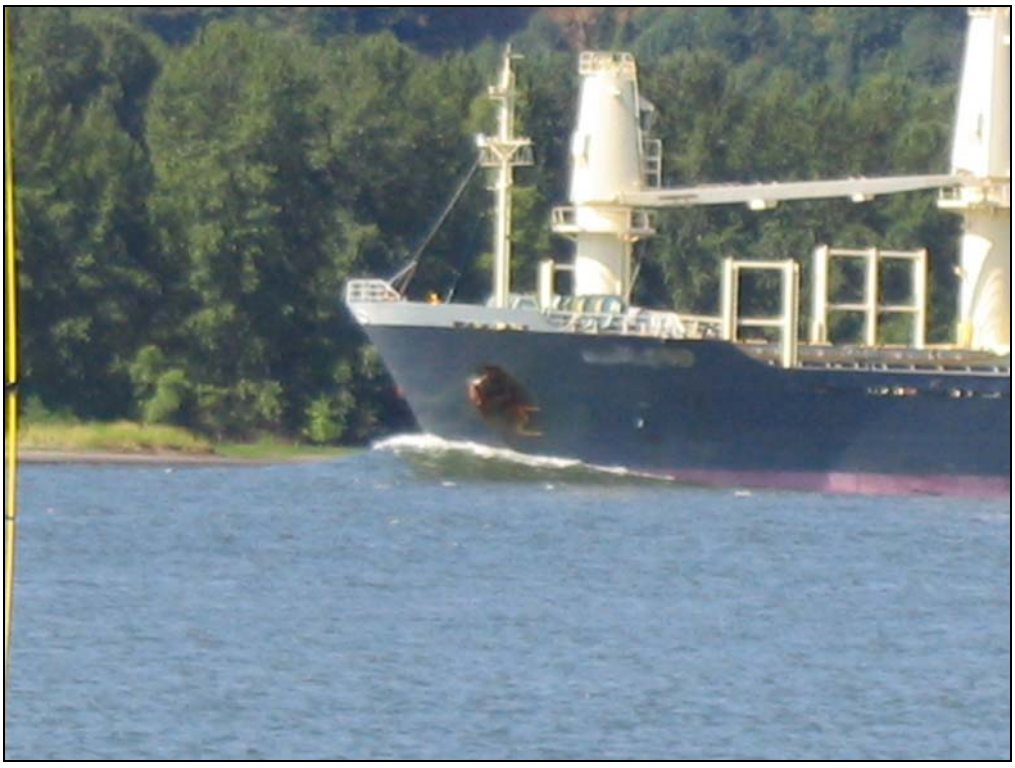


Figure A-7. Vessel passage depicting bow-wake.



Figure A-8. Wave run-up gage, as installed at Barlow Point site



Figure A-9. Waves triggering floats on the wave run-up gage. The two floats at the right in the picture are activated in this photo.



Figure A-10. Site layout, with wave run-up gage to left of photo and wave staff gages offshore to right of photo.

Appendix B

Statistical Analyses/ANODEV Tables

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B-1

ANODEV tables for single-factor models for Regression 1

Location	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	117	157.81			
	Location	2	13.67	6.853	$F_{2,115} = 5.4532$	0.0055
	Error	115	144.14	1.2534		
Season	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	117	157.807			
	Season	2	4.111	2.0555	$F_{2,115} = 1.5380$	0.2192
	Error	115	153.696	1.3365		
River Flow	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	117	157.807			
	Flow	1	4.422	4.422	$F_{1,116} = 3.3442$	0.0700
	Error	116	153.385	1.3223		
Tidal Stage	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	117	157.807			
	Stage	3	5.029	1.676	$F_{3,114} = 1.2508$	0.2947
	Error	114	152.778	1.3402		
Tidal Height	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	117	157.807			
	Height	1	10.659	10.659	$F_{1,116} = 8.4027$	0.0045
	Error	116	147.148	1.2685		
Current Velocity (knots)	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	117	157.807			
	Velocity	1	7.158	7.158	$F_{1,116} = 5.5117$	0.0206
	Error	116	150.649	1.2987		

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Ship Type	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	116	155.909			
	Type	4	11.161	2.9025	$F_{4,112} = 2.2458$	0.0686
	Error	112	144.748	1.2924		

Ship Direction	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	117	157.807			
	Direction	1	5.873	5.873	$F_{1,116} = 4.4840$	0.0363
	Error	116	151.934	1.3098		

Ship Condition	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	109	145.286			
	Condition	2	6.934	3.467	$F_{2,107} = 2.6813$	0.0731
	Error	107	138.352	1.2930		

Ship Distance	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	116	155.91			
	Distance	4	4.33	1.0825	$F_{4,112} = 0.7998$	0.5278
	Error	112	151.58	1.3534		

Ship Time	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	112	149.125			
	Time	1	9.478	9.478	$F_{1,111} = 7.5337$	0.0071
	Error	111	139.647	1.2581		

Ship Speed (knots)	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	112	149.125			
	Speed	1	7.547	7.547	$F_{1,111} = 5.917$	0.0166
	Error	111	141.578	1.2755		

Ship Draft	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	103	141.043			
	Draft	1	3.654	3.654	$F_{1,102} = 2.7128$	0.1026
	Error	102	137.389	1.3470		

Ship Beam	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	110	149.88			
	Beam	1	8.14	8.14	$F_{1,109} = 6.2598$	0.0138
	Error	109	141.74	1.3004		

Ship Length	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	110	149.882			
	Length	1	3.807	3.807	$F_{1,109} = 2.8408$	0.0948
	Error	109	146.075	1.3401		

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Ship Block	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	103	141.043			
	Block	1	6.699	6.699	$F_{1,102} = 5.0862$	0.0263
	Error	102	134.344	1.3171		

Ship Force	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	98	132.755			
	Force	1	8.037	8.037	$F_{1,97} = 6.2509$	0.0141
	Error	97	124.717	1.2857		

Chinook Index	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	117	157.807			
	Chinook	1	5.038	5.038	$F_{1,116} = 3.8255$	0.0529
	Error	116	152.768	1.3170		

Salmonid Index	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	117	157.807			
	Salmonid	1	4.077	4.077	$F_{1,116} = 3.0764$	0.0821
	Error	116	153.730	1.3253		

B-2

ANODEV tables for bivariate models for Regression 1

Season	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	117	157.807			
	Location	2	13.670	6.853		
	Season	2	4.779	2.3895	$F_{2,113} = 1.9376$	0.1488
	Error	113	139.357	1.2332		

River Flow	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	117	157.807			
	Location	2	13.670	6.853		
	Flow	1	2.942	2.942	$F_{1,114} = 2.3754$	0.1260
	Error	114	141.194	1.2385		

Tidal Stage	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	117	157.807			
	Location	2	13.670	6.853		
	Stage	3	1.816	0.6053	$F_{1,112} = 0.4764$	0.6994
	Error	112	142.320	1.2707		

Tidal Height	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	117	157.807			
	Location	2	13.670	6.853		
	Height	1	6.104	6.104	$F_{1,114} = 5.0412$	0.0268
	Error	114	138.033	1.2108		

Current Velocity (knots)	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	117	157.807			
	Location	2	13.670	6.853		
	Velocity	1	5.46	5.46	$F_{1,114} = 4.4884$	0.0363
	Error	114	138.68	1.2165		

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Ship Type	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	116	155.909			
	Location	2	12.931	6.4655		
	Type	4	15.123	3.7808	$F_{1,110} = 3.2528$	0.0146
	Error	110	127.855	1.1623		

Ship Direction	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	117	157.807			
	Location	2	13.670	6.852		
	Direction	1	5.998	5.998	$F_{1,114} = 4.9499$	0.0281
	Error	114	138.138	1.2117		

Ship Condition	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	109	145.286			
	Location	2	11.268	5.634		
	Condition	2	6.757	3.3785	$F_{1,105} = 2.7875$	0.0661
	Error	105	127.261	1.0021		

Ship Distance	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	116	155.909			
	Location	2	12.931	6.4655		
	Distance	4	6.448	1.612	$F_{1,110} = 1.2988$	0.2750
	Error	110	136.530	1.2412		

Ship Time	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	112	149.125			
	Location	2	11.800	5.9000		
	Time	1	14.931	14.931	$F_{1,109} = 13.2971$	0.0004
	Error	109	122.394	1.1229		

Ship Speed (knots)	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	112	149.125			
	Location	2	11.800	5.9000		
	Speed	1	13.28	13.28	$F_{1,109} = 11.6693$	0.0009
	Error	109	124.05	1.1381		

Ship Draft	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	103	141.043			
	Location	2	14.929	7.4645		
	Draft	1	5.239	5.239	$F_{1,100} = 4.3342$	0.0399
	Error	100	120.875	1.2088		

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Ship Beam	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	110	149.882			
	Location	2	17.242	8.621		
	Beam	1	11.390	11.390	$F_{1,107} = 10.0514$	0.0020
	Error	107	121.249	1.1332		

Ship Length	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	110	149.882			
	Location	2	17.242	8.621		
	Length	1	5.970	5.970	$F_{1,107} = 5.0430$	0.0268
	Error	107	126.670	1.1838		

Ship Draft	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	103	141.043			
	Location	2	14.929	7.4645		
	Draft	1	8.764	8.764	$F_{1,100} = 7.4682$	0.0074
	Error	100	117.350	1.1735		

Ship Force	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	98	132.755			
	Location	2	12.870	6.435		
	Force	1	13.489	13.489	$F_{1,95} = 12.0443$	0.0008
	Error	95	106.395	1.1199		

Chinook Index	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	117	157.807			
	Location	2	13.670	6.852		
	Chinook	1	5.054	5.054	$F_{1,114} = 4.1425$	0.0441
	Error	114	139.083	1.2200		

Salmonid Index	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	117	157.807			
	Location	2	13.670	6.852		
	Salmonid	1	5.155	5.155	$F_{1,114} = 4.2284$	0.0420
	Error	114	138.982	1.2191		

B-3

ANODEV tables for single-factor models for Regression 2

Location	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	117	157.81			
	Location	2	13.67	6.853	$F_{2,115} = 5.4532$	0.0055
	Error	115	144.14	1.2534		
Season	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	117	157.807			
	Season	2	4.111	2.0555	$F_{2,115} = 1.5380$	0.2192
	Error	115	153.696	1.3365		
River Flow	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	117	157.807			
	Flow	1	4.422	4.422	$F_{1,116} = 3.3442$	0.0700
	Error	116	153.385	1.3223		
Tidal Stage	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	117	157.807			
	Stage	3	5.029	1.676	$F_{3,114} = 1.2508$	0.2947
	Error	114	152.778	1.3402		
Tidal Height	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	117	157.807			
	Height	1	10.659	10.659	$F_{1,116} = 8.4027$	0.0045
	Error	116	147.148	1.2685		
Current Velocity (knots)	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	117	157.807			
	Velocity	1	7.158	7.158	$F_{1,116} = 5.5117$	0.0206
	Error	116	150.649	1.2987		

Run-up Distance	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	116	156.813			
	Run-up	1	13.105	13.105	$F_{1,115} = 10.4868$	0.0016
	Error	115	143.708	1.2496		
Draw-down Distance	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	116	156.81			
	Draw-down	1	15.32	15.32	$F_{1,115} = 12.4518$	0.0006
	Error	115	141.49	1.2303		
Total Wave Distance	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	116	156.813			
	Wave	1	16.189	16.189	$F_{1,115} = 13.2395$	0.0004
	Error	115	140.624	1.2228		
Run-up Velocity (camera)	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	45	63.770			
	Camera	1	7.6×10^{-5}	7.6×10^{-5}	$F_{1,44} = 5.3 \times 10^{-5}$	0.9943
	Error	44	63.769	1.4493		
Run-up Velocity (gage)	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	27	35.165			
	Gage	1	2.733	2.733	$F_{1,26} = 2.1908$	0.1509
	Error	26	32.432	1.2474		
Wash-back Velocity	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	32	42.010			
	Wash-back	1	0.188	0.188	$F_{1,31} = 0.1390$	0.7118
	Error	31	41.822	1.3491		
Maximum Draw-down Height	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	70	90.840			
	Draw-down	1	5.462	5.462	$F_{1,69} = 4.4138$	0.0393
	Error	69	85.379	1.2374		
Maximum Run-up Height	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	70	90.840			
	Run-up	1	3.608	3.608	$F_{1,69} = 2.8543$	0.0956
	Error	69	87.232	1.2642		
Maximum Water Level	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	73	93.253			
	Level	1	1.196	1.196	$F_{1,72} = 0.9351$	0.3368
	Error	72	92.057	1.2786		

B-4

Select ANODEV tables for trivariate models for Regression 2

Season	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	116	156.813			
	Location	2	13.644	6.822		
	Wave	1	16.087	16.087		
	Season	2	10.544	5.272	$F_{2,111} = 5.0215$	0.0082
	Error	111	116.538	1.0499		
River Flow	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	116	156.813			
	Location	2	13.644	6.822		
	Wave	1	16.087	16.087		
	Flow	1	4.731	4.731	$F_{1,112} = 4.3308$	0.0397
	Error	112	122.350	1.0924		
Tidal Height	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	116	156.813			
	Location	2	13.644	6.822		
	Wave	1	16.087	16.087		
	Height	1	5.091	5.091	$F_{1,112} = 4.6741$	0.0327
	Error	112	121.991	1.0892		
Salmonid Index	Source	DF	DEV	MDEV	F	P
	Total_{Corr}	116	156.813			
	Location	2	13.644	6.822		
	Wave	1	16.087	16.087		
	Salmonid	1	11.297	11.297	$F_{1,112} = 10.9278$	0.0013
	Error	112	115.784	1.0338		

Appendix C

Stranding Plots

Exhibit List 364

C-1 Stranding Events by Sampling Period and Study Site

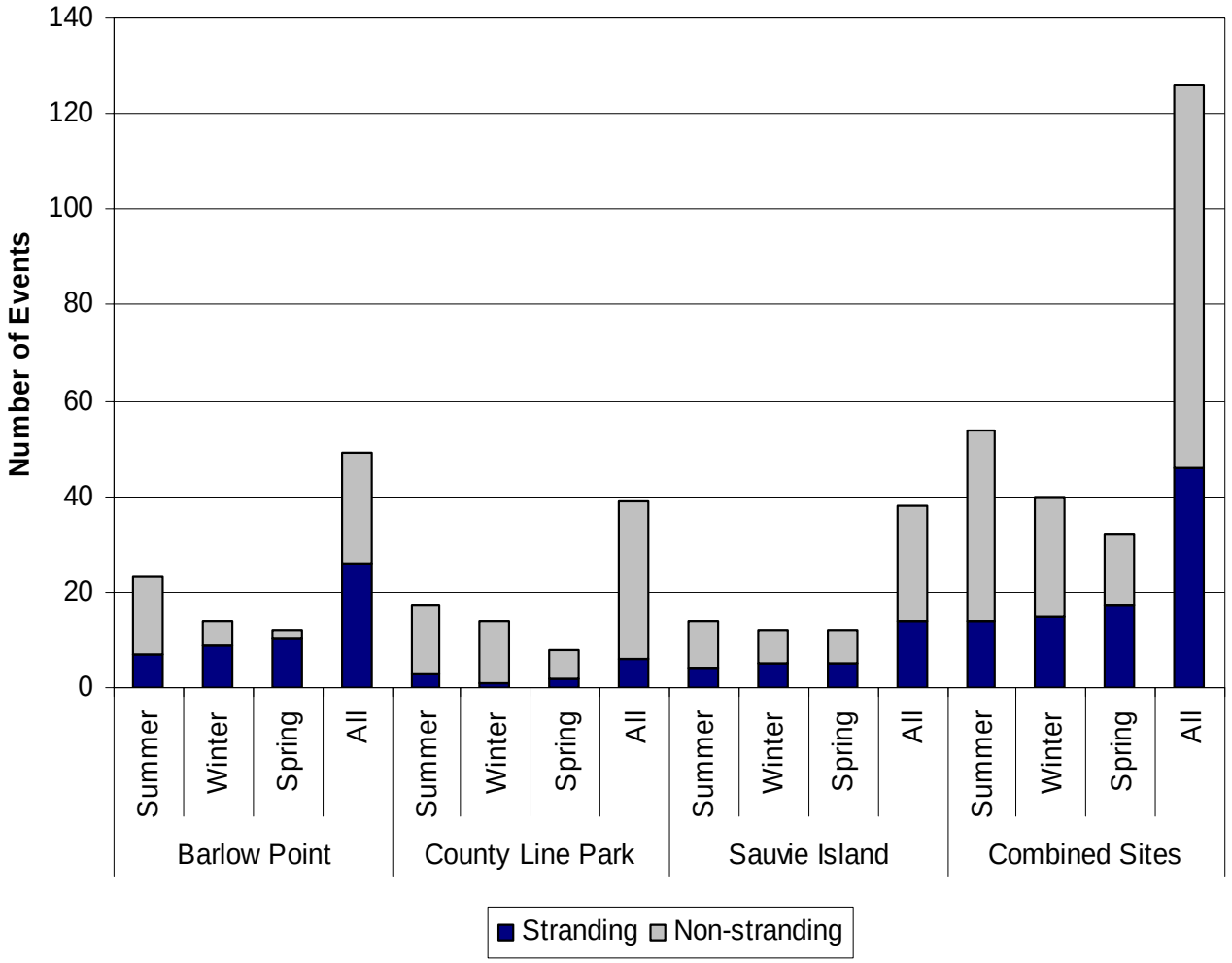
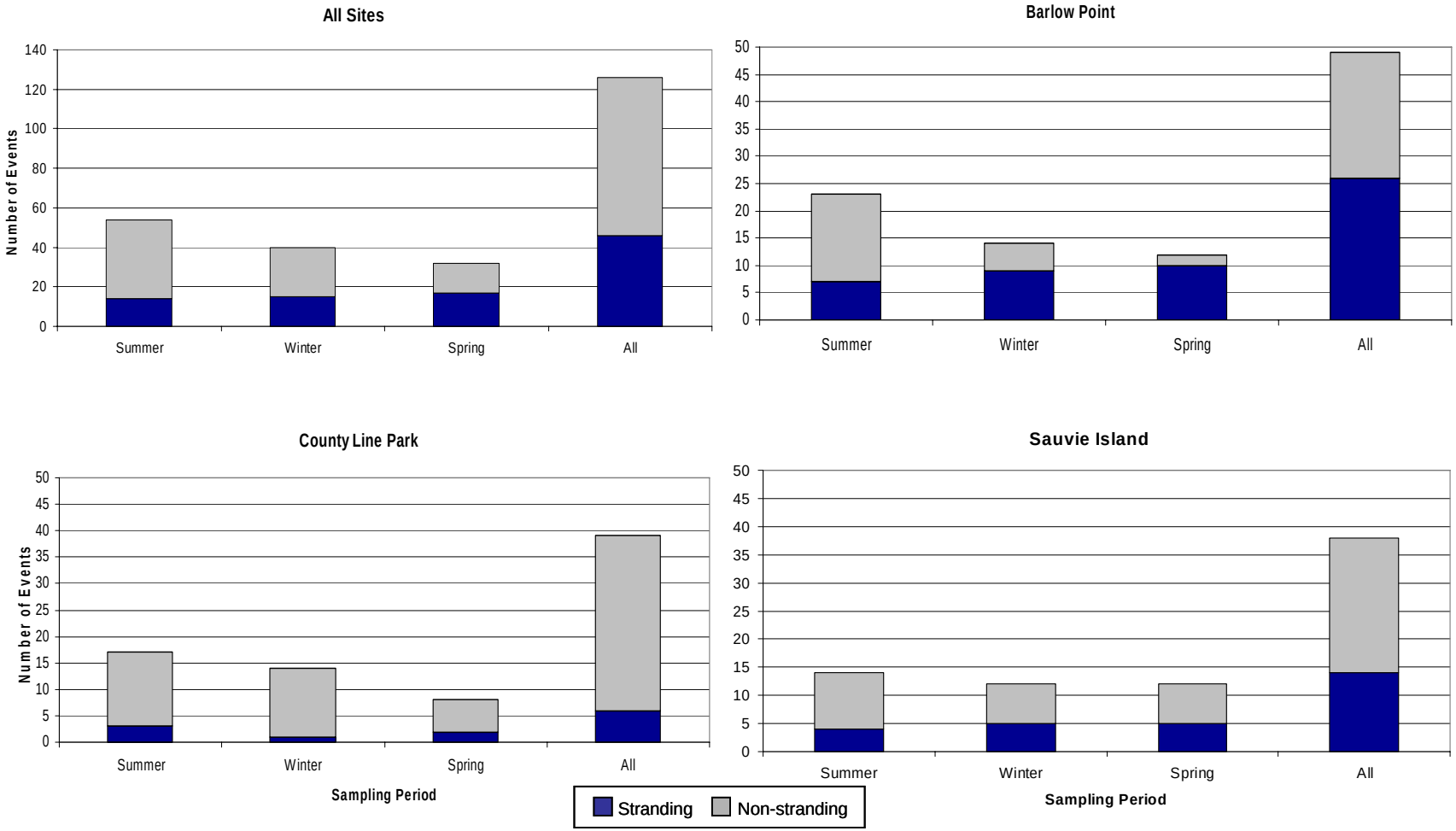
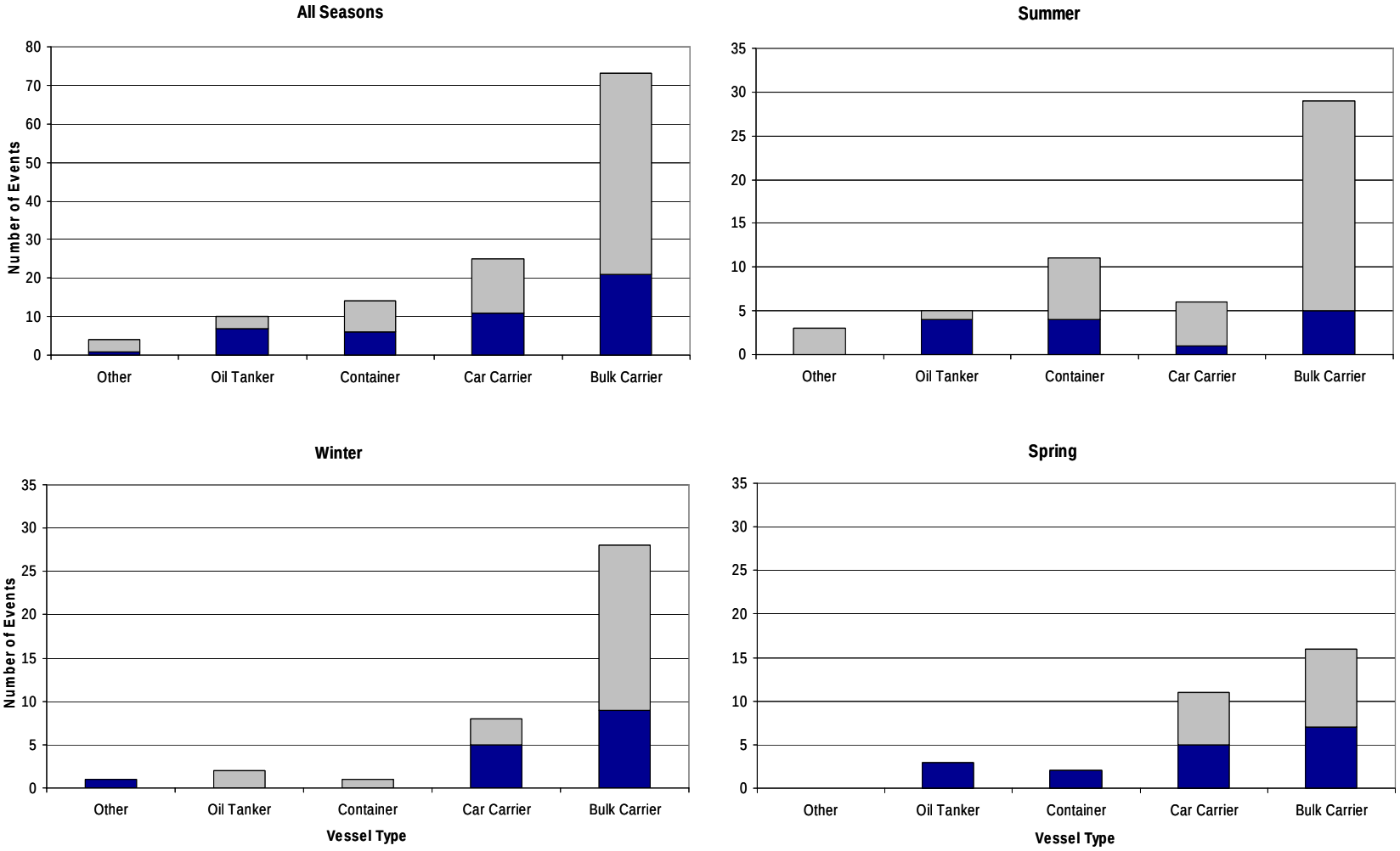


Exhibit List 365

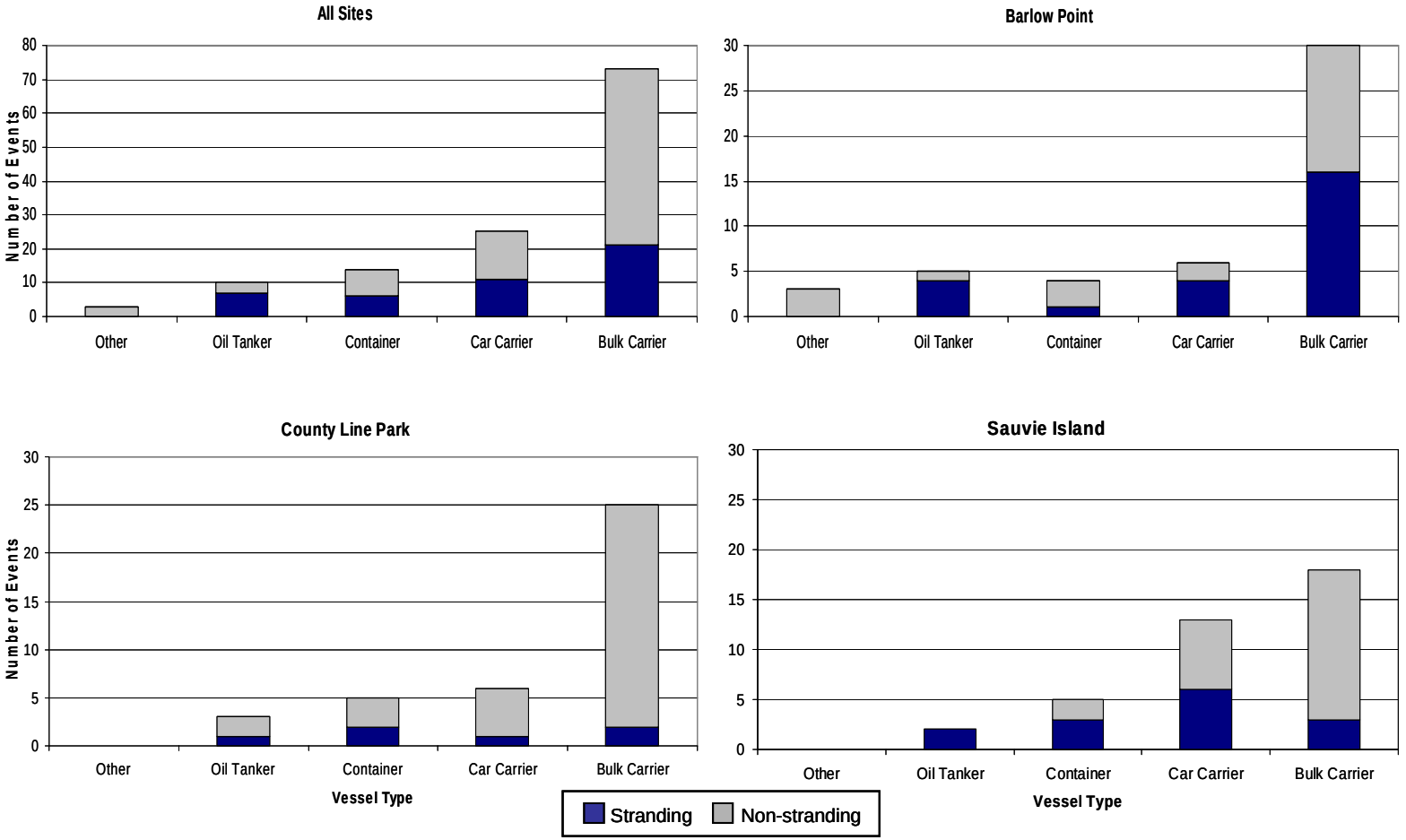
C-2 Stranding by Sampling Period



C-3 Stranding by Vessel Type for Each Season



C-4 Stranding by Vessel Type for Each Site



C-5 Stranding by Vessel Speed

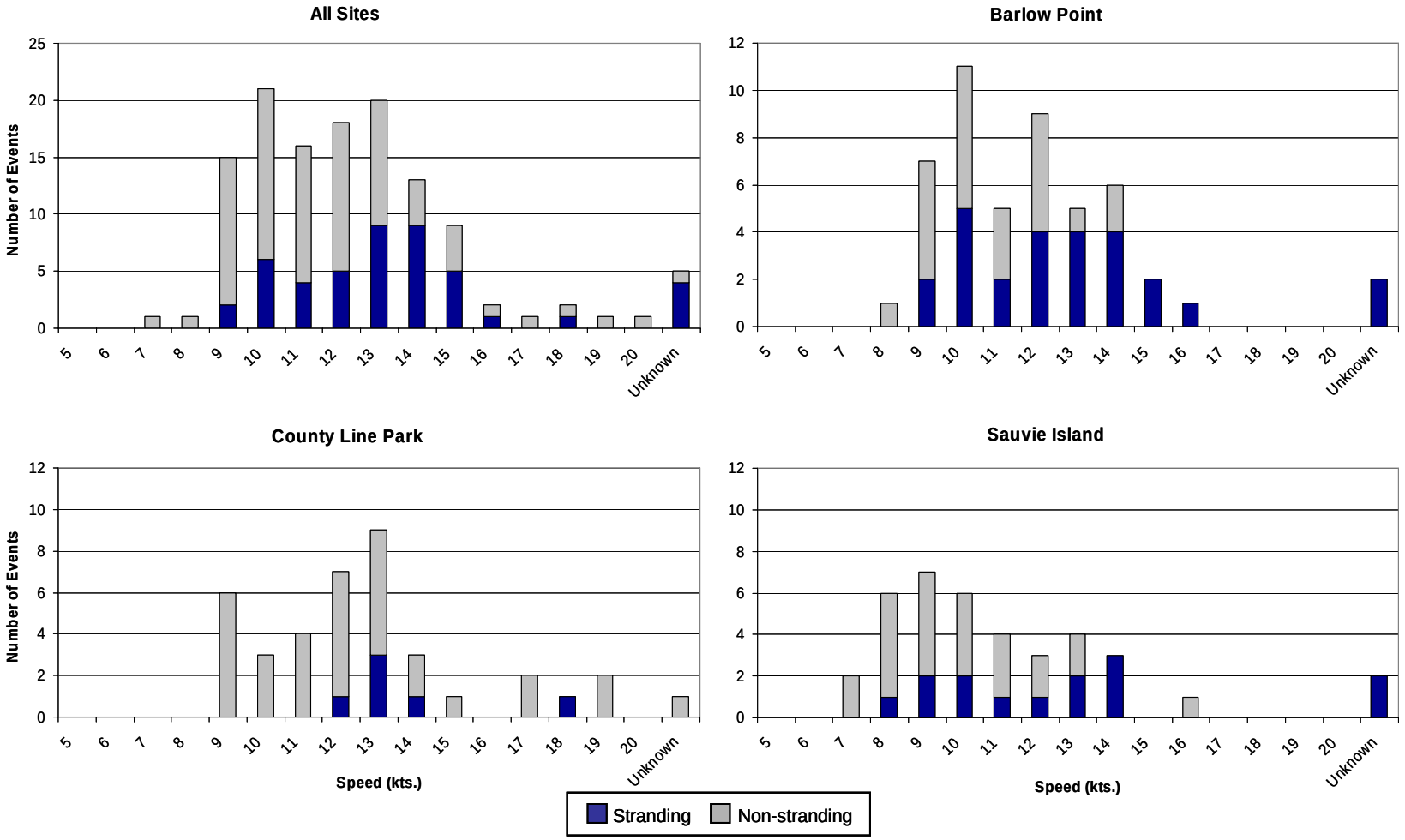
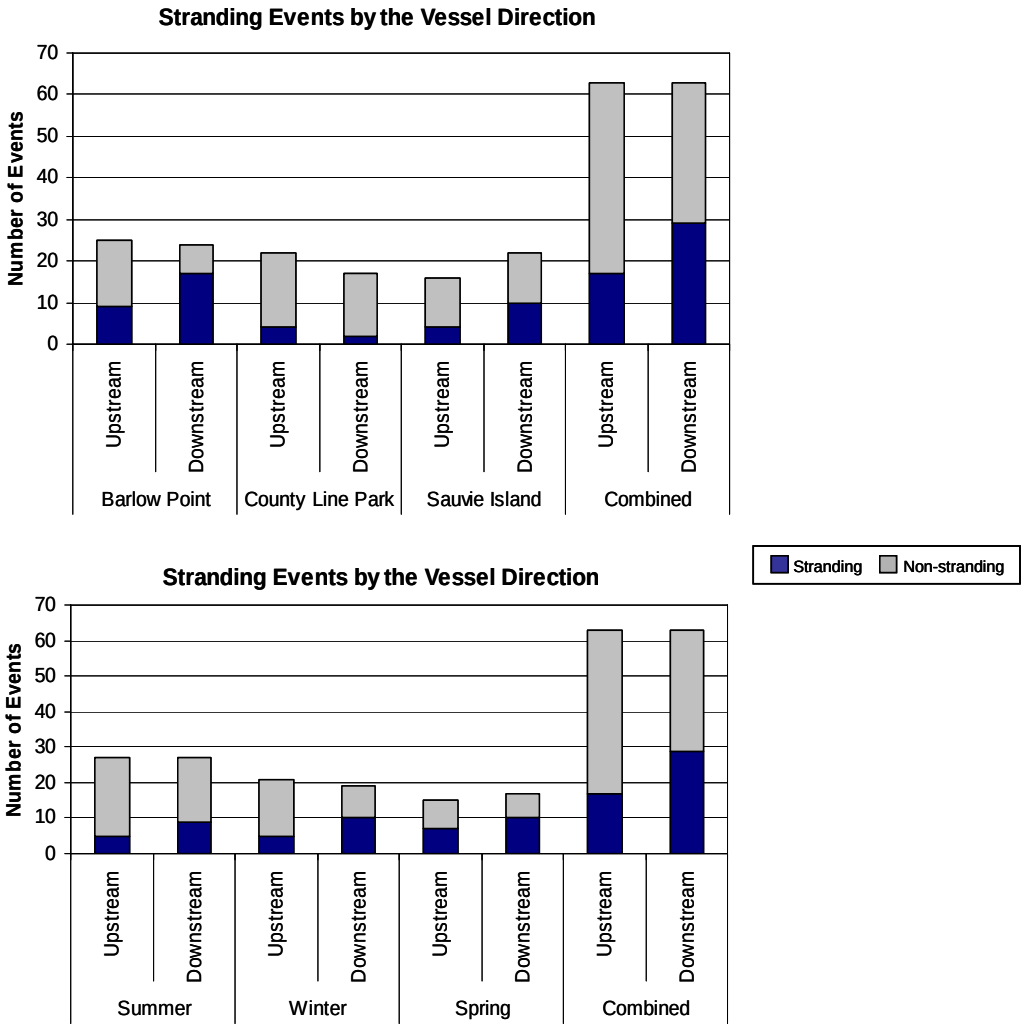


Exhibit List 369

C-6 Stranding by Vessel Direction by Site and Season



C-7 Stranding by Ship Block Coefficient for Each Site

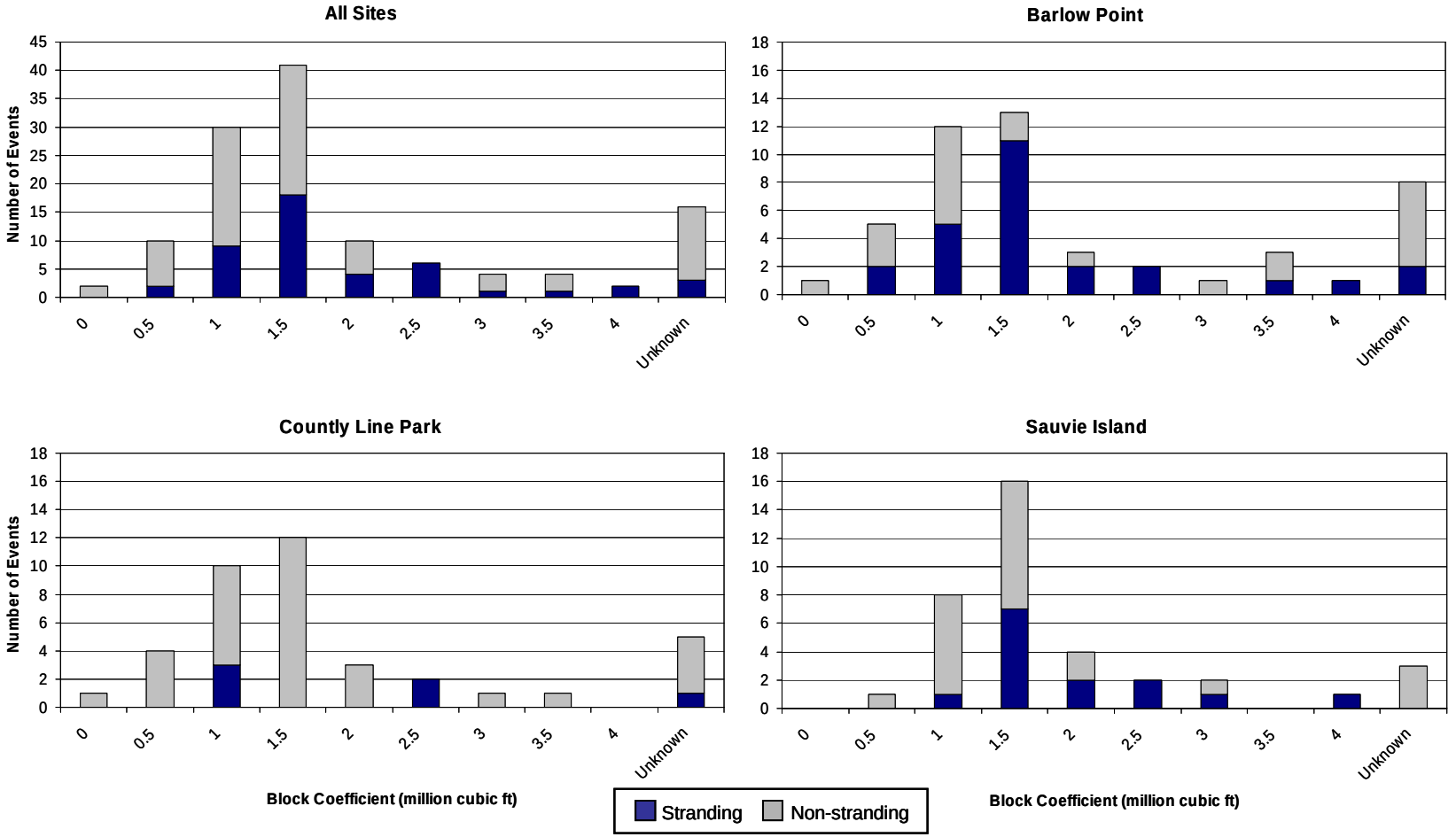
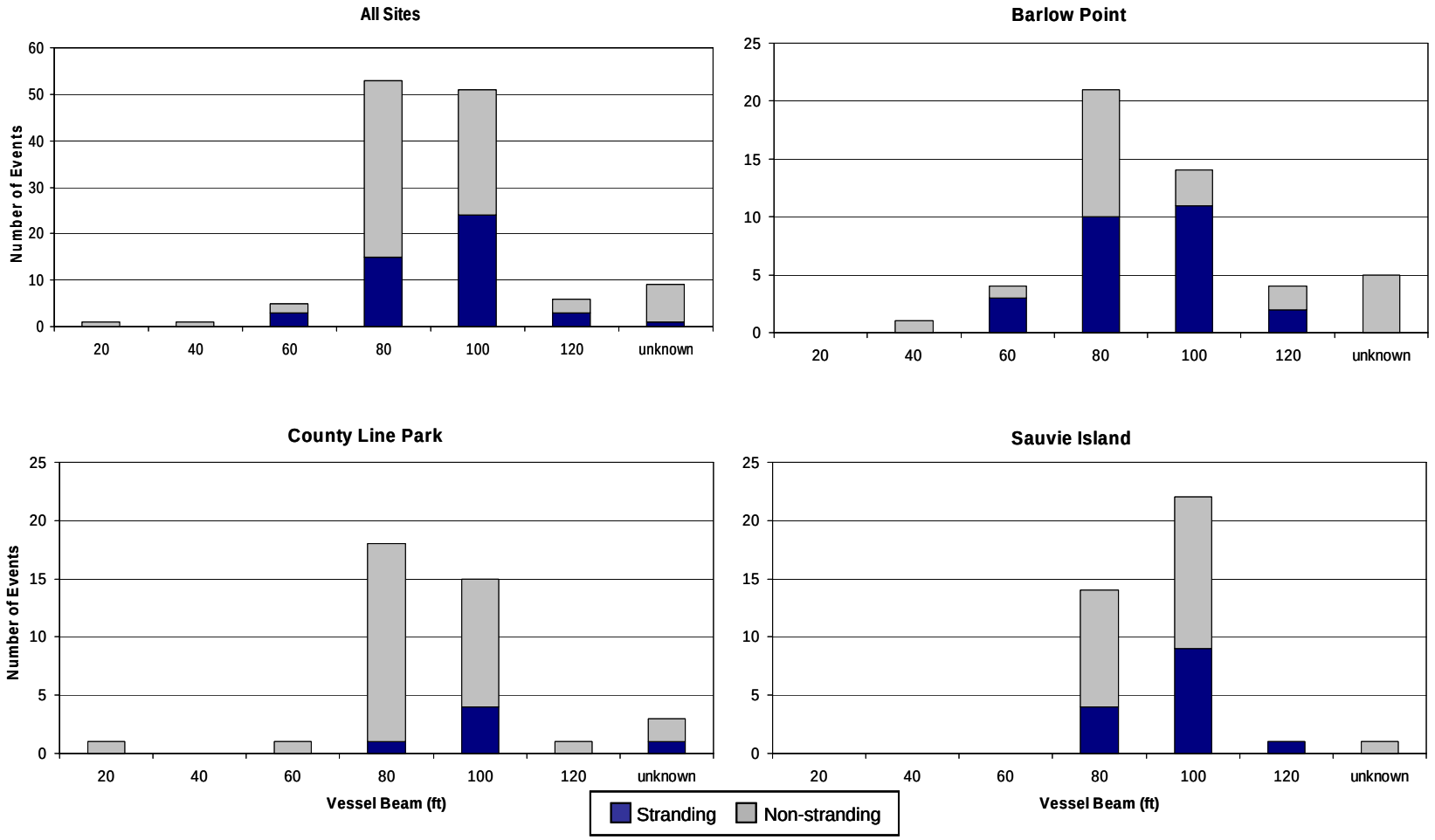
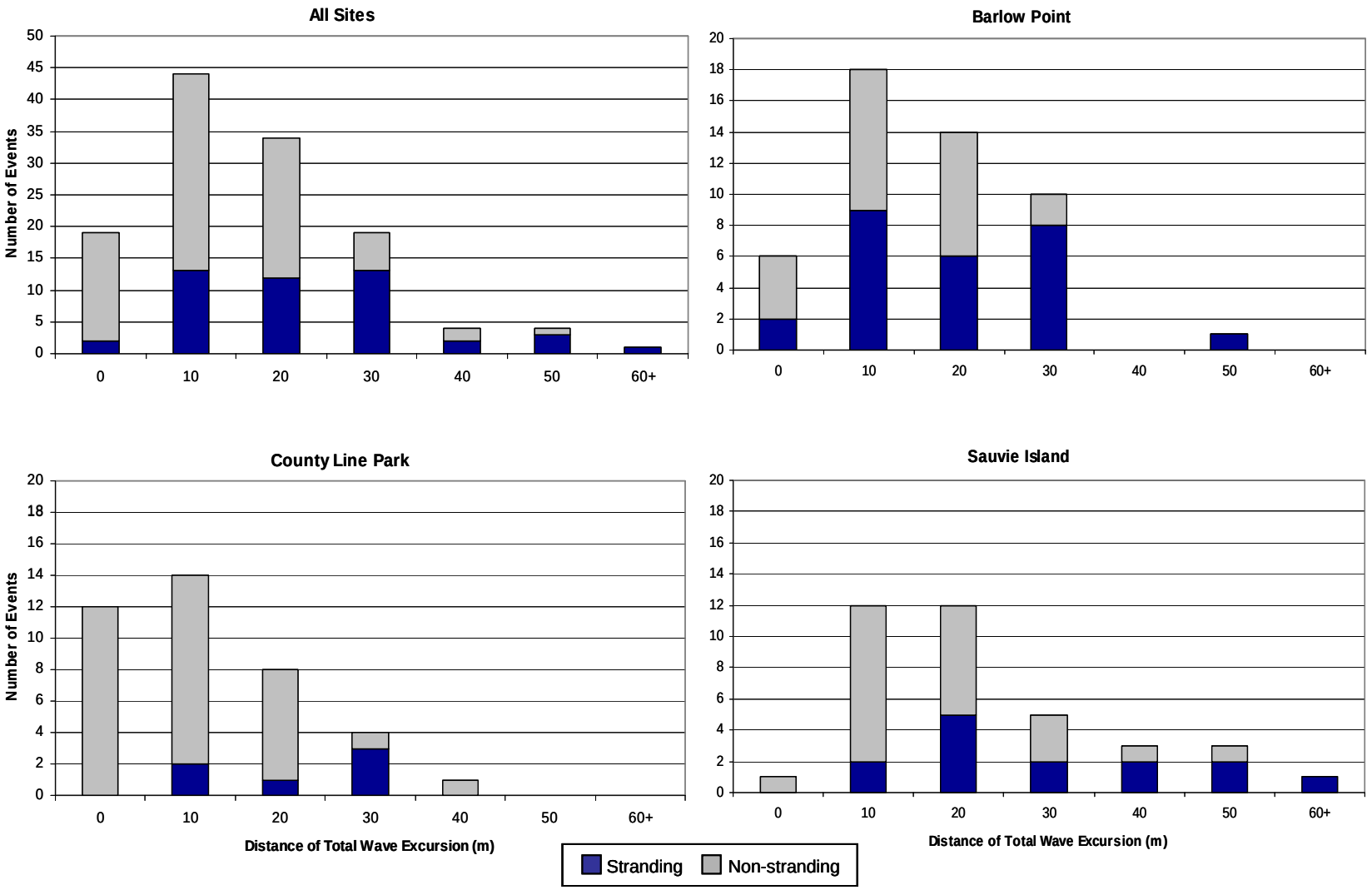


Exhibit List 371

C-8 Stranding by Vessel Beam for Each Site



C-9 Stranding by Total Wave Excursion for Each Site



C-10 Stranding by Maximum Wave Height for Each Site

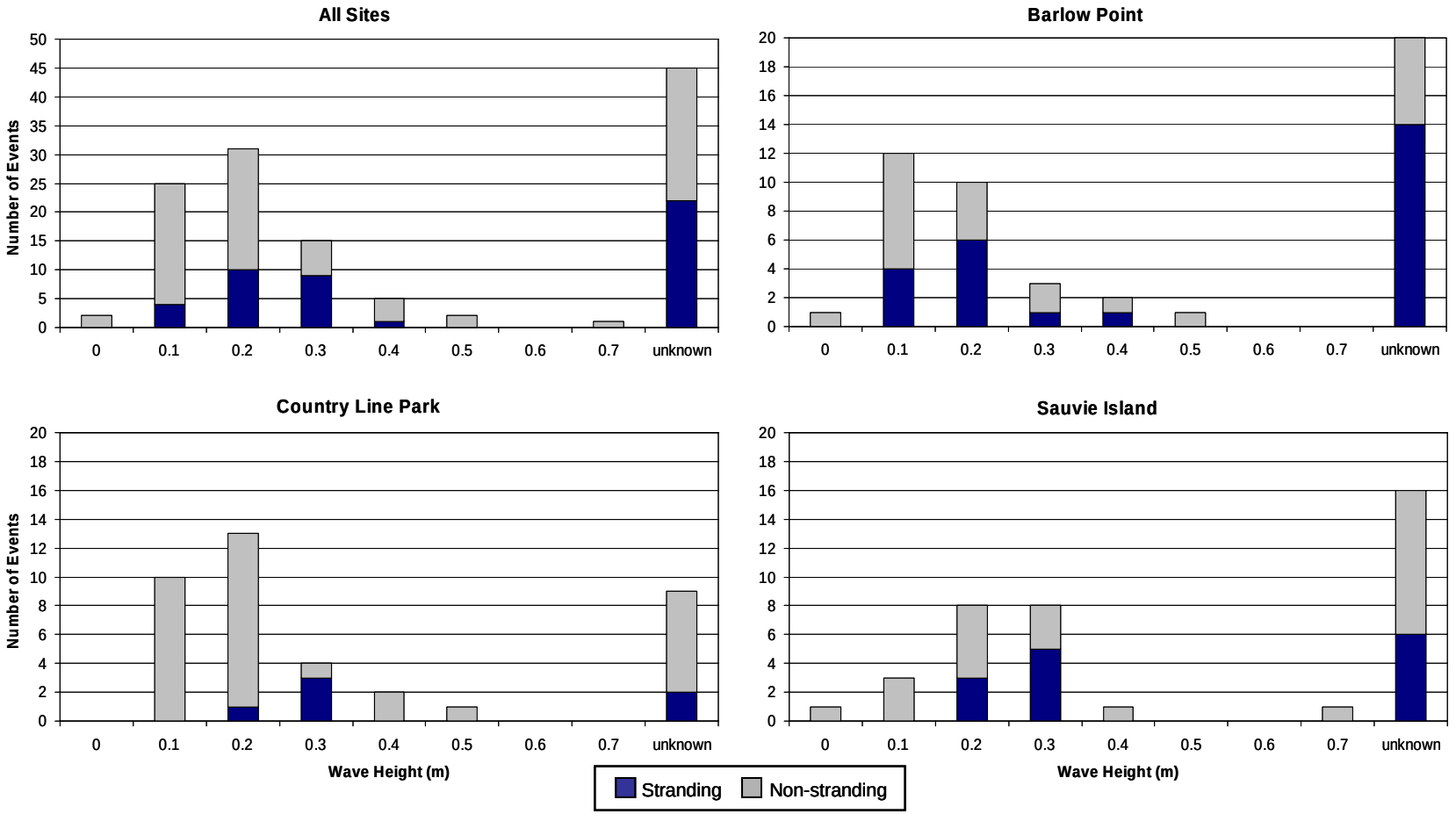
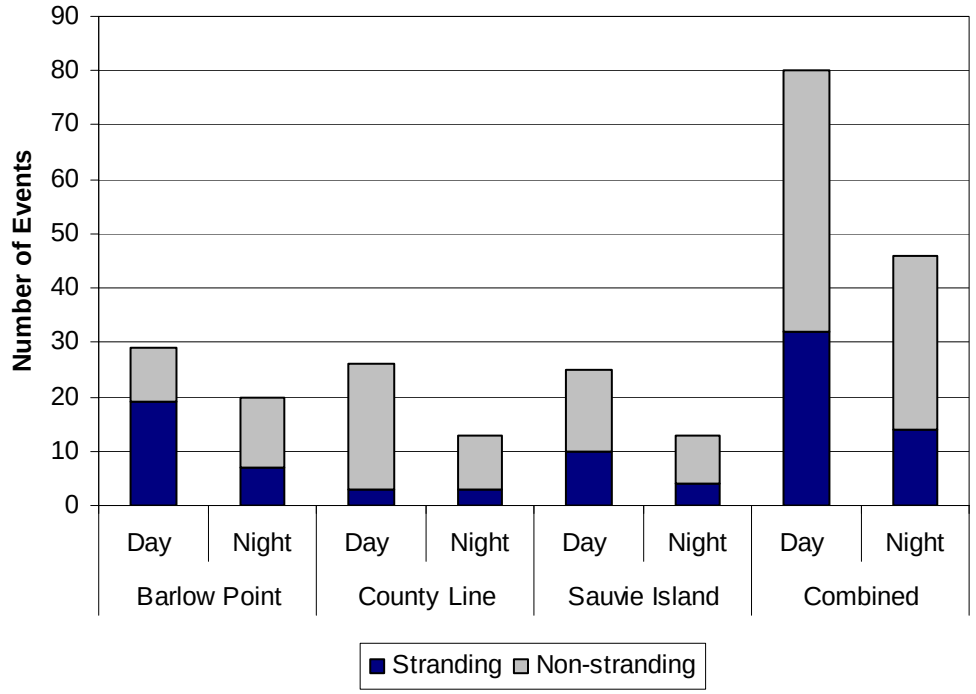
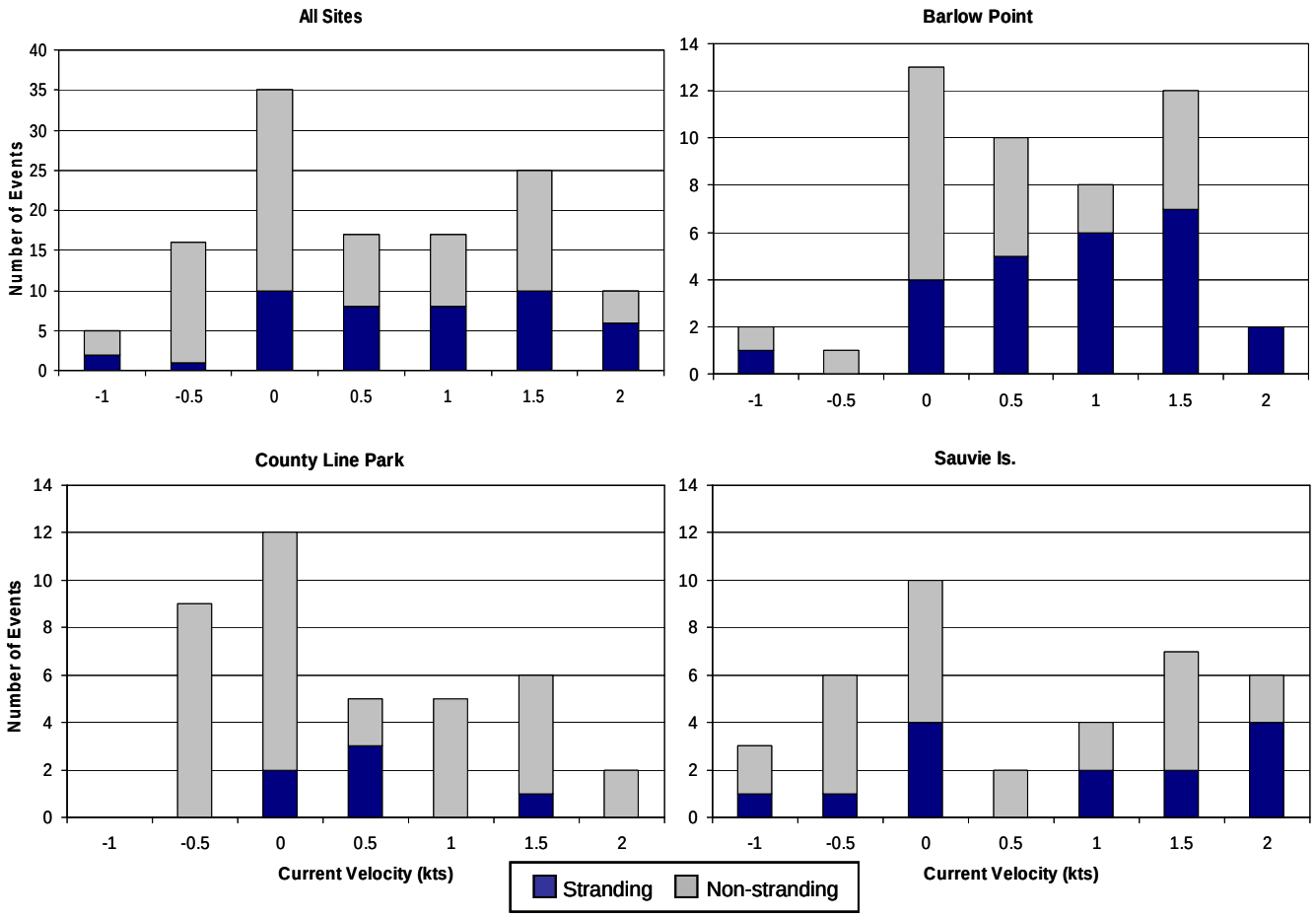


Exhibit List 374

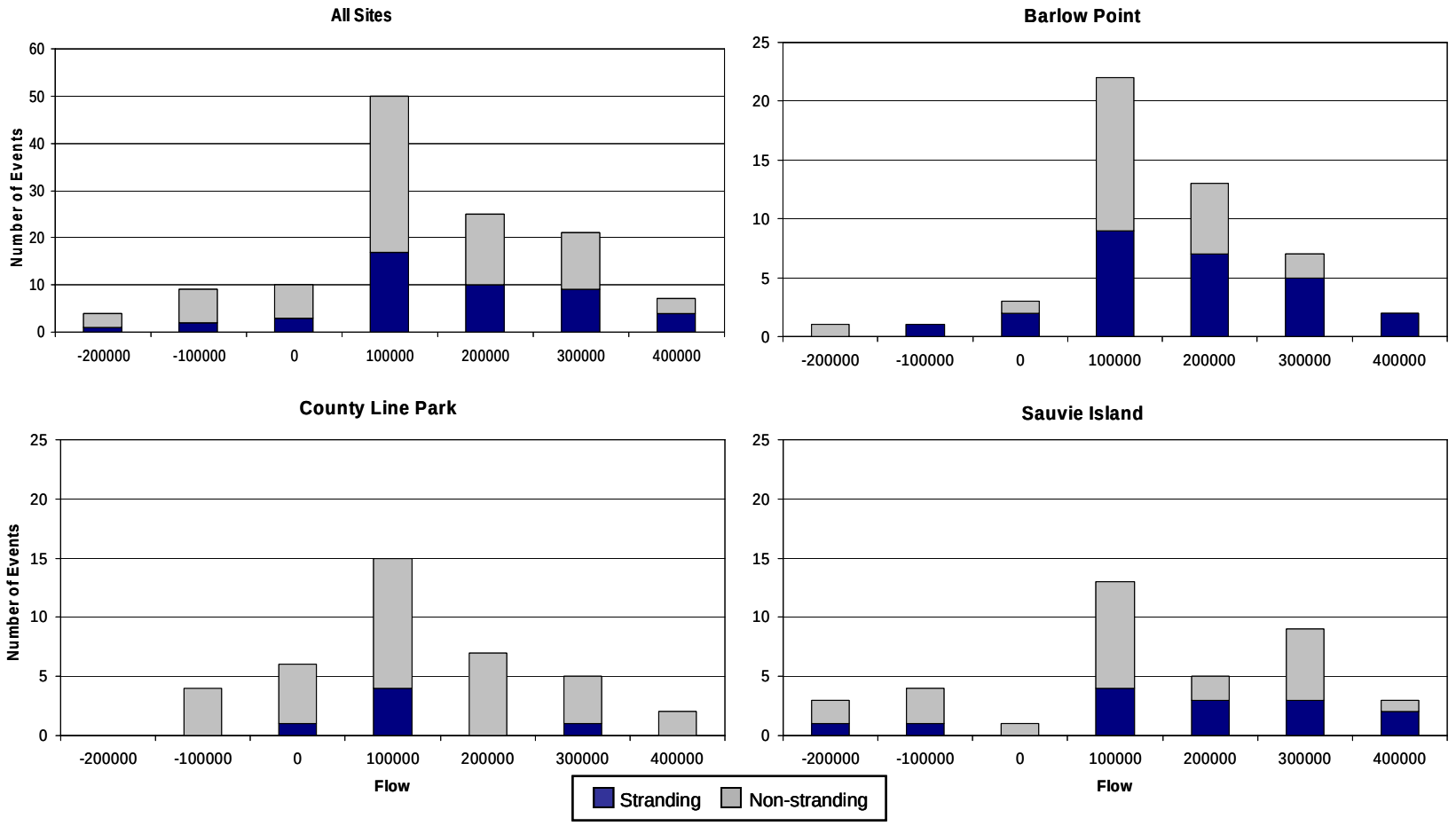
C-11 Stranding by Time of Day for Each Site



C-12 Stranding by River Velocity for Each Site



C-13 Stranding by River Flow for Each Site



C-14 Stranding by Tidal Height for Each Season

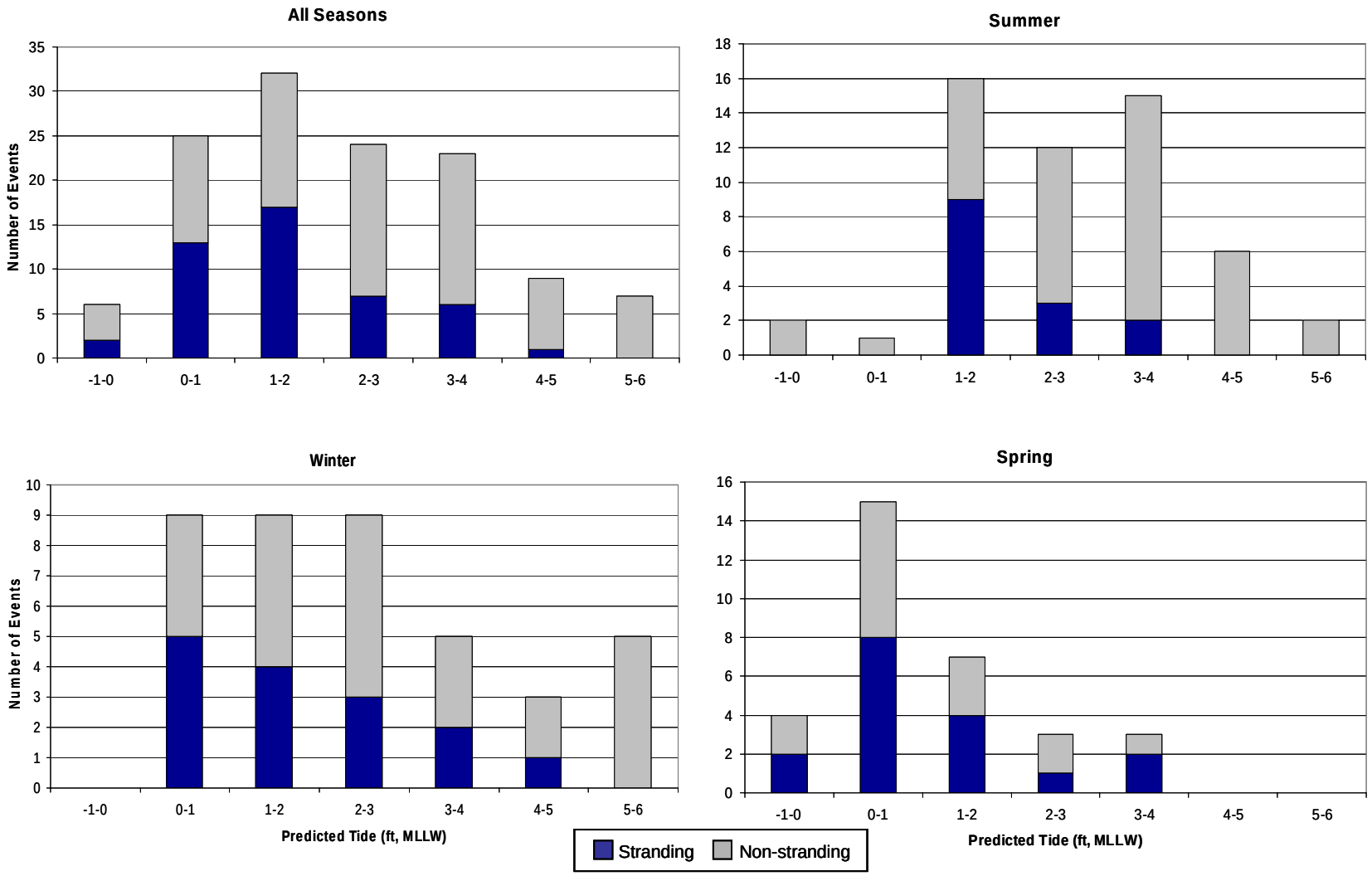
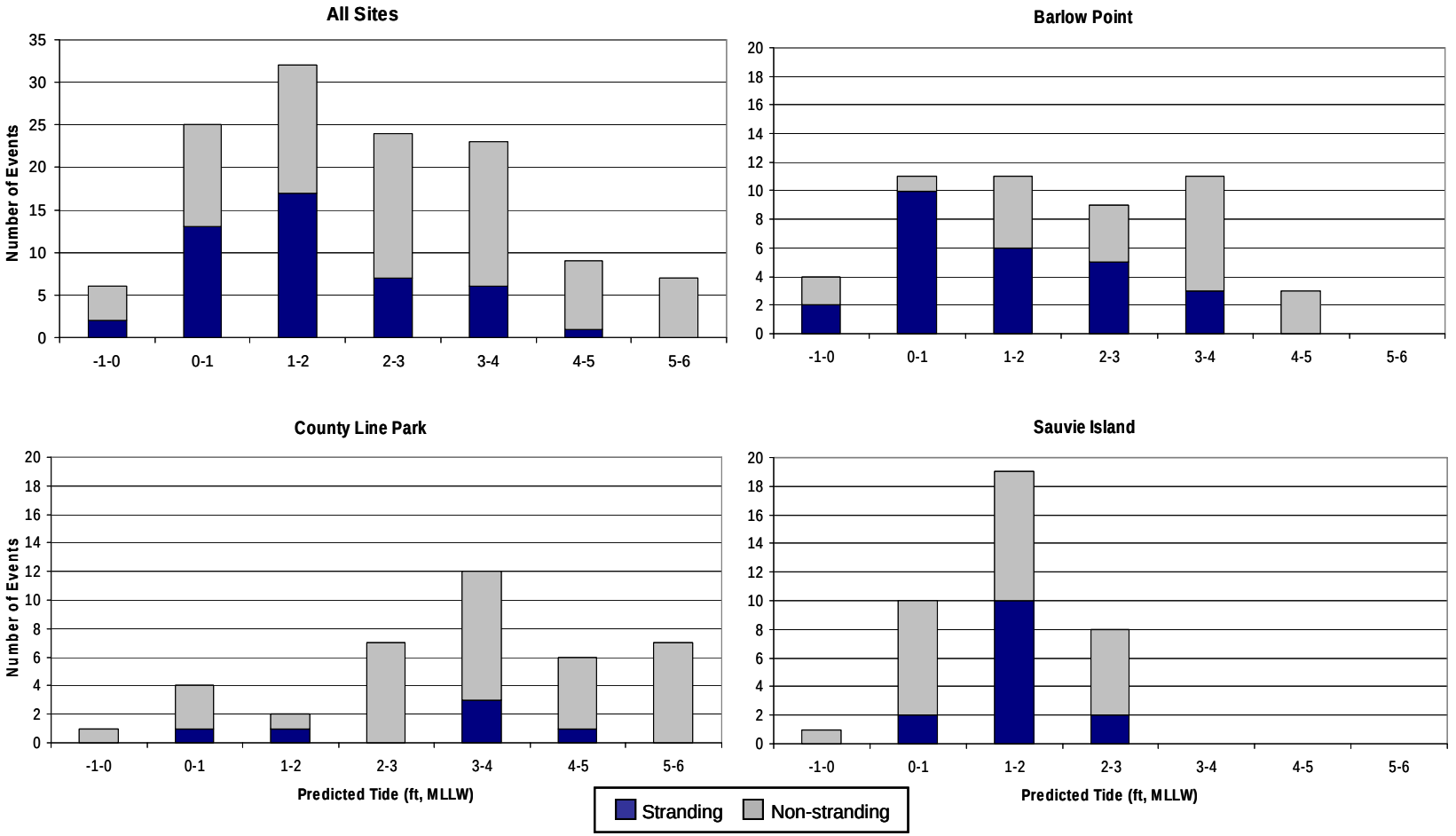


Exhibit List 378

C-15 Stranding by Tidal Height for Each Site



Appendix D

Data

Exhibit List 380

D-1. Basic Identifiers

Basic Identifiers								**River Characteristics**				
Deep Draft Passage #	Date	Location	Diel Sampling Phase	Phase	Season	Field Trip	Data Collection Trial #	River Flow (Quincy, OR)	Tidal Stage	Tidal Height, ft.	Current Velocity (Qunicy, OR)	
		County Line= CL Barlow = BP Sauvie = SI		Before (B) or After (A) Deepening	Sp=spring, Su=summer, Win=winter			cubic ft/sec		SI=St. Helens, BP=Longview, CLP=Eagle Cliff	f/s	Kts
1	06/29/04	CL	Day	B	Su	1	3	205,000	Flooding	3.00	0.85	0.503
2	06/29/04	CL	Day	B	Su	1	4	205,000	Flooding	3.20	0.8	0.474
3	06/29/04	CL	Day	B	Su	1	6	205,000	Ebbing	3.00	1.72	1.018
4	06/29/04	CL	Day	B	Su	1	7	205,000	Ebbing	2.50	2.51	1.486
5	06/30/04	BP	Day	B	Su	1	8	204,000	Flooding	-0.50	3.1	1.835
6	06/30/04	BP	Day	B	Su	1	13	204,000	Flooding	3.20	0.82	0.485
7	06/30/04	BP	Day	B	Su	1	14	204,000	Ebbing	3.20	1.35	0.799
8	07/01/04	SI	Day	B	Su	1	16	211,000	Low Slack	-0.50	0.99	0.586
9	07/19/04	BP	Night	B	Su	2	19	125,000	Ebbing	2.00	2.86	1.693
10	07/19/04	BP	Night	B	Su	2	20	125,000	Ebbing	1.90	2.68	1.587
11	07/20/04	BP	Night	B	Su	2	21	147,000	Low Slack	1.30	0.81	0.480
12	07/20/04	BP	Night	B	Su	2	22	147,000	Flooding	1.40	0.2	0.118
13	07/20/04	SI	Night	B	Su	2	25	147,000	Ebbing	2.00	1.82	1.077
14	07/21/04	CL	Night	B	Su	2	26	137,000	Ebbing	3.40	1.64	0.971
15	07/21/04	CL	Night	B	Su	2	27	137,000	Ebbing	3.00	2.26	1.338
16	07/22/04	CL	Night	B	Su	2	28	132,000	Flooding	5.00	-0.61	-0.361
17	08/09/04	CL	Night	B	Su	3	29	107,000	Flooding	3.00	-0.17	-0.101
18	08/09/04	CL	Night	B	Su	3	30	107,000	High Slack	5.00	-0.27	-0.161
19	08/10/04	CL	Night	B	Su	3	31	129,000	Ebbing	1.00	0.86	0.507
20	08/10/04	CL	Night	B	Su	3	32	129,000	Flooding	2.40	0.39	0.233
21	08/10/04	CL	Night	B	Su	3	33	129,000	Flooding	3.00	0.25	0.146
22	08/10/04	CL	Night	B	Su	3	34	129,000	Flooding	4.00	-0.24	-0.141
23	08/11/04	CL	Night	B	Su	3	35	153,000	Ebbing	4.80	-0.04	-0.023
24	08/11/04	CL	Night	B	Su	3	36	153,000	Ebbing	4.50	0.35	0.206
25	08/11/04	CL	Night	B	Su	3	37	153,000	Ebbing	4.50	0.43	0.253

Exhibit List 381

Basic Identifiers								River Characteristics				
Deep Draft Passage #	Date	Location	Diel Sampling Phase	Phase	Season	Field Trip	Data Collection Trial #	River Flow (Quincy, OR)	Tidal Stage	Tidal Height, ft.	Current Velocity (Qunicy, OR)	
26	08/11/04	CL	Night	B	Su	3	38	153,000	Ebbing	3.20	0.74	0.440
27	08/11/04	BP	Night	B	Su	3	39	153,000	Ebbing	2.00	0.69	0.406
28	08/11/04	BP	Night	B	Su	3	40	153,000	Ebbing	1.80	0.62	0.370
29	08/12/04	BP	Night	B	Su	3	41	172,000	Ebbing	3.60	0.40	0.235
30	08/12/04	BP	Night	B	Su	3	42	172,000	Ebbing	3.00	0.70	0.413
31	08/13/04	SI	Night	B	Su	3	43	154,000	Ebbing	1.50	0.63	0.374
32	08/13/04	SI	Night	B	Su	3	44	154,000	Ebbing	1.00	0.19	0.114
33	08/14/04	SI	Night	B	Su	3	45	145,000	Ebbing	1.80	0.72	0.424
34	08/14/04	SI	Night	B	Su	3	46	145,000	Ebbing	0.00	0.02	0.009
35	08/15/04	SI	Night	B	Su	3	47	122,000	High Slack	2.10	0.27	0.159
36	08/15/04	SI	Night	B	Su	3	48	122,000	Ebbing	2.00	0.34	0.204
37	08/15/04	SI	Night	B	Su	3	49	122,000	Ebbing	1.70	0.74	0.440
38	08/15/04	SI	Night	B	Su	3	50	122,000	Ebbing	1.50	0.77	0.458
39	08/15/04	SI	Night	B	Su	3	51	122,000	Ebbing	1.10	0.64	0.381
40	08/16/04	SI	Night	B	Su	3	52	121,000	Flooding	1.00	-0.45	-0.267
41	08/16/04	SI	Night	B	Su	3	53	121,000	Flooding	2.00	-0.26	-0.153
42	08/16/04	SI	Night	B	Su	3	54	121,000	High Slack	2.30	0.02	0.009
43	08/29/04	BP	Night	B	Su	4	55	174,000	Ebbing	3.00	0.85	0.502
44	08/29/04	BP	Night	B	Su	4	56	174,000	Ebbing	2.10	0.91	0.538
45	08/29/04	BP	Night	B	Su	4	57	174,000	Ebbing	1.90	0.95	0.563
46	08/29/04	BP	Night	B	Su	4	58	174,000	Ebbing	1.60	0.91	0.541
47	08/30/04	BP	Night	B	Su	4	59	163,000	High Slack	4.30	-0.13	-0.078
48	08/30/04	BP	Night	B	Su	4	60	163,000	Ebbing	4.00	0.48	0.287
49	08/30/04	BP	Night	B	Su	4	61	163,000	Ebbing	3.80	0.31	0.186
50	08/30/04	BP	Night	B	Su	4	62	163,000	Ebbing	3.80	0.51	0.300
51	08/30/04	BP	Night	B	Su	4	63	163,000	Ebbing	2.50	0.93	0.549
52	08/30/04	BP	Night	B	Su	4	64	163,000	Ebbing	2.50	0.93	0.550
53	08/30/04	BP	Night	B	Su	4	65	163,000	Ebbing	1.20	1.01	0.595
54	08/30/04	BP	Night	B	Su	4	66	163,000	Ebbing	1.20	0.98	0.577

Exhibit List 382

Basic Identifiers								River Characteristics				
Deep Draft Passage #	Date	Location	Diel Sampling Phase	Phase	Season	Field Trip	Data Collection Trial #	River Flow (Quincy,OR)	Tidal Stage	Tidal Height, ft.	Current Velocity (Qunicy, OR)	
55	02/08/05	SI	Day	B	Win	1	1	98,600	Ebbing	1.00	0.89	0.527
56	02/08/05	SI	Day	B	Win	1	2	-116,000	Flooding	1.60	-0.98	-0.580
57	02/08/05	SI	Day	B	Win	1	3	-94,400	Flooding	2.10	-0.79	-0.468
58	02/08/05	SI	Day	B	Win	1	4	-51,900	Flooding	2.40	-0.44	-0.260
59	02/08/05	SI	Day	B	Win	1	5	-51,900	Flooding	2.40	-0.44	-0.260
60	02/09/05	SI	Day	B	Win	1	6	-20,100	Low Slack	0.70	-0.18	-0.107
61	02/09/05	SI	Day	B	Win	1	7	-101,000	Low Slack	0.70	-0.87	-0.515
62	02/09/05	SI	Day	B	Win	1	8	-119,000	Flooding	1.70	-1.00	-0.592
63	02/10/05	BP	Day	B	Win	1	9	255,000	Low Slack	0.90	2.39	1.415
64	02/10/05	BP	Day	B	Win	1	10	-93,500	Flooding	2.70	-0.8	-0.474
65	02/10/05	BP	Day	B	Win	1	11	-109,000	Flooding	3.90	-0.92	-0.545
66	02/10/05	BP	Day	B	Win	1	12	12,200	High Slack	4.80	0.1	0.059
67	02/11/05	BP	Day	B	Win	1	13	276,000	Ebbing	3.40	2.5	1.480
68	02/11/05	BP	Day	B	Win	1	14	303,000	Ebbing	2.20	2.81	1.664
69	02/11/05	BP	Day	B	Win	1	15	340,000	Ebbing	1.30	3.2	1.894
70	02/11/05	BP	Day	B	Win	1	16	267,000	Low Slack	0.70	2.5	1.480
71	02/11/05	BP	Day	B	Win	1	17	234,000	Low Slack	0.70	2.17	1.285
72	02/11/05	BP	Day	B	Win	1	18	75,700	Flooding	0.80	0.68	0.403
73	02/12/05	CL	Day	B	Win	1	19	70,400	Flooding	2.50	0.63	0.373
74	02/12/05	CL	Day	B	Win	1	20	-46,000	Flooding	5.20	-0.39	-0.231
75	02/12/05	CL	Day	B	Win	1	21	-55,000	High Slack	5.50	-0.47	-0.278
76	02/13/05	CL	Day	B	Win	1	22	300,000	Low Slack	0.70	2.84	1.681
77	02/13/05	CL	Day	B	Win	1	23	59,700	Flooding	2.70	0.54	0.320
78	02/13/05	CL	Day	B	Win	1	24	11,800	Flooding	3.90	0.1	0.059
79	03/16/05	BP	Day	B	Win	2	25	273,000	Ebbing	1.00	2.57	1.521
80	03/17/05	BP	Day	B	Win	2	26	75,100	High Slack	3.80	0.67	0.397
81	03/17/05	BP	Day	B	Win	2	27	289,000	Ebbing	1.40	2.74	1.622
82	03/17/05	BP	Day	B	Win	2	28	210,000	Low Slack	0.50	2	1.184
83	03/18/05	SI	Day	B	Win	2	29	261,000	Ebbing	1.00	2.49	1.474
84	03/18/05	SI	Day	B	Win	2	30	231,000	Ebbing	0.70	2.21	1.308
85	03/19/05	SI	Day	B	Win	2	31	265,000	Ebbing	1.10	2.5	1.480

Exhibit List 383

Basic Identifiers								River Characteristics				
Deep Draft Passage #	Date	Location	Diel Sampling Phase	Phase	Season	Field Trip	Data Collection Trial #	River Flow (Quincy, OR)	Tidal Stage	Tidal Height, ft.	Current Velocity (Qunicy, OR)	
86	03/20/05	SI	Day	B	Win	2	32	276,000	Ebbing	1.30	2.57	1.521
87	03/21/05	CL	Day	B	Win	2	33	105,000	Flooding	3.10	0.95	0.562
88	03/21/05	CL	Day	B	Win	2	34	3,920	High Slack	5.00	0.03	0.018
89	03/21/05	CL	Day	B	Win	2	35	25,400	High Slack	5.00	0.22	0.130
90	03/21/05	CL	Day	B	Win	2	36	179,000	Ebbing	4.30	1.6	0.947
91	03/21/05	CL	Day	B	Win	2	37	271,000	Ebbing	2.90	2.5	1.480
92	03/21/05	CL	Day	B	Win	2	38	297,000	Ebbing	2.20	2.76	1.634
93	03/22/05	CL	Day	B	Win	2	39	-37,700	Flooding	4.50	-0.33	-0.195
94	03/22/05	CL	Day	B	Win	2	40	-79,300	Flooding	5.00	-0.69	-0.408
95	04/11/05	CL	Day	B	Sp	1	1	46,400	Flooding	3.50	0.41	0.243
96	04/12/05	CL	Day	B	Sp	1	2	362,000	Ebbing	1.30	3.35	1.983
97	04/12/05	CL	Day	B	Sp	1	3	357,000	Ebbing	0.60	3.31	1.960
98	04/12/05	CL	Day	B	Sp	1	4	324,000	Low Slack	-0.03	3.07	1.817
99	04/12/05	CL	Day	B	Sp	1	5	236,000	Flooding	0.50	2.21	1.308
100	04/13/05	BP	Day	B	Sp	1	6	335,000	Ebbing	0.40	3.17	1.877
101	04/13/05	BP	Day	B	Sp	1	7	321,000	Low Slack	0.00	3.04	1.800
102	04/13/05	BP	Day	B	Sp	1	8	191,000	Flooding	0.30	1.76	1.042
103	04/13/05	BP	Day	B	Sp	1	9	116,000	Flooding	0.90	1.05	0.622
104	04/14/05	BP	Day	B	Sp	1	10	258,000	Ebbing	3.30	2.33	1.379
105	04/14/05	BP	Day	B	Sp	1	11	314,000	Ebbing	2.60	2.88	1.705
106	04/14/05	BP	Day	B	Sp	1	12	232,000	Low Slack	0.20	2.2	1.302
107	04/15/05	SI	Day	B	Sp	1	13	330,000	Ebbing	0.90	3.13	1.853
108	04/16/05	SI	Day	B	Sp	1	14	302,000	Ebbing	1.20	2.87	1.699
109	04/16/05	SI	Day	B	Sp	1	15	300,000	Ebbing	0.90	2.83	1.675
110	05/16/05	SI	Day	B	Sp	2	16	374,000	Ebbing	1.40	3.4	2.013
111	05/16/05	SI	Day	B	Sp	2	17	373,000	Ebbing	0.80	3.44	2.036
112	05/16/05	SI	Day	B	Sp	2	18	377,000	Ebbing	0.70	3.49	2.066
113	05/17/05	SI	Day	B	Sp	2	19	359,000	Ebbing	1.00	3.32	1.965
114	05/17/05	SI	Day	B	Sp	2	20	356,000	Ebbing	0.90	3.3	1.954

Exhibit List 384

Basic Identifiers								River Characteristics				
Deep Draft Passage Trial #	Date	Location	Diel Sampling Phase	Phase	Season	Field Trip	Data Collection Trial #	River Flow (Quincy, RM 53.8)	Tidal Stage	Tidal Height, ft.	Current Velocity (Qunicy, OR RM 53.8)	
115	05/18/05	SI	Day	B	Sp	2	21	410,000	Ebbing	1.50	3.64	2.155
116	05/18/05	SI	Day	B	Sp	2	22	414,000	Ebbing	1.40	3.69	2.184
117	05/19/05	SI	Day	B	Sp	2	23	300,000	Flooding	0.60	2.59	1.533
118	05/19/05	SI	Day	B	Sp	2	24	414,000	Ebbing	1.20	3.64	2.155
119	05/20/05	CL	Day	B	Sp	2	25	447,000	Low Slack	0.80	4.01	2.374
120	05/20/05	CL	Day	B	Sp	2	26	358,000	Flooding	2.10	3.17	1.877
121	05/20/05	CL	Day	B	Sp	2	27	427,000	Ebbing	3.00	3.75	2.220
122	05/22/05	BP	Day	B	Sp	2	28	451,000	Low Slack	-0.10	4.08	2.415
123	05/22/05	BP	Day	B	Sp	2	29	229,000	Flooding	2.80	1.93	1.143
124	05/23/05	BP	Day	B	Sp	2	30	450,000	Ebbing	0.90	4.02	2.380
125	05/23/05	BP	Day	B	Sp	2	31	363,000	Low Slack	-0.40	3.26	1.930
126	05/23/05	BP	Day	B	Sp	2	32	345,000	Low Slack	-0.10	3.08	1.823

Exhibit List 385

D-2. Vessel Characteristics

Basic Identifiers			Vessel Characteristics											
Deep Draft Passage #	Location	Date	Name	Vessel Type	Vessel Direction	Condition	Distance from Shore	Time (s)	Vessel Speed over Ground		Vessel Draft	Vessel Beam	Vessel Length	Block Coefficient
	County Line= CL Barlow = BP Sauvie = SI		not included in report		U= upriver D=downriver	Unloaded, Partially loaded, Loaded	N=Near M=Middle F=Far		meters/sec	knots	ft	ft	ft	
1	CL	06/29/04		Car Carrier	U	Unloaded	M	16.4	6.10	11.85	28.0	90	568	1431360
2	CL	06/29/04		Bulk Carrier	U	Loaded	M	18.34	5.45	10.60	28.0	90	614	1547280
3	CL	06/29/04		Bulk Carrier	D	Loaded	M	15.57	6.42	12.48	33.2	85	579	1632313.91
4	CL	06/29/04		Car Carrier	D	Unloaded	M	9.8	10.20	19.83	27.0	106	656	1877472
5	BP	06/30/04		Container Ship	D	Partially	F	15.35	6.51	12.66	35.0	122	902	3851540
6	BP	06/30/04		Bulk Carrier	U	Loaded	F	20.53	4.87	9.47				
7	BP	06/30/04		Car Carrier	D	Unloaded	F	12.99	7.70	14.96	27.0	90	568	1380240
8	SI	07/01/04		Car Carrier	D	Unloaded	F	14.35	6.97	13.55				
9	BP	07/19/04		Bulk Carrier	D		F	28.9	6.92	13.45	35.1	100	593	2080244
10	BP	07/19/04		Oil Tanker	U		F	37.63	5.31	10.33	32.3	99	574	1832638.5
11	BP	07/20/04		Bulk Carrier	D		F	26.51	7.54	14.66	30.8	95	609	1783669.65
12	BP	07/20/04		Bulk Carrier	D		M	25.44	7.86	15.28	21.0	95	525	1047375
13	SI	07/20/04		Container Ship	U	Loaded	N	34.12	5.86	11.39	32.0	106	950	3222400
14	CL	07/21/04		Container Ship	D	Unloaded	N	21.38	9.35	18.18	33.4	106	950	3365394
15	CL	07/21/04		Container Ship	U	Partially	M	25.22	7.93	15.41	35.0	122	903	3855810
16	CL	07/22/04		Bulk Carrier	D	Loaded	M	20.17	9.92	19.27				
17	CL	08/09/04		Bulk Carrier	D	Loaded	F	29.57	6.76	13.15	30.0	106	590	1876200
18	CL	08/09/04		Bulk Carrier	D	Unloaded	M-F	31.93	6.26	12.18	33.3	89	558	1651261.5
19	CL	08/10/04		Container Ship	U	Loaded	N	27.97	7.15	13.90	30.3	106	950	3054231
20	CL	08/10/04		Bulk Carrier	U	Unloaded	M	30.45	6.57	12.77	26.1	106	640	1769267.2
21	CL	08/10/04		Container Ship	D	Loaded	M	38.95	5.13	9.98	34.4	106	907	3309207.64
22	CL	08/10/04		Bulk Carrier	U	Unloaded	F	28.81	6.94	13.49	20.5	75	567	871762.5
23	CL	08/11/04		Bulk Carrier	U	Unloaded	F	29.19	6.85	13.32	21.0	85	494	881790
24	CL	08/11/04		Bulk Carrier	U	Partially	M-F	32.33	6.19	12.02	24.3	85	520	1075386
25	CL	08/11/04		Bulk Carrier	D	Loaded	M	31.77	6.30	12.24				
26	CL	08/11/04		Oil Tanker	U	Loaded	M	30.66	6.52	12.68				

Exhibit List 386

Basic Identifiers			Vessel Characteristics											
Deep Draft Passage #	Location	Date	Name	Vessel Type	Vessel Direction	Condition	Distance from Shore	Time (s)	Vessel Speed over Ground		Vessel Draft	Vessel Beam	Vessel Length	Block Coefficient
27	BP	08/11/04		Container Ship	U	Loaded	M	39.19	5.10	9.92	34.8	122	902	3824029
28	BP	08/11/04		Bulk Carrier	U	Partially	N-M	44.72	4.47	8.69	23.1	93	580	1244935
29	BP	08/12/04		Bulk Carrier	U	Unloaded	M	37.8	5.29	10.28				
30	BP	08/12/04		Other	U	Unknown	M	37.34	5.36	10.41				
31	SI	08/13/04		Container Ship	D	Loaded	N				39.0	122	902	4291716
32	SI	08/13/04		Bulk Carrier	D	Loaded	F	38.45	5.20	10.11	37.4	106	640	2538573
33	SI	08/14/04		Bulk Carrier	D	Loaded	F	42.55	4.70	9.14	31.1	85	580	1532244
34	SI	08/14/04		Bulk Carrier	D		M	39.15	5.11	9.93	25.4	85	504	1088993
35	SI	08/15/04		Car Carrier	U	Loaded	N-M	55.13	3.63	7.05	25.1	100	568	1424544
36	SI	08/15/04		Bulk Carrier	U	Loaded	M-F	42.25	4.73	9.20	35.8	89	558	1775417
37	SI	08/15/04		Container Ship	D	Unloaded	N-M	45.47	4.40	8.55	25.3	102	650	1674075
38	SI	08/15/04		Container Ship	U	Loaded	N	45.4	4.41	8.56	33.3	106	907	3196722
39	SI	08/15/04		Bulk Carrier	D	Unloaded	M	35.04	5.71	11.09	??	84	556	
40	SI	08/16/04		Bulk Carrier	U	Unloaded	M	48.69	4.11	7.98	19.5	89	558	968409
41	SI	08/16/04		Bulk Carrier	U	Partially	M	44.22	4.52	8.79		106	738	
42	SI	08/16/04		Tanker	U	Loaded	M	39.67	5.04	9.80	35.2	96	651	2197984
43	BP	08/29/04		Bulk Carrier	U	Unloaded	M	32.75	6.11	11.87	21.2	88	558	1039532
44	BP	08/29/04		Bulk Carrier	U	Unloaded	M	37.69	5.31	10.31	22.3	100	600	1335000
45	BP	08/29/04		Dredge	D	Unloaded	M	26	7.69	14.95				
46	BP	08/29/04		Oil Tanker	D	Loaded	M-F	32.44	6.17	11.98	22.0	82	495	892980
47	BP	08/30/04		Research Ves.	D	Unloaded	M	31.26	6.40	12.44	16.0	51	274	223584
48	BP	08/30/04		Container Ship	U	Loaded	M	30.63	6.53	12.69	34.4	106	907	3309208
49	BP	08/30/04		Bulk Carrier	U	Loaded	F	33.1	6.04	11.75	33.8	96	589	1912884
50	BP	08/30/04		Bulk Carrier	D	Loaded	M	32.36	6.18	12.01	36.8	85	575	1796156
51	BP	08/30/04		Car Carrier	D	Unloaded	M-F	24.09	8.30	16.14	27.0	106	610	1745820
52	BP	08/30/04		Bulk Carrier	D	Loaded	M	26.46	7.56	14.69	27.0	96	650	1684800
53	BP	08/30/04		Oil Tanker	U	Loaded	F	38.9	5.14	9.99	16.2	83	640	858950
54	BP	08/30/04		Bulk Carrier	D	Loaded	N	27.97	7.15	13.90	29.5	106	738	2307726
55	SI	02/08/05		Bulk Carrier	U	Unloaded	M	44.23	4.52	8.79	24.0	85	600	1224000
56	SI	02/08/05		Car Carrier	D	Loaded	M	36.20	5.52	10.74	26.0	106	656	1807936
57	SI	02/08/05		Bulk Carrier	D	Unloaded	F	35.10	5.70	11.08	21.0	106	623	1386798

Exhibit List 387

Basic Identifiers			Vessel Characteristics											
Deep Draft Passage #	Location	Date	Name	Vessel Type	Vessel Direction	Condition	Distance from Shore	Time (s)	Vessel Speed over Ground		Vessel Draft	Vessel Beam	Vessel Length	Block Coefficient
58	SI	02/08/05		Car Carrier	D	Unloaded	F	36.00	5.56	10.80	26.0	106	655	1805180
59	SI	02/08/05		Car Carrier	U	Loaded	N	38.00	5.26	10.23	26.6	106	623	1756611
60	SI	02/09/05		Bulk Carrier	U	Unloaded	M	44.85	4.46	8.67	29.8	102	623	1893671
61	SI	02/09/05		Bulk Carrier	D	Unloaded	M	31.45	6.36	12.36	26.6	102	600	1627920
62	SI	02/09/05		Car Carrier	D	Unloaded	M	39.47	5.07	9.85	25.0	106	623	1650950
63	BP	02/10/05		Bulk Carrier	U	Unloaded	F	39.47	5.07	9.85	21.0	102	623	1334466
64	BP	02/10/05		Bulk Carrier	D	Loaded	F	36.44	5.49	10.67	35.5	75	567	1509638
65	BP	02/10/05		Bulk Carrier	D	Loaded	M	41.73	4.79	9.32		89	558	
66	BP	02/10/05		Bulk Carrier	U	Unloaded	M	35.69	5.60	10.89	21.0	92	588	1136016
67	BP	02/11/05			D						36.0	132	915	4348080
68	BP	02/11/05		Bulk Carrier	U	Unloaded	F	40.94	4.89	9.50	23.5	106	738	1838358
69	BP	02/11/05		Bulk Carrier	U	Unloaded	F	35.72	5.60	10.88	20.7	85	494	869193
70	BP	02/11/05		Bulk Carrier	D	Loaded	M	36.96	5.41	10.52	39.0	106	623	2575482
71	BP	02/11/05		Bulk Carrier	U	Unloaded	F	40.46	4.94	9.61	20.0	76	617	937840
72	BP	02/11/05		Bulk Carrier	U	Loaded	M	32.27	6.20	12.05	25.0	102	650	1657500
73	CL	02/12/05		Bulk Carrier	U	Unloaded	M	39.81	5.02	9.77	25.0	90	574	1291500
74	CL	02/12/05		Bulk Carrier	U	Unloaded	M	37.49	5.33	10.37	23.0	102	600	1407600
75	CL	02/12/05		Car Carrier	D	Unloaded	N	42.30	4.73	9.19	27.0	106	625	1788750
76	CL	02/13/05		Bulk Carrier	U	Unloaded	M	41.80	4.78	9.30		89	554	
77	CL	02/13/05		Bulk Carrier	U	Unloaded	F	40.66	4.92	9.56		93	581	
78	CL	02/13/05		Bulk Carrier	D	Loaded	M	40.45	4.94	9.61	32.8	26	504	429811
79	BP	03/16/05		Bulk Carrier	U	Unloaded	F	35.98	5.56	10.80	20.6	89	564	1034038
80	BP	03/17/05		Bulk Carrier	D	Loaded	M	30.53	6.55	12.73	30.0	90	573	1547100
81	BP	03/17/05		Bulk Carrier	U	Unloaded	F	38.48	5.20	10.10	19.0	85	494	797810
82	BP	03/17/05		Car Carrier	D		M				23.0	90	541	1119870
83	SI	03/18/05		Bulk Carrier	U	Unloaded	F	39.89	5.01	9.75	22.0	106	623	1452836
84	SI	03/18/05		Bulk Carrier	D	Loaded	F	31.30	6.39	12.42	39.2	106	653	2713346
85	SI	03/19/05		Bulk Carrier	D	Unloaded	M	27.33	7.32	14.22	24.7	94	615	1427907
86	SI	03/20/05		Car Carrier	D	Unloaded	M				26.0	106	653	1799668
87	CL	03/21/05		Bulk Carrier	U	Unloaded	M	29.65	6.75	13.11	23.0	89	555	1136085

Exhibit List 388

Basic Identifiers			Vessel Characteristics											
Deep Draft Passage #	Location	Date	Name	Vessel Type	Vessel Direction	Condition	Distance from Shore	Time (s)	Vessel Speed over Ground		Vessel Draft	Vessel Beam	Vessel Length	Block Coefficient
88	CL	03/21/05		Bulk Carrier	U	Unloaded	M	26.81	7.46	14.50	21.3	106	731	1650452
89	CL	03/21/05		Bulk Carrier	D	Unloaded	N	27.33	7.32	14.22	31.9	85	506	1372019
90	CL	03/21/05		Car Carrier	U	Partially	M	29.70	6.73	13.09	25.0	106	599	1587350
91	CL	03/21/05		Bulk Carrier	D	Unloaded	F	21.74	9.20	17.88	18.4	85	525	821100
92	CL	03/21/05		Container Ship	D	Loaded	M	32.91	6.08	11.81	37.4	98	663	2430028
93	CL	03/22/05		Oil Tanker	U	Loaded	M				26.0	96	651	1624896
94	CL	03/22/05		Oil Tanker	U	Loaded	F	34.23	5.84	11.36	37.0	106	600	2353200
95	CL	04/11/05		Bulk Carrier	U	Partially	M	29.69	6.74	13.09	25.9	106	656	1800982
96	CL	04/12/05		Bulk Carrier	D	Loaded	M	30.26	6.61	12.85	37.8	100	609	2302020
97	CL	04/12/05		Bulk Carrier	D	Loaded	M	26.56	7.53	14.64	33.9	93	580	1828566
98	CL	04/12/05		Bulk Carrier	U	Unloaded	M	35.83	5.58	10.85	19.2	89	555	948384
99	CL	04/12/05		Bulk Carrier	U	Loaded	M	32.88	6.08	11.82	28.5	91	554	1436799
100	BP	04/13/05		Bulk Carrier	D	Partially	M	29.17	6.86	13.33	25.8	106	656	1794029
101	BP	04/13/05		Oil Tanker	U	Loaded	F	36.48	5.48	10.66	33.5	79	485	1283553
102	BP	04/13/05		Bulk Carrier	D	Loaded	M	32.5	6.15	11.96	39.9	102	623	2535485
103	BP	04/13/05		Bulk Carrier	U	Unloaded	F	29.95	6.68	12.98	21.0	106	623	1386798
104	BP	04/14/05		Bulk Carrier	D	Loaded	M	28.74	6.96	13.53		93	581	
105	BP	04/14/05		Bulk Carrier	D	Loaded	M	30.94	6.46	12.56	37.8	100	607	2294460
106	BP	04/14/05		Oil Tanker	D	Partially	M	27.05	7.39	14.37		79	485	
107	SI	04/15/05		Car Carrier	D	Partially	M	24.05	8.32	16.16	25.0	105	586	1538250
108	SI	04/16/05		Car Carrier	U	Loaded	N	29.38	6.70	13.03	27.5	106	621	1810215
109	SI	04/16/05		Bulk Carrier	D	Loaded	M	27.92	7.16	13.92	38.5	103	623	2470507
110	SI	05/16/05		Oil Tanker	D	Loaded	M	27.02	7.40	14.39	27	96	650	1684800
111	SI	05/16/05		Container Ship	D	Loaded	M	27.78	7.20	13.99	33.9	98	680	2259096
112	SI	05/16/05		Bulk Carrier	U	Unloaded	N	42.43	4.71	9.16	25	92	617	1419100
113	SI	05/17/05		Car Carrier	U	Unloaded	M	38.09	5.25	10.21	25.3	106	599	1606398
114	SI	05/17/05		Car Carrier	D	Partially	M	44.48	4.50	8.74	26	98	573	1460004
115	SI	05/18/05		Bulk Carrier	U	Unloaded	M	35.75	5.59	10.87	19	89	558	943578
116	SI	05/18/05		Car Carrier	D	Partially	M	27.05	7.39	14.37	24	106	599	1523856
117	SI	05/19/05		Bulk Carrier	D	Loaded	M	31.65	6.32	12.28	36.7	92	617	2083239

Exhibit List 389

Basic Identifiers			Vessel Characteristics											
Deep Draft Passage Trial #	Location	Date	Name	Vessel Type	Vessel Direction	Condition	Distance from Shore	Time (s)	Vessel Speed over Ground		Vessel Draft	Vessel Beam	Vessel Length	Block Coefficient
118	SI	05/19/05		Car Carrier	U	Loaded	M	33.25	6.02	11.69	27	106	625	1788750
119	CL	05/20/05		Bulk Carrier	D	Loaded	M	29.4	6.80	13.22	33.7	89	555	1664612
120	CL	05/20/05		Car Carrier	U	Loaded	M	28.18	7.10	13.80	28	106	590	1751120
121	CL	05/20/05		Car Carrier	D	Partially	M	22.66	8.83	17.16	25	106	625	1656250
122	BP	05/22/05		Car Carrier	U	Partially	F	27.5	7.27	14.14	26.7	98	590	1543794
123	BP	05/22/05		Bulk Carrier	U	Loaded	F	33.98	5.89	11.44				0
124	BP	05/23/05		Container Ship	D	Partially	M	25.56	7.82	15.21	31.5	132	915	3804570
125	BP	05/23/05		Car Carrier	U	Loaded	F	30.99	6.45	12.54	27.5	84	555	1282050
126	BP	05/23/05		Car Carrier	U	Loaded	M	28.8	6.94	13.50	29	106	588	1807512

Exhibit List 390

D-3 Wave Characteristics

Basic Identifiers			**Wave Characteristics**								
Deep Draft Passage #	Location	Date	Run-up distance	Draw-down distance	Total Dist – Run-up to Draw-down	Run-up Velocity	Run-up Velocity	Wash-back Velocity	Maximum draw-down height	Maximum run-up height	Maximum Water Level
	County Line= CL Barlow = BP Sauvie = SI		m	m	m	camera m/s	run-up gage, m/s	run-up gage m/s	staff gage m	staff gage m	staff gage m
1	CL	06/29/04			15.1				-0.18	0.11	0.19
2	CL	06/29/04			20.55		0.064	0.101	-0.20	0.12	0.22
3	CL	06/29/04			9.5				-0.11	0.05	0.13
4	CL	06/29/04			34.5		0.357	0.274	-0.25	0.21	0.27
5	BP	06/30/04			27				n/a	n/a	n/a
6	BP	06/30/04			23				-0.10	n/a	0.12
7	BP	06/30/04			20.6				-0.07	0.05	0.13
8	SI	07/01/04	6.2	6.8	13			0.314	n/a	n/a	0.76
9	BP	07/19/04	5.1	4.3	9.4				-0.15*	0.05	0.15
10	BP	07/19/04	6.65	6.2	12.85				-0.15*	0.07	0.23
11	BP	07/20/04	17.9	18	35.9				n/a	n/a	n/a
12	BP	07/20/04	8.8	12.3	21.1			0.500	-0.13	0.06	0.23
13	SI	07/20/04	22	28.9	50.9		0.360	0.960	-0.36	0.10	0.49
14	CL	07/21/04	10.3	14.9	25.2				-0.33	0.17	0.35
15	CL	07/21/04	24.6	23	47.6		0.107	0.799	-0.43*	0.22	0.46
16	CL	07/22/04	9.3	11.8	21.1		0.320	0.774	-0.21	0.09	0.19
17	CL	08/09/04	13.3	15.4	28.7		0.509	0.445	-0.27*	0.11	0.17
18	CL	08/09/04	7.8	8.7	16.5				-0.18	0.08	0.34
19	CL	08/10/04	14.6	18.9	33.5				-0.40*	0.14	0.28
20	CL	08/10/04	8	19.8	27.8		0.616	0.475	-0.44	0.13	0.27
21	CL	08/10/04	6.1	6.6	12.7		0.305	0.393	n/a	n/a	0.25
22	CL	08/10/04	5.4	2.9	8.3		0.018	0.030	-0.08	0.03	0.20
23	CL	08/11/04	5.4	3.8	9.2				-0.07	0.06	0.15
24	CL	08/11/04	6	6.8	12.8				-0.08	0.07	0.20
25	CL	08/11/04	9.5	14	23.5				-0.25	0.15	0.17
26	CL	08/11/04	8.3	29.1	37.4		0.796	0.814	-0.40	0.16	0.53
27	BP	08/11/04	5.6	24.9	30.5				-0.35	0.15	0.34

Exhibit List 391

Basic Identifiers			Wave Characteristics								
Deep Draft Passage #	Location	Date	Run-up distance	Draw-down distance	Total Dist – Run-up to Draw-down	Run-up Velocity	Run-up Velocity	Wash-back Velocity	Maximum draw-down height	Maximum run-up height	Maximum Water Level
28	BP	08/11/04	3.6	5.9	9.5				-0.11	0.05	0.25
29	BP	08/12/04	8.1	12.6	20.7				n/a	n/a	n/a
30	BP	08/12/04	5.9	6.4	12.3			0.701	n/a	n/a	0.46
31	SI	08/13/04	27	30.7	57.7				-0.40*	0.16	0.28
32	SI	08/13/04	13	28.5	41.5				-0.25*	0.20	0.30
33	SI	08/14/04	7.7	7	14.7			0.396	-0.11	0.08	0.30
34	SI	08/14/04	6.1	13.4	19.5				n/a	n/a	n/a
35	SI	08/15/04	7.8	15.2	23		0.482	0.485	-0.12	0.01	0.12
36	SI	08/15/04	17	17.3	34.3		0.969	0.335	-0.27	0.06	0.38
37	SI	08/15/04	8.9	17.4	26.3				-0.18	0.10	n/a
38	SI	08/15/04	21.8	27.1	48.9			0.604	-0.38*	0.23	0.39
39	SI	08/15/04	4.8	8.8	13.6				-0.13	0.10	0.27
40	SI	08/16/04	7.7	10.9	18.6				-0.11	0.07	0.24
41	SI	08/16/04	6.3	5.7	12				-0.07	0.04	0.07
42	SI	08/16/04	25.9	29.3	55.2				-0.30	0.07	0.34
43	BP	08/29/04	3.5	6.7	10.2				n/a	n/a	n/a
44	BP	08/29/04	3.2	6.8	10				-0.08	0.03	0.15
45	BP	08/29/04	6.8	11.3	18.1				-0.07	0.07	0.27
46	BP	08/29/04	11.2	7.9	19.1				n/a	n/a	n/a
47	BP	08/30/04	1.8	1.8	3.6				n/a	n/a	0.13
48	BP	08/30/04	10	13.4	23.4		0.143	0.482	-0.12	0.07	0.57
49	BP	08/30/04	11.4	16.2	27.6		0.140	0.384	-0.06	0.06	0.24
50	BP	08/30/04	10.7	19.1	29.8			0.408	-0.14	0.04	0.11
51	BP	08/30/04	11.9	23.2	35.1				-0.20	0.15	0.20
52	BP	08/30/04	11	20.5	31.5				-0.15	0.13	0.22
53	BP	08/30/04	13.4	19	32.4				-0.19*	0.19	0.28
54	BP	08/30/04	13.4	19	32.4				n/a	n/a	n/a
55	SI	2/8/2005	10.7	8.5	19.2				-0.17	0.08	0.14
56	SI	2/8/2005	8.5	14.5	23	0.561	1.060	1.720	-0.18	0.08	0.12
57	SI	2/8/2005	15.1	8.2	23.3	0.576			-0.10	0.07	0.25

Exhibit List 392

Basic Identifiers			Wave Characteristics								
Deep Draft Passage #	Location	Date	Run-up distance	Draw-down distance	Total Dist – Run-up to Draw-down	Run-up Velocity	Run-up Velocity	Wash-back Velocity	Maximum draw-down height	Maximum run-up height	Maximum Water Level
58	SI	2/8/2005	29	49	78	2.251					
59	SI	2/8/2005							-0.12	0.03	0.28
60	SI	2/9/2005	17.7	21.3	39	0.516	1.100	3.290			
61	SI	2/9/2005	19.1	18.1	37.2		1.190	1.070			
62	SI	2/9/2005	8.3	7.5	15.8	0.616	0.950	0.330			
63	BP	2/10/2005	3.8	5.5	9.3						
64	BP	2/10/2005	11.3	15.8	27.1	0.755					
65	BP	2/10/2005	10.1	9.4	19.5				-0.15	0.06	0.07
66	BP	2/10/2005	4.2	3.8	8				n/a	n/a	0.12
67	BP	2/11/2005	10.8	19.4	30.2	0.646					
68	BP	2/11/2005	4.1	9.4	13.5		0.530	0.269	-0.12	0.06	0.17
69	BP	2/11/2005	3.4	7.5	10.9	0.681			-0.07	0.05	0.30
70	BP	2/11/2005	5.4	6.2	11.6				-0.17*	0.05	0.23
71	BP	2/11/2005	6.2	7.9	14.1	0.556					
72	BP	2/11/2005	14.7	19.8	34.5	1.885	0.515	2.200	-0.47	0.04	0.43
73	CL	2/12/2005	5.3	5.9	11.2		0.297	0.833			
74	CL	2/12/2005	2.3	4.2	6.5				-0.12	0.08	0.27
75	CL	2/12/2005	2.1	2.3	4.4				0.12	0.06	0.20
76	CL	2/13/2005	-4	12	8				0.18	0.08	0.28
77	CL	2/13/2005	4.7	4	8.7						
78	CL	2/13/2005	4.1	4.7	8.8						
79	BP	3/16/2005	4.2	8.3	12.5						
80	BP	3/17/2005	6.5	10.5	17	0.795			-0.08	0.08	0.15
81	BP	3/17/2005	2.2	4.8	7						
82	BP	3/17/2005	10	15	25						
83	SI	3/18/2005	9.4	14	23.4	1.107			-0.17	0.08	0.24
84	SI	3/18/2005	15.9	15.8	31.7	0.987					
85	SI	3/19/2005	10.7	18.2	28.9	1.349	0.707	0.769	-0.17	0.08	0.28
86	SI	3/20/2005	13.5	10.5	23.5						

Exhibit List 393

Basic Identifiers			Wave Characteristics								
Deep Draft Passage #	Location	Date	Run-up distance	Draw-down distance	Total Dist – Run-up to Draw-down	Run-up Velocity	Run-up Velocity	Wash-back Velocity	Maximum draw-down height	Maximum run-up height	Maximum Water Level
87	CL	3/21/2005	8.6	4.5	13.1	3.299			-0.13	0.05	0.10
88	CL	3/21/2005	1.7	4.1	5.8				-0.06	0.06	0.10
89	CL	3/21/2005	7	19	26	1.180			-0.36	0.20	0.27
90	CL	3/21/2005	7.5	12	19.5	1.374			-0.19	0.18	0.30
91	CL	3/21/2005	9.6	8.8	18.4	0.607			-0.17	0.20	0.50
92	CL	3/21/2005	2.5	5	7.5	0.832			-0.15	0.08	0.16
93	CL	3/22/2005	4.6	9	13.6	1.222			-0.18	0.13	0.26
94	CL	3/22/2005	2.1	2.6	4.7	0.836			-0.13	0.07	0.12
95	CL	4/11/2005	7.1	5.5	12.6	0.980					
96	CL	4/12/2005	8.5	7.1	15.6	0.934	0.804	7.619	-0.24*	0.23	0.28
97	CL	4/12/2005	18.7	17.9	36.6	1.458	1.264	3.333			
98	CL	4/12/2005	2.3	3.9	6.2	0.999					
99	CL	4/12/2005	6.7	11.3	18	1.688					
100	BP	4/13/2005	10.8	6.1	16.9						
101	BP	4/13/2005	6.5	16.7	23.2	0.910					
102	BP	4/13/2005	13	14.6	27.6	0.786					
103	BP	4/13/2005	6.4	7.4	13.8	0.872			-0.12	0.03	0.21
104	BP	4/14/2005	9.5	11.4	20.9	0.796	0.612	1.750	-0.15	0.12	0.14
105	BP	4/14/2005	9.3	10	19.3				-0.12	0.10	0.11
106	BP	4/14/2005	5.5	10.4	15.9	0.430					
107	SI	4/15/2005	8.2	11.4	19.6	1.298	1.306	1.468			
108	SI	4/16/2005	11.1	10	21.1	0.662					
109	SI	4/16/2005	24.4	22	46.4	2.080					
110	SI	5/16/2005	9.4	13.6	23	1.182	0.287	0.370	-0.20	0.12	0.30
111	SI	5/16/2005	12.9	17.5	30.4	1.709			-0.27	0.23	0.30
112	SI	5/16/2005	5.8	11.1	16.9	1.253					
113	SI	5/17/2005	9.2	15	24.2						
114	SI	5/17/2005	10.4	11	21.4	1.557	0.316	0.513	-0.15	0.12	0.30
115	SI	5/18/2005	4.9	4.4	9.3	1.102					
116	SI	5/18/2005	7.5	8.1	15.6	1.749			-0.16	0.11	0.28
117	SI	5/19/2005	6.1	3.9	10	1.696					

Exhibit List 394

Basic Identifiers			Wave Characteristics								
Deep Draft Passage #	Location	Date	Run-up distance	Draw-down distance	Total Dist – Run-up to Draw-down	Run-up Velocity	Run-up Velocity	Wash-back Velocity	Maximum draw-down height	Maximum run-up height	Maximum Water Level
118	SI	5/19/2005	8.2	14.7	22.9						
119	CL	5/20/2005	3.2	7.9	11.1	0.775					
120	CL	5/20/2005	10.3	17.1	27.4		0.748	1.355	-0.47	0.24	0.43
121	CL	5/20/2005	4.2	6.4	10.6						
122	BP	5/22/2005	9.3	21.4	30.7	1.415			-0.25	0.13	0.30
123	BP	5/22/2005	3.5	7.2	10.7				-0.10	0.07	0.12
124	BP	5/23/2005	30.9	27.6	58.5	1.413	2.486	4.182			
125	BP	5/23/2005	13.4	11.8	25.2	1.000					
126	BP	5/23/2005	13.4	18.6	32	1.303					

Exhibit List 395

D-4 Stranding Estimates By Species

	Stranding Estimates by Species														
Deep Draft Passage #	Chinook 0+	Coho 0+	Chum	Three-spine Stickleback	Peamouth Chub	Banded Killifish	Bass Fry	American Shad	Yellow Perch	Mountain Whitefish	Starry Flounder	Crappie	Sunfish / Bluegill	UID	Total
1															0
2															0
3															0
4															0
5															0
6															0
7															0
8															0
9															0
10	5			1						1					7
11	8				1	1									10
12	2			1											3
13															0
14	15														15
15															0
16															0
17															0
18															0
19	1						2								3
20															0
21															0
22															0
23															0
24															0
25															0
26	1					4									5
27															0
28															0
29															0
30															0

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	Stranding Estimates by Species														
Deep Draft Passage	Chinook 0+	Coho 0+	Chum	Three-spine Stickleback	Peamouth Chub	Banded Killifish	Bass Fry	American Shad	Yellow Perch	Mountain Whitefish	Starry Flounder	Crappie	Sunfish / Bluegill	UID	Total
31				11				1	1		1				14
32				13	1		1		1			1			17
33															0
34															0
35															0
36															0
37															0
38							1								1
39															0
40															0
41															0
42				8											8
43															0
44															0
45															0
46							1	1							2
47															0
48															0
49															0
50															0
51				2				1					1		4
52	2			2	6			1							11
53															0
54				1											1
55															0
56															0
57															0
58	3														3
59															0
60															0

Exhibit List 397

	Stranding Estimates by Species														
Deep Draft Passage #	Chinook 0+	Coho 0+	Chum	Three-spine Stickleback	Peamouth Chub	Banded Killifish	Bass Fry	American Shad	Yellow Perch	Mountain Whitefish	Starry Flounder	Crappie	Sunfish / Bluegill	UID	Total
61															0
62	1														1
63	1														1
64	3														3
65															0
66															0
67	44					1									45
68	2					1									3
69															0
70	4														4
71															0
72	19														19
73															0
74															0
75															0
76															0
77															0
78															0
79															0
80	14														14
81	10														10
82	122														122
83															0
84	3														3
85	1														1
86			1												1
87															0
88															0
89															0
90	4	4	3												11

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	Stranding Estimates by Species														
Deep Draft Passage #	Chinook 0+	Coho 0+	Chum	Three-spine Stickleback	Peamouth Chub	Banded Killifish	Bass Fry	American Shad	Yellow Perch	Mountain Whitefish	Starry Flounder	Crappie	Sunfish / Bluegill	UID	Total
91															0
92															0
93															0
94															0
95	3														3
96															0
97	6		1												7
98															0
99															0
100	16		1												17
101	16	1													17
102	16														16
103	5	1													6
104	39	1													40
105	5														5
106	12													1	13
107															0
108	2														2
109															0
110	1														1
111	25		2	1											28
112															0
113															0
114															0
115															0
116	5														5
117															0
118	4														4
119															0
120															0

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	Stranding Estimates by Species														
Deep Draft Passage #	Chinook 0+	Coho 0+	Chum	Three-spine Stickleback	Peamouth Chub	Banded Killifish	Bass Fry	American Shad	Yellow Perch	Mountain Whitefish	Starry Flounder	Crappie	Sunfish / Bluegill	UID	Total
121															0
122	5														5
123															0
124	1				1					6					8
125															0
126										1					1

Exhibit List 400

D-5 Seine Data (Density estimates are fish per 100 m^2)

Date	Location	Sampling Period	ID	Area	0+ Chinook	1+ Chinook	Chum	Coho	Cutthroat	Steelhead	Trout	UID Salmonid	Mountain whitefish	Threespine Stickleback	American Shad	Banded Killifish
		summer=su winter=win spring=sp	Location at each site	Area swept	^{2}											
06/29/04	CL	su	Ref 1	600	23							1		599		2
06/29/04	CL	su	Ref 2	518	8											22
06/29/04	CL	su	Ref 3	600	3									2		22
06/29/04	CL	su	Hotspot 1	600	25									1		1
06/29/04	CL	su	Hotspot 2	600	14									10		1
06/30/04	BP	su	Ref 1	660	89									431		7
06/30/04	BP	su	Ref 2	743	38							1		36		18
06/30/04	BP	su	Ref 3	645	5									3		2
06/30/04	BP	su	Hotspot 1	788	12									2		6
06/30/04	BP	su	Hotspot 2	788	17									1		2
07/01/04	SI	su	Ref 1	743	31											
07/01/04	SI	su	Ref 2	788	39								1	2		
07/01/04	SI	su	Ref 3	788	14									1		1
07/01/04	SI	su	Hotspot 1	900	5											
07/01/04	SI	su	Hotspot 2	870	10											
07/19/04	BP	su	Ref 1	823	12											1
07/20/04	BP	su	Ref 2	705	17									2	56	
07/20/04	BP	su	Ref 3	788	14									2	11	
07/20/04	BP	su	Hotspot 1	675	25									2	17	
07/20/04	BP	su	Hotspot 2	675	30									11	9	
07/20/04	SI	su	Ref 1	350	16									2		
07/21/04	SI	su	Ref 2	500	7										43	
07/21/04	SI	su	Ref 3	563	9									36	17	
07/21/04	SI	su	Hotspot 1	563	6									20	11	
07/21/04	SI	su	Hotspot 2	450	0									34	3	
07/21/04	CL	su	Ref 1	150	2									43		
07/22/04	CL	su	Ref 2	146	10									1		6
07/22/04	CL	su	Ref 3	200	2									3		1
07/22/04	CL	su	Hotspot 1	300	21									6		6

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Date	Location	Sampling Period	ID	Blue gill/sunfish/pumpkinseed	Crappie	All Peamouth Chub	Large Scale Sucker	Northern Pike Minnow	Sculpin (Prickly)	Starry Flounder	Other UID
06/29/04	CL	su	Ref 1			11					
06/29/04	CL	su	Ref 2			3					
06/29/04	CL	su	Ref 3			0					
06/29/04	CL	su	Hotspot 1			0					
06/29/04	CL	su	Hotspot 2			0					
06/30/04	BP	su	Ref 1			5				6	
06/30/04	BP	su	Ref 2			13				5	
06/30/04	BP	su	Ref 3			13	1				
06/30/04	BP	su	Hotspot 1			6					
06/30/04	BP	su	Hotspot 2			9					
07/01/04	SI	su	Ref 1			17					
07/01/04	SI	su	Ref 2			13	1	1			
07/01/04	SI	su	Ref 3	1		18					
07/01/04	SI	su	Hotspot 1			77		2			
07/01/04	SI	su	Hotspot 2			10				1	
07/19/04	BP	su	Ref 1			20				2	
07/20/04	BP	su	Ref 2			26			4	10	
07/20/04	BP	su	Ref 3			43					
07/20/04	BP	su	Hotspot 1			41					
07/20/04	BP	su	Hotspot 2			47					
07/20/04	SI	su	Ref 1			1233					
07/21/04	SI	su	Ref 2			26				1	
07/21/04	SI	su	Ref 3		1	47			1		
07/21/04	SI	su	Hotspot 1			34					
07/21/04	SI	su	Hotspot 2			24	1				
07/21/04	CL	su	Ref 1			2					
07/22/04	CL	su	Ref 2			0			7		
07/22/04	CL	su	Ref 3			18		1			
07/22/04	CL	su	Hotspot 1			46					

Exhibit List 402

Date	Location	Sampling Period	ID	Area	0+ Chinook	1+ Chinook	Chum	Coho	Cutthroat	Steelhead	Trout	UID Salmonid	Mountain whitefish	Threespine Stickleback	American Shad	Banded Killifish
07/22/04	CL	su	Hotspot 2	300	4									31		
08/09/04	CL	su	Ref 1	350	2											2
08/09/04	CL	su	Ref 2	400	3											
08/10/04	CL	su	Ref 3	200	6									2		28
08/10/04	CL	su	Hotspot 1	200	5									3		4
08/10/04	CL	su	Hotspot 2	338	41								1	3		10
08/10/04	CL	su	Ref 1	400	5											
08/10/04	CL	su	Ref 2	300	2											
08/11/04	CL	su	Ref 3	200	7									2		16
08/11/04	CL	su	Hotspot 1	450	3											6
08/11/04	CL	su	Hotspot 2	470	26								1	4		19
08/11/04	BP	su	Ref 1	563	3										80	1
08/12/04	BP	su	Ref 2	563	9									1		
08/12/04	BP	su	Ref 3	563	7									13	45	
08/12/04	BP	su	Hotspot 1	450	8									9	14	
08/12/04	BP	su	Hotspot 2	563	9									9	10	
08/12/04	BP	su	Ref 1	563	7									3	20	1
08/13/04	BP	su	Ref 2	675	7										39	
08/13/04	BP	su	Ref 3	563	16									14	79	1
08/13/14	BP	su	Hotspot 1	675	19									79	29	1
08/13/04	BP	su	Hotspot 2	563	5									28	26	
08/13/04	SI	su	Ref 1	300	5									3	1	1
08/14/04	SI	su	Ref 2	563	0									49	1	
08/14/04	SI	su	Ref 3	563	2									22	7	
08/14/04	SI	su	Hotspot 1	675	1									6	1	
08/14/04	SI	su	Hotspot 2	338	0									8		
08/14/04	SI	su	Ref 1	450	0									1	6	
08/15/04	SI	su	Ref 2	338	1									58	4	
08/15/04	SI	su	Ref 3	394	2									1037		
08/15/04	SI	su	Hotspot 1	563	1									25	1	
08/15/04	SI	su	Hotspot 2	450	0									9		
08/15/04	SI	su	Ref 1	450	1									3	2	

Exhibit List 403

Date	Location	Sampling Period	ID	Blue gill/sunfish/pumpkinseed	Crappie	All Peamouth Chub	Large Scale Sucker	Northern Pike Minnow	Sculpin (Prickly)	Starry Flounder	Other UID
07/22/04	CL	su	Hotspot 2			93					
08/09/04	CL	su	Ref 1			7					
08/09/04	CL	su	Ref 2			6					
08/10/04	CL	su	Ref 3			4			11	3	1
08/10/04	CL	su	Hotspot 1			1			6	1	3
08/10/04	CL	su	Hotspot 2			27			2	2	
08/10/04	CL	su	Ref 1			0		1			
08/10/04	CL	su	Ref 2			3			1	1	
08/11/04	CL	su	Ref 3			3			11		
08/11/04	CL	su	Hotspot 1			5					
08/11/04	CL	su	Hotspot 2			26			3	3	
08/11/04	BP	su	Ref 1			15					
08/12/04	BP	su	Ref 2			9				1	
08/12/04	BP	su	Ref 3			5				4	
08/12/04	BP	su	Hotspot 1		1	18				4	
08/12/04	BP	su	Hotspot 2			6				3	
08/12/04	BP	su	Ref 1			113				1	
08/13/04	BP	su	Ref 2			13	1			1	
08/13/04	BP	su	Ref 3			13				1	
08/13/14	BP	su	Hotspot 1			44					
08/13/04	BP	su	Hotspot 2			36	1				
08/13/04	SI	su	Ref 1			67					
08/14/04	SI	su	Ref 2		1	40	1	1	1		
08/14/04	SI	su	Ref 3			1		2			
08/14/04	SI	su	Hotspot 1			4		1			
08/14/04	SI	su	Hotspot 2		1	9					
08/14/04	SI	su	Ref 1			19		1			
08/15/04	SI	su	Ref 2			10		2	1		
08/15/04	SI	su	Ref 3			0					
08/15/04	SI	su	Hotspot 1			7		1			
08/15/04	SI	su	Hotspot 2			12		1		1	
08/15/04	SI	su	Ref 1			9					

Exhibit List 404

Date	Location	Sampling Period	ID	Area	0+ Chinook	1+ Chinook	Chum	Coho	Cutthroat	Steelhead	Trout	UID Salmonid	Mountain whitefish	Threespine Stickleback	American Shad	Banded Killifish
08/16/04	SI	su	Ref 2	360	0									211	6	1
08/16/04	SI	su	Ref 3	450	0									141		1
08/16/04	SI	su	Hotspot 1	450	0									83	5	1
08/16/04	SI	su	Hotspot 2	450	0									20	18	
08/29/04	BP	su	Ref 1	600	5									11	97	
08/29/04	BP	su	Ref 2	563	1									17	30	
08/30/04	BP	su	Ref 3	400	6									20	12	
08/30/04	BP	su	Hotspot 1	400	2									16	7	
08/30/04	BP	su	Hotspot 2	500	0									2	3	
08/30/04	BP	su	Ref 1	675	7									68	155	
08/31/04	BP	su	Ref 2	600	2									5	49	
02/09/05	SI	win	Ref 1	675	25											1
02/09/05	SI	win	Ref 2	675	1											1
02/09/05	SI	win	Ref 3	675	5											
02/09/05	SI	win	Hotspot 1	675	4											3
02/09/05	SI	win	Hotspot 2	675	5									27		
02/08/05	SI	win	Ref 1	675	4											
02/08/05	SI	win	Ref 2	675												1
02/08/05	SI	win	Ref 3	675	11											
02/08/05	SI	win	Hotspot 1	675	12											1
02/08/05	SI	win	Hotspot 2	675	1	4										
02/10/05	BP	win	Ref 1	675	20											
02/10/05	BP	win	Ref 2	788	12											1
02/10/05	BP	win	Ref 3	500	21									1		
02/10/05	BP	win	Hotspot 1	500	25											
02/10/05	BP	win	Hotspot 2	675	15	1										
02/11/05	BP	win	Ref 1	675	14											
02/11/05	BP	win	Ref 2	823	58									1		
02/11/05	BP	win	Ref 3	675	29											1
02/11/05	BP	win	Hotspot 1	675	57											
02/11/05	BP	win	Hotspot 2	675	16											
02/12/05	CL	win	Rer 1	200	1									1		

Exhibit List 405

Date	Location	Sampling Period	ID	Blue gill/sunfish/pumpkinseed	Crappie	All Peamouth Chub	Large Scale Sucker	Northern Pike Minnow	Sculpin (Prickly)	Starry Flounder	Other UID
08/16/04	SI	su	Ref 2			0		1		1	
08/16/04	SI	su	Ref 3		1	1					
08/16/04	SI	su	Hotspot 1			6					
08/16/04	SI	su	Hotspot 2			12					
08/29/04	BP	su	Ref 1	1		14				2	
08/29/04	BP	su	Ref 2			17				2	
08/30/04	BP	su	Ref 3			15					
08/30/04	BP	su	Hotspot 1			10				2	
08/30/04	BP	su	Hotspot 2	1		23					
08/30/04	BP	su	Ref 1			0					
08/31/04	BP	su	Ref 2			7		1		5	
02/09/05	SI	win	Ref 1								
02/09/05	SI	win	Ref 2								
02/09/05	SI	win	Ref 3								
02/09/05	SI	win	Hotspot 1								
02/09/05	SI	win	Hotspot 2								
02/08/05	SI	win	Ref 1				1				
02/08/05	SI	win	Ref 2						1		
02/08/05	SI	win	Ref 3								
02/08/05	SI	win	Hotspot 1								
02/08/05	SI	win	Hotspot 2								
02/10/05	BP	win	Ref 1								
02/10/05	BP	win	Ref 2								
02/10/05	BP	win	Ref 3								
02/10/05	BP	win	Hotspot 1								
02/10/05	BP	win	Hotspot 2								
02/11/05	BP	win	Ref 1								
02/11/05	BP	win	Ref 2								
02/11/05	BP	win	Ref 3								
02/11/05	BP	win	Hotspot 1								
02/11/05	BP	win	Hotspot 2	1							
02/12/05	CL	win	Ref 1								

Exhibit List 406

Date	Location	Sampling Period	ID	Area	0+ Chinook	1+ Chinook	Chum	Coho	Cutthroat	Steelhead	Trout	UID Salmonid	Mountain whitefish	Threespine Stickleback	American Shad	Banded Killifish
02/12/05	CL	win	Ref 2	450	65									48		
02/12/05	CL	win	Ref 3	375	27									1		
02/12/05	CL	win	Hotspot 1													
02/12/05	CL	win	Hotspot 2													
02/13/05	CL	win	Ref 1	270												
02/13/05	CL	win	Ref 2	563	6									1		
02/13/05	CL	win	Ref 3	300	3											
02/13/05	CL	win	Hotspot 1	400	8									1		1
02/13/05	CL	win	Hotspot 2	400	35											1
03/16/05	BP	win	Ref 1	788	131									2		
03/16/05	BP	win	Ref 2	675	199									1		
03/16/05	BP	win	Ref 3	450	73		2							2		
03/16/05	BP	win	Hotspot 1													
03/16/05	BP	win	Hotspot 2													
03/17/05	BP	win	Ref 1	675	81											
03/17/05	BP	win	Ref 2	675	249		4									
03/17/05	BP	win	Ref 3	338	88									5		
03/17/05	BP	win	Hotspot 1	338	418		3							1		1
03/17/05	BP	win	Hotspot 2	338	59									1		
03/18/05	SI	win	Ref 1	788	57											
03/18/05	SI	win	Ref 2	675	26		4									
03/18/05	SI	win	Ref 3	563	45		8							1		1
03/18/05	SI	win	Hotspot 1	563	26		2							1		
03/18/05	SI	win	Hotspot 2	675	9		1							11		
03/19/05	SI	win	Ref 1	675	8											
03/19/05	SI	win	Ref 2	675	6		1									
03/19/05	SI	win	Ref 3	675	27		1									
03/19/05	SI	win	Hotspot 1	563	27									10		
03/19/05	SI	win	Hotspot 2	675	46	7								1		
03/20/05	SI	win	Ref 1													
03/20/05	SI	win	Ref 2	563	36	1	16									
03/20/05	SI	win	Ref 3	563	53		5									

Exhibit List 407

Date	Location	Sampling Period	ID	Blue gill/sunfish/pumpkinseed	Crappie	All Peamouth Chub	Large Scale Sucker	Northern Pike Minnow	Sculpin (Prickly)	Starry Flounder	Other UID
02/12/05	CL	win	Ref 2								
02/12/05	CL	win	Ref 3								
02/12/05	CL	win	Hotspot 1								
02/12/05	CL	win	Hotspot 2								
02/13/05	CL	win	Ref 1								
02/13/05	CL	win	Ref 2								
02/13/05	CL	win	Ref 3								
02/13/05	CL	win	Hotspot 1								
02/13/05	CL	win	Hotspot 2								
03/16/05	BP	win	Ref 1								
03/16/05	BP	win	Ref 2								
03/16/05	BP	win	Ref 3							1	
03/16/05	BP	win	Hotspot 1								
03/16/05	BP	win	Hotspot 2								
03/17/05	BP	win	Ref 1								
03/17/05	BP	win	Ref 2								
03/17/05	BP	win	Ref 3								
03/17/05	BP	win	Hotspot 1								
03/17/05	BP	win	Hotspot 2								
03/18/05	SI	win	Ref 1								
03/18/05	SI	win	Ref 2								
03/18/05	SI	win	Ref 3						1		
03/18/05	SI	win	Hotspot 1								
03/18/05	SI	win	Hotspot 2								
03/19/05	SI	win	Ref 1								
03/19/05	SI	win	Ref 2								
03/19/05	SI	win	Ref 3								
03/19/05	SI	win	Hotspot 1								
03/19/05	SI	win	Hotspot 2								
03/20/05	SI	win	Ref 1								
03/20/05	SI	win	Ref 2								
03/20/05	SI	win	Ref 3								

Exhibit List 408

Date	Location	Sampling Period	ID	Area	0+ Chinook	1+ Chinook	Chum	Coho	Cutthroat	Steelhead	Trout	UID Salmonid	Mountain whitefish	Threespine Stickleback	American Shad	Banded Killifish
03/20/05	SI	win	Hotspot 1													
03/20/05	SI	win	Hotspot 2													
03/21/05	CL	win	REF 1	450	1		12									
03/21/05	CL	win	REF 2	100	19		13	8								
03/21/05	CL	win	REF 3	338	23		31	6						2		
03/21/05	CL	win	Hotspot 1	300	11		1									
03/21/05	CL	win	Hotspot 2	450	33		2					1		41		
03/22/05	CL	win	REF 1	563	23		7	3						1		1
03/22/05	CL	win	REF 2	100	6											
03/22/05	CL	win	REF 3	400	2	1		1						21		
03/22/05	CL	win	Hotspot 1	788	73		25	4						8		1
03/22/05	CL	win	Hotspot 2	675	98		56	5						10		1
04/11/05	CL	sp	REF 1	225				0								
04/11/05	CL	sp	REF 2	450	46		3	0						4		1
04/11/05	CL	sp	REF 3	270	9	2		0								
04/11/05	CL	sp	Hotspot 1	500	45	2	5	2								
04/11/05	CL	sp	Hotspot 2	500	175		25	0								
04/12/05	CL	sp	REF 1	180	1			0	1							
04/12/05	CL	sp	REF 2	225	31	8		0						5		
04/12/05	CL	sp	REF 3	338	15	8	2	4								
04/12/05	CL	sp	Hotspot 1	563	64		7	0						1		
04/12/05	CL	sp	Hotspot 2	450	174	2	18	3						1		
04/13/05	BP	sp	REF 1	788	175	1	4	0								
04/13/05	BP	sp	REF 2	788	107	2	2	1							1	1
04/13/05	BP	sp	REF 3	675	152	4	2	0						2	10	2
04/13/05	BP	sp	Hotspot 1	675	92		2	0						7	1	
04/13/05	BP	sp	Hotspot 2	675	44			0						5	1	
04/14/05	BP	sp	REF 1	675	88			0						26		1
04/14/05	BP	sp	REF 2	675	67	1		0						1	1	
04/14/05	BP	sp	REF 3	450	138	2		0						2	5	
04/14/05	BP	sp	Hotspot 1	450	146	1	1	0								
04/14/05	BP	sp	Hotspot 2	563	86	1	1	0						21		1

Exhibit List 409

Date	Location	Sampling Period	ID	Blue gill/sunfish/pumpkinseed	Crappie	All Peamouth Chub	Large Scale Sucker	Northern Pike Minnow	Sculpin (Prickly)	Starry Flounder	Other UID
03/20/05	SI	win	Hotspot 1								
03/20/05	SI	win	Hotspot 2								
03/21/05	CL	win	REF 1								
03/21/05	CL	win	REF 2								
03/21/05	CL	win	REF 3								
03/21/05	CL	win	Hotspot 1								
03/21/05	CL	win	Hotspot 2							2	
03/22/05	CL	win	REF 1								
03/22/05	CL	win	REF 2								
03/22/05	CL	win	REF 3								
03/22/05	CL	win	Hotspot 1								
03/22/05	CL	win	Hotspot 2								
04/11/05	CL	sp	REF 1								
04/11/05	CL	sp	REF 2							1	
04/11/05	CL	sp	REF 3								
04/11/05	CL	sp	Hotspot 1								
04/11/05	CL	sp	Hotspot 2								1
04/12/05	CL	sp	REF 1								
04/12/05	CL	sp	REF 2								
04/12/05	CL	sp	REF 3								
04/12/05	CL	sp	Hotspot 1							1	
04/12/05	CL	sp	Hotspot 2								
04/13/05	BP	sp	REF 1								
04/13/05	BP	sp	REF 2								
04/13/05	BP	sp	REF 3								
04/13/05	BP	sp	Hotspot 1							3	
04/13/05	BP	sp	Hotspot 2								
04/14/05	BP	sp	REF 1							1	
04/14/05	BP	sp	REF 2								
04/14/05	BP	sp	REF 3							1	
04/14/05	BP	sp	Hotspot 1								
04/14/05	BP	sp	Hotspot 2								

Exhibit List 410

Date	Location	Sampling Period	ID	Area	0+ Chinook	1+ Chinook	Chum	Coho	Cutthroat	Steelhead	Trout	UID Salmonid	Mountain whitefish	Threespine Stickleback	American Shad	Banded Killifish
04/15/05	SI	sp	REF 1					0								
04/15/05	SI	sp	REF 2	563	52			0		1						
04/15/05	SI	sp	REF 3	450	88	2	1	0								1
04/15/05	SI	sp	Hotspot 1	675	28	1		0								
04/15/05	SI	sp	Hotspot 2	675	26	2		0								
04/16/05	SI	sp	REF 1	563	43	1		0								
04/16/05	SI	sp	REF 2	563	23			0								1
04/16/05	SI	sp	REF 3	675	58		4	0						12		
04/16/05	SI	sp	Hotspot 1	675	42	1		0						1		
04/16/05	SI	sp	Hotspot 2	500	38		6	0								
05/16/05	SI	sp	REF 1	788	96	1		0					1			
05/16/05	SI	sp	REF 2	700	122			0					3			
05/16/05	SI	sp	REF 3	675	83			0								
05/16/05	SI	sp	Hotspot 1	400	72	1		0						1	2	
05/16/05	SI	sp	Hotspot 2	300	127	1		1					2		1	
05/17/05	SI	sp	REF 1	500	134	1		0						1		
05/17/05	SI	sp	REF 2	563	153	2		0					1			2
05/17/05	SI	sp	REF 3	675	138	3		0								
05/17/05	SI	sp	Hotspot 1	675	222	3		0					1		1	
05/17/05	SI	sp	Hotspot 2	450	205	4		0							4	
05/18/05	SI	sp	REF 1	563	147	1		0					1			1
05/18/05	SI	sp	REF 2	563	83	1		0					1		4	1
05/18/05	SI	sp	REF 3	563	67	2		0					1		2	
05/18/05	SI	sp	Hotspot 1	400	139	7		0					2			2
05/18/05	SI	sp	Hotspot 2	350	104	2		0								2
05/19/05	SI	sp	REF 1	563	21			0				1			3	2
05/19/05	SI	sp	REF 2	563	47	1		0				1	2		2	
05/19/05	SI	sp	REF 3	450	58	2		0								1
05/19/05	SI	sp	Hotspot 1	300	126	7		0							13	
05/19/05	SI	sp	Hotspot 2	338	185			0							1	
05/20/05	CL	sp	REF 1	450	26	1		0						1	1	1
05/20/05	CL	sp	REF 2	113	24			0		1				3		

Exhibit List 411

Date	Location	Sampling Period	ID	Blue gill/sunfish/pumpkinseed	Crappie	All Peamouth Chub	Large Scale Sucker	Northern Pike Minnow	Sculpin (Prickly)	Starry Flounder	Other UID
04/15/05	SI	sp	REF 1								
04/15/05	SI	sp	REF 2								
04/15/05	SI	sp	REF 3								
04/15/05	SI	sp	Hotspot 1								
04/15/05	SI	sp	Hotspot 2								
04/16/05	SI	sp	REF 1								
04/16/05	SI	sp	REF 2								
04/16/05	SI	sp	REF 3								
04/16/05	SI	sp	Hotspot 1								
04/16/05	SI	sp	Hotspot 2								
05/16/05	SI	sp	REF 1			2					
05/16/05	SI	sp	REF 2			1					
05/16/05	SI	sp	REF 3			1					
05/16/05	SI	sp	Hotspot 1								
05/16/05	SI	sp	Hotspot 2								
05/17/05	SI	sp	REF 1			1		2		1	
05/17/05	SI	sp	REF 2					1			
05/17/05	SI	sp	REF 3								
05/17/05	SI	sp	Hotspot 1								
05/17/05	SI	sp	Hotspot 2								
05/18/05	SI	sp	REF 1								
05/18/05	SI	sp	REF 2			7					
05/18/05	SI	sp	REF 3			4		1			
05/18/05	SI	sp	Hotspot 1	1		1		1			
05/18/05	SI	sp	Hotspot 2			1					
05/19/05	SI	sp	REF 1								
05/19/05	SI	sp	REF 2			2					
05/19/05	SI	sp	REF 3	1		3		1			
05/19/05	SI	sp	Hotspot 1								
05/19/05	SI	sp	Hotspot 2			6					
05/20/05	CL	sp	REF 1								
05/20/05	CL	sp	REF 2								

Exhibit List 412

ate	Location	Sampling Period	ID	Area	0+ Chinook	1+ Chinook	Chum	Coho	Cutthroat	Steelhead	Trout	UID Salmonid	Mountain whitefish	Threespine Stickleback	American Shad	Banded Killifish
05/20/05	CL	sp	REF 3	100	12			0						1		
05/20/05	CL	sp	Hotspot 1	450	77			0						41	1	
05/20/05	CL	sp	Hotspot 2	225	121			0			1			3	35	
05/21/05	CL	sp	REF 1	400	24	1		0			1				28	
05/21/05	CL	sp	REF 2	270	12	2		0						1	4	
05/21/05	CL	sp	REF 3	40	1			0								
05/21/05	CL	sp	Hotspot 1					0								
05/21/05	CL	sp	Hotspot 2					0								
05/22/05	BP	sp	REF 1	563	96			0			1		9			4
05/22/05	BP	sp	REF 2	675	60	1		0			1		12	70	20	
05/22/05	BP	sp	REF 3	563	35			0					4	1		
05/22/05	BP	sp	Hotspot 1	225	17			0			1		2	3	6	
05/22/05	BP	sp	Hotspot 2	450	77			0					6	4	18	
05/23/05	BP	sp	REF 1	450	70			0					8	3	4	
05/23/05	BP	sp	REF 2	450	55			0			5		6	13	14	
05/23/05	BP	sp	REF 3	563	37			0							3	
05/23/05	BP	sp	Hotspot 1	563	17			0		1	1					
05/23/05	BP	sp	Hotspot 2	563	85	1		0			2		7	1	2	

Exhibit List 413

Date	Location	Sampling Period	ID	Blue gill/sunfish/pumpkinseed	Crappie	All Peamouth Chub	Large Scale Sucker	Northern Pike Minnow	Sculpin (Prickly)	Starry Flounder	Other UID
05/20/05	CL	sp	REF 3					1			
05/20/05	CL	sp	Hotspot 1					1			
05/20/05	CL	sp	Hotspot 2								
05/21/05	CL	sp	REF 1			2	1				
05/21/05	CL	sp	REF 2								
05/21/05	CL	sp	REF 3								
05/21/05	CL	sp	Hotspot 1								
05/21/05	CL	sp	Hotspot 2								
05/22/05	BP	sp	REF 1								
05/22/05	BP	sp	REF 2			2					
05/22/05	BP	sp	REF 3								
05/22/05	BP	sp	Hotspot 1			4				1	
05/22/05	BP	sp	Hotspot 2			1					
05/23/05	BP	sp	REF 1			6		1			
05/23/05	BP	sp	REF 2			3					
05/23/05	BP	sp	REF 3								
05/23/05	BP	sp	Hotspot 1								
05/23/05	BP	sp	Hotspot 2	1		1					

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NATIONAL MARINE FISHERIES SERVICE
West Coast Region
1201 NE Lloyd Boulevard, Suite 1100
PORTLAND, OR 97232-1274

Refer to NMFS No:
WCRO-2023-00488

March 20, 2025

William Abadie
Chief, Regulatory Branch
Department of the Army
U.S. Army Corps of Engineers, Portland District
P.O. Box 2946
Portland, Oregon 97208-2946

Re: Endangered Species Act Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the NEXT Renewable Fuels, Oregon, LLC Renewable Green Fuels Facility, Port Westward, Columbia County, Oregon (HUC 170800030900) (NWP-2020-383)

Dear Mr. Abadie:

Thank you for your letter of March 28, 2022, requesting initiation of consultation with NOAA's National Marine Fisheries Service (NMFS) pursuant to section 7 of the Endangered Species Act of 1973 (ESA) (16 U.S.C. 1531 et seq.) for the NEXT Renewable Fuels, Oregon, LLC Renewable Green Fuels Facility, Port Westward, Oregon.

Thank you, also, for your request for essential fish habitat (EFH) consultation. NMFS reviewed the proposed action for potential effects on EFH pursuant to Section 305(b) of the Magnuson–Stevens Fishery Conservation and Management Act (16 U.S.C. 1855(b)), implementing regulations at 50 CFR 600.920, and agency guidance for use of the ESSA consultation process to complete EFH consultation. for this action. We have concluded that the action would adversely affect EFH of Pacific Coast salmon and Pacific Coast groundfish and have included conservation recommendations to avoid, minimize, or otherwise offset potential adverse effects on EFH.

In the biological opinion we concluded that the proposed action is not likely to jeopardize the survival or recovery of:

1. Lower Columbia River Chinook salmon
2. Upper Willamette River Chinook salmon
3. Upper Columbia River spring Chinook salmon
4. Snake River spring/summer Chinook salmon
5. Snake River fall Chinook salmon
6. Lower Columbia River coho salmon
7. Columbia River chum salmon
8. Snake River Sockeye salmon
9. Lower Columbia River steelhead
10. Middle Columbia River steelhead
11. Upper Columbia River steelhead
12. Upper Willamette River steelhead

13. Snake River Basin steelhead
14. Green Sturgeon
15. Eulachon
16. Blue whale
17. Fin whale
18. Sei whale
19. Humpback whale-Central America DPS
20. Humpback whale Mexico DPS
21. Sperm whale
22. Leatherback sea turtle
23. Southern Resident killer whales

or result in the destruction or adverse modification of their designated critical habitats.

We also concluded that the proposed action is not likely to adversely affect:

1. Guadalupe fur seals
2. Green turtles
3. Loggerhead turtles
4. Olive Ridley turtles
5. Western Pacific Gray whales
6. North Pacific Right whales

As required by section 7 of the ESA, NMFS is providing an incidental take statement with the biological opinion. Please contact Tom Hausmann, in Portland, Oregon, at 503-231-2315, or tom.hausmann@noaa.gov if you have any questions concerning this consultation, or if you require additional information.

Sincerely,



Kathleen Wells
Assistant Regional Administrator
Oregon Washington Coastal Office

cc: Katherine Mott, USACE
Chris Efird, NEXT Renewables
Laurie Parry, Stewardship Solutions

Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion and Magnuson–Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the

NEXT Renewable Fuels, Oregon, LLC Renewable Green Fuels Facility
Port Westward, Columbia County, Oregon

NMFS Consultation Number: WCRO-2023-00488

Action Agency: U.S. Army Corps of Engineers

Affected Species and NMFS' Determinations:

ESA-Listed Species	Status	Is Action Likely to Adversely Affect Species?	Is Action Likely to Jeopardize the Species?	Is Action Likely to Adversely Affect Critical Habitat?	Is Action Likely to Destroy or Adversely Modify Critical Habitat?
Lower Columbia River Chinook Salmon (*Onchorhynchus tshawytscha*)	Threatened	Yes	No	Yes	No
Upper Willamette River Chinook	Threatened	Yes	No	Yes	No
Upper Columbia River Spring-run Chinook	Endangered	Yes	No	Yes	No
Snake River Spring-run Chinook	Threatened	Yes	No	Yes	No
Snake River Fall-run Chinook	Threatened	Yes	No	Yes	No
Columbia River Chum Salmon (*O. keta*)	Threatened	Yes	No	Yes	No
Lower Columbia River coho (*O. kisutch*)	Threatened	Yes	No	Yes	No
Snake River Sockeye (*O. nerka*)	Endangered	Yes	No	Yes	No
Lower Columbia River steelhead (*O. mykiss*)	Threatened	Yes	No	Yes	No
Upper Willamette River steelhead	Threatened	Yes	No	Yes	No
Middle Columbia River steelhead	Threatened	Yes	No	Yes	No
Upper Columbia River steelhead	Threatened	Yes	No	Yes	No
Snake River Basin steelhead	Threatened	Yes	No	Yes	No
Blue whale (*Balaenoptera musculus*)	Endangered	Yes	No	N/A	N/A
Fin whale (*B. physalus*)	Endangered	Yes	No	N/A	N/A
Sei whale (*Balaenoptera borealis*)	Endangered	Yes	No	N/A	N/A
Mexico DPS Humpback whale (*Megaptera novaeangliae*)	Threatened	Yes	No	Yes	No

ESA-Listed Species	Status	Is Action Likely to Adversely Affect Species?	Is Action Likely to Jeopardize the Species?	Is Action Likely to Adversely Affect Critical Habitat?	Is Action Likely to Destroy or Adversely Modify Critical Habitat?
Central America DPS Humpback whale (*Megaptera novaeangliae*)	Endangered	Yes	No	Yes	No
Sperm whale (*Physeter microcephalus*)	Endangered	Yes	No	N/A	N/A
West Pacific DPS Leatherback turtle (*Dermochelys coriacea*)	Endangered	Yes	No	Yes	No
Southern Resident killer whale (*Orcinus orca*)	Endangered	Yes	No	Yes	No
Green Sturgeon (*Acipenser medirostris*)	Threatened	Yes	No	Yes	No
Eulachon (*Thaleichthys pacificus*)	Threatened	Yes	No	Yes	No
Guadalupe fur seals (*Arctocephalus townsendi*)	Threatened	No	No	No	No
Green turtle (*Chelonia mydas*)	Threatened	No	No	No	No
Loggerhead turtle (*Caretta caretta*)	Endangered	No	No	No	No
Olive ridley turtle (*Lepidochelys olivacea*)	Threatened	No	No	No	No
Western Pacific gray whale (*Eschrichtius robustus*)	Endangered	No	No	No	No
North Pacific right whale (*Eubalaena japonica*)	Endangered	No	No	No	No

Fishery Management Plan That Identifies EFH in the Project Area	Does Action Have an Adverse Effect on EFH?	Are EFH Conservation Recommendations Provided?
Pacific Coast Salmon	Yes	Yes
Groundfish	Yes	Yes

Consultation Conducted By: National Marine Fisheries Service
West Coast Region

Issued By:

Kathleen Wells
Assistant Regional Administrator
Oregon Washington Coastal Office

Date: March 20, 2025

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1. INTRODUCTION

This Introduction section provides information relevant to the other sections of this document and is incorporated by reference into Sections 2 and 3, below.

1.1. Background

The National Marine Fisheries Service (NMFS) prepared the biological opinion (opinion) and incidental take statement (ITS) portions of this document in accordance with section 7(b) of the Endangered Species Act (ESA) of 1973 (16 U.S.C. 1531 et seq.), as amended, and implementing regulations at 50 CFR part 402.

We also completed an essential fish habitat (EFH) consultation on the proposed action, in accordance with section 305(b)(2) of the Magnuson–Stevens Fishery Conservation and Management Act (MSA) (16 U.S.C. 1801 et seq.) and implementing regulations at 50 CFR part 600.

We completed pre-dissemination review of this document using standards for utility, integrity, and objectivity in compliance with applicable guidelines issued under the Data Quality Act (DQA) (section 515 of the Treasury and General Government Appropriations Act for Fiscal Year 2001, Public Law 106-554). The document will be available at the NOAA Library Institutional Repository [https://repository.library.noaa.gov/welcome].

1.2. Consultation History

On April 18, 2023, NMFS received a biological assessment (BA) and a letter from the U.S. Army Corps of Engineers (USACE), requesting formal ESA consultation and EFH consultation on a Clean Water Act (CWA) Section 404 permit to NEXT Renewable Fuels Oregon, LLC (the applicant, or NEXT), to construct and operate a new bio-refinery facility. The proposed NEXT bio-refinery would be built in the Port Westward Industrial Park (Port Westward) and would use the existing Port Westward dock, operated by the Columbia Pacific Bio Refinery (CPBR), to receive feedstocks and export biofuels. The proposed bio-refinery would also use the Port Westward raw water intake, wastewater pumps and wastewater outfall. Existing tenants at Port Westward include Portland General Electric's Beaver Power Plant, the Port Westward 1 and 2 Generation Plants, and CPBR.

On May 5, 2023, NMFS requested additional information on the quantity and rate of water withdrawal from the Columbia River for the NEXT facility and information on the fish screen on the Port Westward raw water intake pump intake. On May 19, 2023 the USACE supplied us with this information and we initiated consultation on May 19, 2023.

Updates to the regulations governing interagency consultation (50 CFR part 402) were effective on May 6, 2024 (89 Fed. Reg. 24268). We are applying the updated regulations to this consultation. The 2024 regulatory changes, like those from 2019, were intended to improve and

clarify the consultation process, and, with one exception from 2024 (offsetting reasonable and prudent measures), were not intended to result in changes to the Services' existing practice in implementing section 7(a)(2) of the Act. 89 Fed. Reg. at 24268; 84 Fed. Reg. at 45015. We have considered the prior rules and affirm that the substantive analysis and conclusions articulated in this biological opinion and incidental take statement would not have been any different under the 2019 regulations or pre-2019 regulations.

1.3. Proposed Federal Action

Under the ESA, "action" means all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by Federal agencies (see 50 CFR 402.02). Under MSA, federal action means any action authorized, funded, or undertaken, or proposed to be authorized, funded or undertaken by a federal agency (50 CFR 600.910).

The USACE proposes to permit, under Section 404 of the Clean Water Act, NEXT Renewable Fuels, LLC to construct and operate a biofuel refinery at the Port Westward Industrial Park in Columbia County, Oregon. The NEXT facility will not involve the construction of a dock or other over-water structures. In-water work is not proposed for the NEXT project. Therefore, there are no in-water work windows.

The biofuel production facility would be constructed on upland property. Construction activities include; creating equipment staging areas, stripping vegetation from and grading the site, construction of the main access road and rail spur, construction of pipelines, construction of stormwater treatment facilities, construction of the facility foundations and construction of facility structures.

After the facility site is stripped of vegetation and graded by removing approximately 6 – 18 inches of soil, it would be treated with glyphosate herbicide to prevent reed canary grass and weed regrowth. **Figure** 1 shows the location of the facility in the industrial park and the Columbia River.

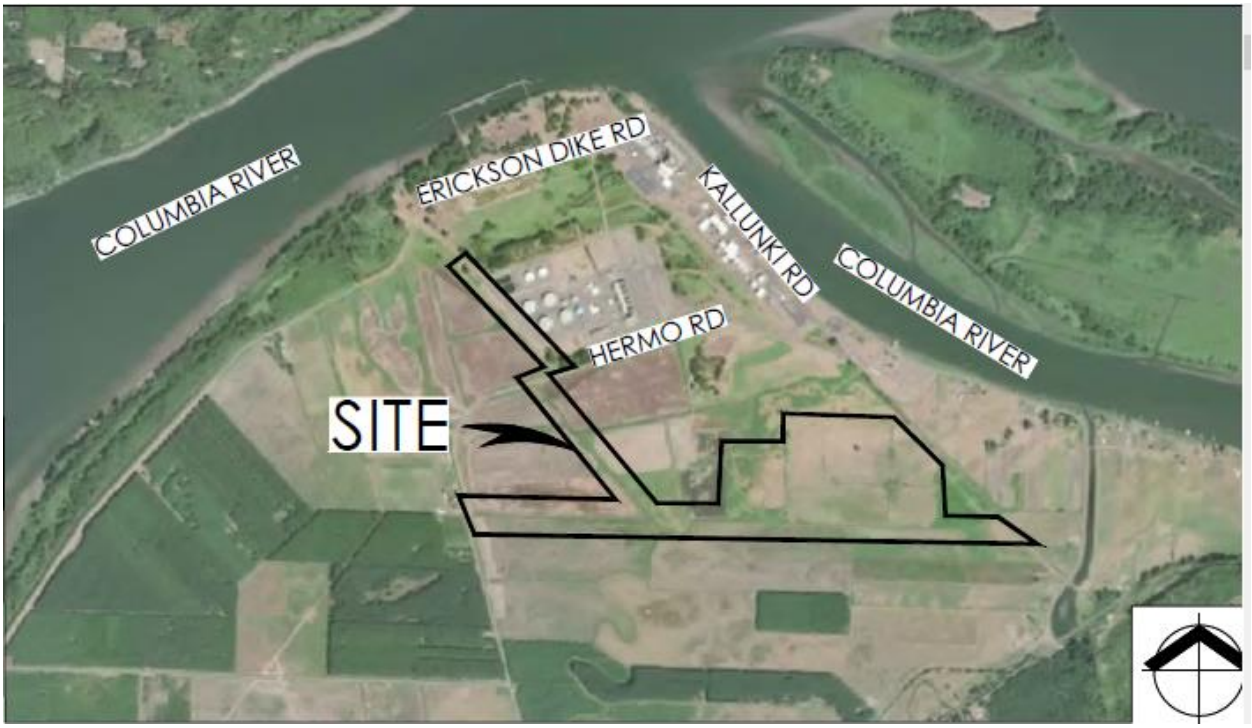


Figure 1. Perimeter of the NEXT facility outlined in black.

NEXT proposes to construct two new loading arms for transferring biofuel and sustainable aviation fuel (SAF) to OGVs at the Berth 1 of the Port Westward dock and a new unloading arm for transferring raw feedstock to pipelines at Berth 2.

The project would include the following BMPs that will be implemented during construction to minimize project impacts:

1. Conditions in local, state, and federal permits will be followed.
2. Construction limits will be clearly defined with stakes prior to the beginning of ground-disturbing activities. The project engineer or construction representative will meet with the contractor to ensure that all workers understand the locations of project construction limits and measures that will be taken to protect them. No disturbance will occur beyond these limits. Erosion and sediment control measures as outlined in the Oregon Department of Environmental Quality Construction 1200-C Stormwater Permit and the Erosion and Sediment Control Plan (ESCP) will be implemented to minimize and control erosion and discharges of pollutants from stormwater.
3. Construction will occur between the hours of 7:00 a.m. and 6:00 p.m.
4. All construction equipment will be maintained and in good working order to minimize the risk of fuel and fluid leaks or spills.
5. A spill containment plan will be developed, and all necessary materials will be onsite prior to, and during, construction.
6. If a leak or spill occurs, work will cease near any waterbody or wetland until the source of the leak is identified and corrected and the contaminants have been removed.

7. All base temporary erosion and sediment control measures (i.e., inlet protection, perimeter sediment control, gravel construction entrances, etc.) must be in place, functional, and approved in an initial inspection prior to beginning construction activities. Temporary erosion and sediment control measures will be inspected regularly and maintained throughout construction.
8. All clearing and excavation will be accomplished in ways that minimizes soil disturbance, compaction, and impacts to vegetation whenever possible.
9. Refueling activities will be conducted within designated refueling areas away from waterbody or wetland areas. For track-mounted equipment, and other equipment whose limited mobility makes it impractical to move for refueling, precautions will be taken to minimize the risk of fuel reaching the project's regulated work area. Spill prevention measures and fuel containment systems designed to completely contain a potential spill will be implemented, as well as other pollution control devices and measures (such as diapering, parking on absorbent material, etc.) that are adequate to provide containment of hazardous materials.
10. Temporary stabilization measures will be employed on slopes, inactive areas, and areas subject to wind erosion.
11. Construction BMPs will be implemented to control dust and limit impacts to air quality and will include the following measures:
    a) Cover loads and ensure adequate freeboard to prevent soil particles from blowing away during transport.
    b) Wet down fill material and dust on site, whenever practicable.
    c) Remove excess dirt, dust, and debris from roadway.
    d) Revegetate disturbed soil as soon as practicable.
12. Measures to minimize noise impacts will be implemented during construction and will include the following measures:
    a) Turn off equipment when not in use for more than 30 minutes.
    b) Use a vibratory hammer to install steel piles.
    c) Use only well-maintained and properly functioning equipment and vehicles.
13. BMPs for stormwater runoff controls will be implemented as follows:
    a) Install temporary sediment control devices such as filter fabric fences or sediment traps.
    b) Sediment barriers shall be installed immediately following establishment of earthwork activities prone to erosion.
    c) Exposed soils and soil stockpiles will be temporarily stabilized at the end of shifts and before holidays and weekends, if needed. Stockpiles shall be placed in a stable location and configuration and covered with plastic sheeting during "wet weather."
    d) Temporary stabilization with a covering of blown straw and a tackifier, loose straw, or an adequate covering of compost mulch will be provided for portions of the site where construction activities will cease for 14 days or more.
    e) Minimize soil disturbance and reseed disturbed areas as soon as practicable.
14. BMPs will be implemented for culvert installation to maintain water quality, and will include the following measures:
    a) Wetland areas and waterways will be designated for protection with silt fencing.
    b) Refueling activities will be conducted within designated refueling areas away from waterbody or wetland areas.

c) All vehicles and equipment operated within 150 ft. of any waterbody will be inspected daily for fluid leaks before leaving the vehicle staging area. Any leaks detected will be repaired before the vehicle resumes operation. When not in use, vehicles will be parked in the designated staging area, which will be located outside all wetlands and waterways and their buffers.
d) Vegetation removal will be minimized to the greatest extent possible, and erosion control blankets will be used to assist rapidly revegetating sites disturbed by culvert replacements and associated temporary impacts.

15. No pollutants, such as green concrete, contaminated water, welding slag, sandblasting abrasive, or grout cured less than 24 hours will contact any waterbody.

Operation

The NEXT facility would refine and export biofuel and SAF from feedstocks such as vegetable oil, used cooking oil, animal tallow and inedible corn oil. The NEXT facility uses the Honeywell UOP Ecofining™ Green Diesel technology. Triglycerides are treated with hydrogen in pressurized reactors where catalysts produce 100% Fatty Acid Methyl Ester (FAME, or biofuel), which is a hydrocarbon product. SAF production incorporates an additional selective cracking step to reduce carbon chain lengths (Figure 2). SAF is a mix of mostly volatile organic hydrocarbons and some light semi-volatile organic hydrocarbons. These substances would have similar effects on the environment as light-weight petroleum hydrocarbons and light-weight PAHs. The biofuel refinery would produce renewable fuels to increase supply and to help meet the renewable fuel requirements of the Federal Renewable Fuel Standard Program and Washington, Oregon, California and British Columbia fuel standard requirements that decrease the carbon intensity of transportation fuels.

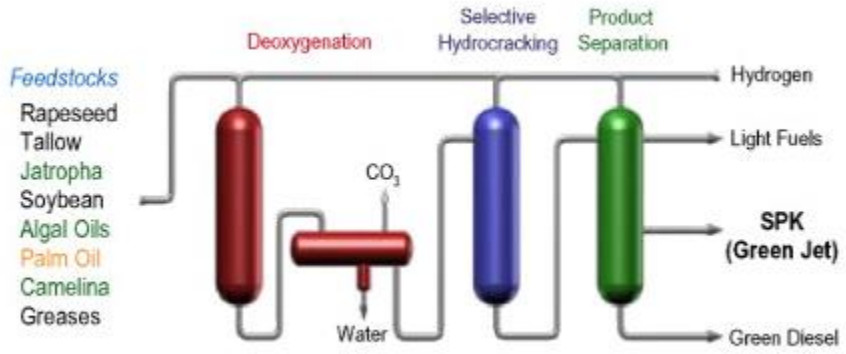


Figure 2. A process schematic of UOP's proprietary process for production of renewable fuels from triglycerides.

Port Westward has Oregon State-permitted water intake and outfall structures in the Columbia River just east of the existing dock. Water for NEXT operations will be supplied from this Port Westward intake structure under the existing water right. NEXT biofuel production wastewater includes oily water, pre-treatment water, stripped sour water,[1] cooling tower blowdown, boiler

[1] Sour water is produced in refinery process units when water is used for steam stripping and quenching. Sour water is contaminated mostly with ammonia (NH3) and hydrogen sulfide (H2S), which must be removed before the water

blowdown, and reverse osmosis reject water. The facility's wastewater treatment system is designed to treat wastewater produced from processing 50,000 barrels per day of vegetable oil and animal fats into renewable fuel and SAF such that it can be combined with Port Westward wastewater and meet the requirements of the Port Westward NPDES permit and 1200Z industrial stormwater permit contaminant concentrations. The wastewater treatment systems are described as meeting 40 CFR 60 Subpart QQQ, Standards of Performance for volatile organic chemical (VOC) Emissions from Petroleum Refinery Wastewater Systems requirements (ELS 2023).

When burned, pure biofuels generally produce fewer emissions of particulates, sulfur dioxide, and air toxics than fossil-fuels. Biodiesel combustion may result in slightly higher amounts of nitrogen oxides relative to petroleum diesel. Nevertheless, biofuels can produce greenhouse gases (GHG), especially when combined or blended with petroleum-based fuels.

Stormwater Treatment
Runoff, water-quality treatment, and flow control (stormwater quantity) would be provided by four vegetated ponds to provide detention, settling, and biofiltration. Absorbent socks or booms would be used to remove floatables, if any, from the water surface in the pond. Pond outlets would be equipped with downturned elbows to trap oil sheen and other floatables in the ponds. Pond construction and components of the stormwater system would be completed contemporaneously with the facility construction.

Ponds 1 and 2 would run parallel along the west rail spur between the access road and the west rail spur. Pond 1 will be 23 feet wide extending east from Hermo Road for approximately 2,684 feet and would collect runoff from the paved access road, gravel laydown area, and rail areas west of the main plant into a series of catch basins with gravity flow to Pond 1 (Figure 3). Runoff from the main plant rail spur would sheet flow to a series of catch basins and would be conveyed via gravity flow to Pond 2 that extends from the main plant westward for approximately 1,064 feet. Stormwater from Ponds 1 and 2 would discharge to McLean Slough.

Runoff from the rail area southeast of the Main Plant (East Rail Spur) would sheet flow to a catch basin and would then be conveyed via gravity flow to Pond 4 located on the south side of the east rail spur adjacent to the existing Waterway F (Figure 3). Runoff from the pipe rack and pipeline maintenance roadway would sheet flow into Pond 3 that would run parallel to the maintenance road and would then be conveyed via gravity flow to Waterway D and McLean Slough. Pond construction would permanently impact approximately 2.45 acres of Wetland 1 by permanently removing 2,280 cubic yards of material in the grading process and placing 5,295 cubic yards of material to create the ponds.

The facility's main wastewater system is designed to process wastewater produced from processing 50,000 barrels per day of vegetable oil and animal fats to produce renewable fuel and SAF. Wastewater would be collected and treated based on various contaminants in the waste stream. Once treated, the wastewater and stormwater from main facility would be comingled and processed through the tertiary filters before being sent through a heat exchanger for cooling prior

is recycled back into the process. Refineries typically use trays in their sour water strippers to remove the contaminants.

to entering the existing Port Westward wastewater collection system for eventual discharge at the Port's permitted outfall to the Columbia River (NPDES Permit #102650).

The project will create 72.6 acres of new pollution-generating impervious surfaces (PGIS) that will contaminate stormwater in four different drainage areas (Table 1).

Drainage Area 1
This area is approximately 108.5 acres and consists of the Main Plant, and a portion of the rail yard south and southeast of the Main Plant (referred to as the Main Plant Rail Spur), located in the northeast portion of the site. There will be 102 acres of the 108.5 acres in Drainage Area 1 that would be disturbed during construction. The onsite wastewater treatment facility would provide treatment designed to remove a wide range of pollutants from processing water and stormwater from inside the processing areas. Stormwater from the non-process areas would be detained, providing treatment via sedimentation, and then it would be combined with pretreated wastewater and process area stormwater. Treatment would remove, or partially remove, contaminants including, but not limited to, oils and greases, suspended solids, heavy metals, nutrients, and 6PPD-quinone (from vehicle tire wear).

Drainage Area 2
Drainage Area 2 is approximately 12.2 acres and consists of two areas: the paved main access road and gravel laydown area that includes the rail yard located west of the Main Plant (referred to as the West Rail Spur) and the proposed aboveground pipeline and associated gravel Pipeline/Maintenance Road located northwest of Drainage Area 1. Stormwater runoff from the West Rail Spur would be collected in a series of catch basins and conveyed by gravity piping into one of two proposed stormwater ponds (Ponds 1 and 2) located south of the proposed main access road. The ponds would provide detention to meet the County's flow-control requirements, as well as treatment via sedimentation and biofiltration. Pond outlets would be equipped with a downturned elbow to trap floatables, including oil sheen. The pond outlets would be routed to the existing ditch, Waterway D, that is just north of McLean Slough (Figure 3).

Drainage Area 3
Drainage Area 3 is approximately 0.8 acres and consists of a rail spur located southeast of the Main Plant (East Rail Spur). A gravel road in this area provides access to the adjacent property. Stormwater runoff from the East Rail Spur would be collected in a catch basin and conveyed via gravity piping into Pond 4, located along the southwest boundary of this drainage area. This pond would provide detention to meet the County's flow-control requirements, as well as treatment via sedimentation and biofiltration. The Pond 4 outlet would consist of a grated catch basin (CB-DP003) equipped with a downturned elbow to trap floatables in the pond, including oil sheen.

An existing ditch (Waterway F) flows south and then west through the property on the west side of Drainage Area 3 and conveys runoff from the surrounding areas. Runoff from this ditch would be conveyed via a new culvert under the proposed rail tracks to maintain the existing drainage. Industrial stormwater runoff from the proposed Pond 4 would discharge to the existing Waterway F via Discharge Point 003 and would then be conveyed west to McLean Slough.

Treated stormwater discharge from Ponds 1, 2, and 3 will fluctuate with precipitation events and is expected to be little to none during the dry season, typically from May through mid-October.

Drainage Area 4

Drainage Area 4 is approximately one acre and consists of a proposed aboveground pipeline located northwest of Hermo Road (Figure 3). An existing maintenance road runs parallel to the proposed aboveground pipeline; the road would remain in place to provide maintenance access to the pipeline and other Port properties. An existing ditch runs parallel to the proposed aboveground pipeline and discharges through Discharge Point 004 to Waterway D. Impervious surfaces would not increase in Drainage Area 4, and stormwater runoff would continue to be managed through the existing ditches.

Other Stormwater Sources

NEXT is proposing to improve access to the Port Westward location. Improvements would include paving the existing Hermo gravel roadway to provide 12-foot-wide travel lanes and shoulders ranging from about six feet to approximately 11 feet wide. Stormwater runoff from Hermo Road, which is included in the 72.6 acres to be treated, would be detained and treated in stormwater bioswales as described in the post-construction stormwater plan (ELS 2023).

With upgrades of Hermo Road, the proposed design will accommodate over 3,000 vehicles per day. However, NEXT employee vehicles and truck traffic is estimated to add 667 trips per day along Hermo Road (Mackenzie 2021), which would be paved, widened, and drain to constructed bioswales for stormwater detention and treatment. Kallunki Road is the current main access road into the Port industrial area, and it has no existing stormwater detention or treatment facilities. After project construction, Hermo Road is estimated to have a total of approximately 970 vehicle trips per day (current traffic is estimated to be 303 vehicle trips per day plus the addition of 667 trips per day). Groundwater is between 2 feet to 4 feet below the ground surface and stormwater infiltration is not a feasible discharge option for runoff (ELS 2023).

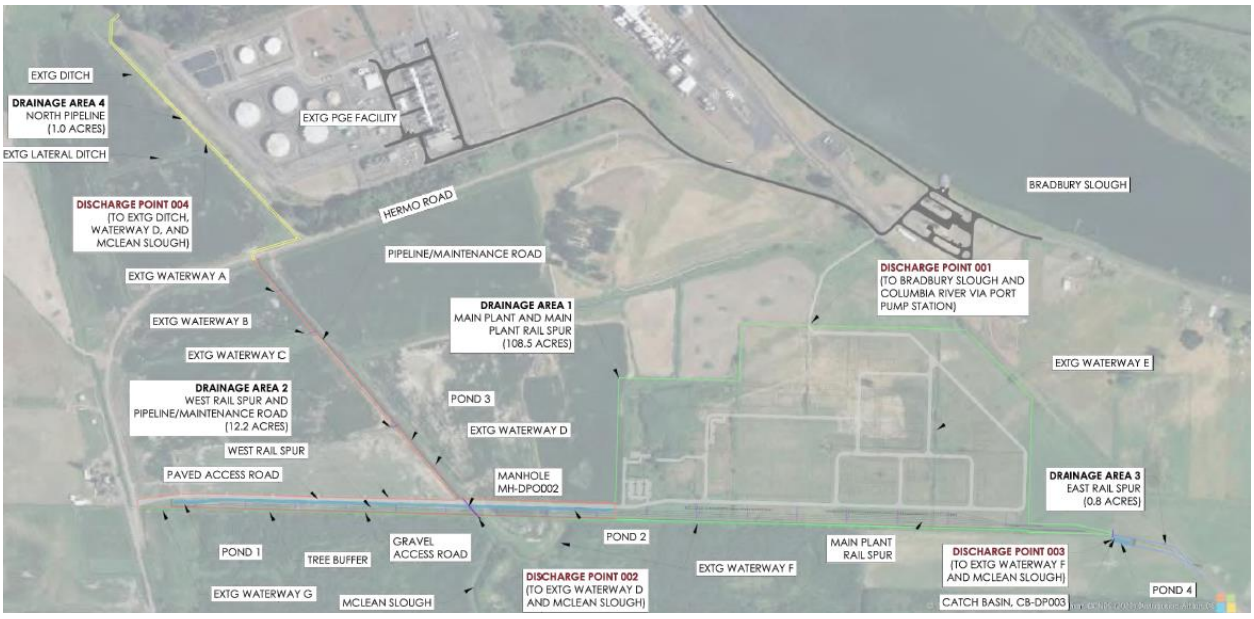


Figure 3. Drainage areas proposed for the NEXT facility.

Table 1. Treatments proposed for stormwater drainage areas (ELS 2023).

Drainage Area	Contaminant sources	Impervious surface area	Treatment
Drainage Area 1 (Main Plant and a portion of the rail spur)	Facility wastewater and stormwater from facility impervious surface including a portion of rail spur	64.2	Stormwater routed to a stormwater basin sized for a 100 year, 24-hour storm and then combined with wastewater and treated to remove contaminants including, but not limited to, oils and greases, suspended solids, heavy metals, nutrients, and 6PPD-quinone. Treated wastewater and stormwater are then filtered and cooled in a heat exchanger against incoming raw water before entering the existing Port Westward wastewater collection system for discharge at the Port's permitted outfall to the Bradbury Slough (Columbia River Side Channel)
Drainage Area 2 (access road, gravel laydown area, West rail yard)	Stormwater from: 1. Paved main access road and West Rail Spur gravel laydown area	8.3	1. Stormwater collected in catch basins and conveyed to one of two stormwater detention ponds (Pond 1 and Pond 2) with outlets routed to a manhole for sampling and an existing ditch discharge to McLean Slough.
	2. Above ground pipeline and gravel road for pipeline maintenance		2. Sheet flow into a detention pond (Pond 3) parallel to road, then combined with treated stormwater from Pond 1 and Pond 2 and discharged to McLean Slough.
Drainage Area 3 (East rail spur)	Stormwater from East Rail Spur and gravel road	0.1	Stormwater collected in a catch basin and conveyed to detention pond (Pond 4) with outlet to a ditch to McLean Slough.
Drainage Area 4 (elevated pipeline)	Stormwater from above ground pipeline	0	Collection in a ditch alongside the pipeline and conveyed by a ditch to McLean Slough.

The NEXT project would withdraw water from the Columbia River under an existing Port water right to process biofuel using the Port's existing water intake. A water intake system would be constructed where raw water from water intake would flow through an ultrafiltration system and into a storage tank. The raw water storage tank supplies water for utility water, potable water, fire water, cooling water and boiler feed water systems. The raw water makeup is estimated to be about 1,850 gpm.

The NEXT project would install rail loading and offloading facilities, increasing impervious surface. The facility would develop 10-spot unloading facilities for bleaching earth, 2 15-spot unloading facilities for feedstock oil, and a 10-spot loading facility for renewable oil. In total, the NEXT project would increase rail traffic to the project site by 1,220 rail cars per month. Additionally, 60 semi-trucks would be loaded with renewable fuel per month.

NEXT proposes to mitigate wetland and waterway impacts with restoration of approximately 466 acres of wetland on a parcel owned by the applicant about 0.25 miles south of the facility parcel. Additionally, riparian plantings are proposed along a 1-mile reach of waterway.

NEXT would maintain unwanted vegetation at the facility and at the mitigation site with herbicides. Reed canary grass and other plants would be sprayed initially and as ongoing maintenance with glyphosate.

A full list of conservation measures is provided in ELS (2023, pages 23 - 26), and is adopted here by reference. These avoidance and minimization measures address Best Management Practices (BMPs) in design features, construction, project operations, and vessel loading and unloading procedures. They are intended to maintain clean water, minimize and treat oil spills, and maintain mitigation wetland features.

We considered, under the ESA, whether or not the proposed action would cause any other activities and determined that it would cause the following activities: The NEXT project will facilitate delivery of feedstock to the facility using ocean going vessels. Feedstock will be delivered by an average of 115 general-purpose tankers or articulated tug barges (ATB) per year and NEXT biofuel and SAF will be shipped to west coast markets in California, Oregon, Washington, and (possibly) British Columbia by approximately 56 OGVs per year (i.e., 171 vessels per year). Each vessel is anticipated to moor at Port Westward for about two days. Vessel traffic would not occur but for the proposed action. It is reasonably certain to occur because the NEXT facility could not operate without product to convert into biofuel, or without selling their refined product.

2. ENDANGERED SPECIES ACT BIOLOGICAL OPINION AND INCIDENTAL TAKE STATEMENT

The ESA establishes a national program for conserving threatened and endangered species of fish, wildlife, plants, and the habitat upon which they depend. As required by section 7(a)(2) of the ESA, each Federal agency must ensure that its actions are not likely to jeopardize the continued existence of endangered or threatened species or to adversely modify or destroy their designated critical habitat. Per the requirements of the ESA, Federal action agencies consult with NMFS, and section 7(b)(3) requires that, at the conclusion of consultation, NMFS provide an opinion stating how the agency's actions would affect listed species and their critical habitats. If incidental take is reasonably certain to occur, section 7(b)(4) requires NMFS to provide an ITS that specifies the impact of any incidental taking and includes reasonable and prudent measures (RPMs) and terms and conditions to minimize such impacts.

The USACE determined the proposed action is not likely to adversely affect Gray whales – Western North Pacific DPS, North Pacific right whales, Green sea turtle- East Pacific DPS, Loggerhead sea turtles, Olive Ridley sea turtles, or Guadalupe fur seals or their critical habitat. Our concurrence is documented in the "Not Likely to Adversely Affect" Determinations section (Section 2.13).

2.1. Analytical Approach

This biological opinion includes both a jeopardy analysis and an adverse modification analysis. The jeopardy analysis relies upon the regulatory definition of "jeopardize the continued existence of" a listed species, which is "to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species" (50 CFR 402.02). Therefore, the jeopardy analysis considers both survival and recovery of the species.

This biological opinion also relies on the regulatory definition of "destruction or adverse modification," which "means a direct or indirect alteration that appreciably diminishes the value of critical habitat as a whole for the conservation of a listed species" (50 CFR 402.02).

The designation(s) of critical habitat for; LCR Chinook salmon, UWR Chinook salmon, UCR spring Chinook salmon, SR spring/summer Chinook salmon, SR fall Chinook salmon, LCR coho salmon, CR chum salmon, SR Sockeye salmon, LCR steelhead, MCR steelhead, UCR steelhead, UWR steelhead, SRB steelhead, sDPS Eulachon, sDPS Green Sturgeon, humpback whale and leatherback sea turtle use(s) the term primary constituent element (PCE) or essential features. The 2016 final rule (81 FR 7414; February 11, 2016) that revised the critical habitat regulations (50 CFR 424.12) replaced this term with physical or biological features (PBFs). The shift in terminology does not change the approach used in conducting a "destruction or adverse modification" analysis, which is the same regardless of whether the original designation identified PCEs, PBFs, or essential features. In this biological opinion, we use the term PBF to mean PCE or essential feature, as appropriate for the specific critical habitat.

The ESA Section 7 implementing regulations define effects of the action using the term "consequences" (50 CFR 402.02). As explained in the preamble to the final rule revising the definition and adding this term (84 FR 44976, 44977; August 27, 2019), that revision does not change the scope of our analysis, and in this opinion we use the terms "effects" and "consequences" interchangeably.

We use the following approach to determine whether a proposed action is likely to jeopardize listed species or destroy or adversely modify critical habitat:

- Evaluate the rangewide status of the species and critical habitat expected to be adversely affected by the proposed action.
- Evaluate the environmental baseline of the species and critical habitat.
- Evaluate the effects of the proposed action on species and their critical habitat using an exposure–response approach.
- Evaluate cumulative effects.
- In the integration and synthesis, add the effects of the action and cumulative effects to the environmental baseline, and, in light of the status of the species and critical habitat, analyze whether the proposed action is likely to: (1) directly or indirectly reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species; or (2) directly or

indirectly result in an alteration that appreciably diminishes the value of critical habitat as a whole for the conservation of a listed species.

- If necessary, suggest a reasonable and prudent alternative to the proposed action.

2.2. Rangewide Status of the Species and Critical Habitat

This opinion examines the status of each species that is likely to be adversely affected by the proposed action. The status is determined by the level of extinction risk that the listed species face, based on parameters considered in documents such as recovery plans, status reviews, and listing decisions. This informs the description of the species' likelihood of both survival and recovery. The species status section also helps to inform the description of the species' "reproduction, numbers, or distribution" for the jeopardy analysis. The opinion also examines the condition of critical habitat throughout the designated area, evaluates the conservation value of the various watersheds and coastal and marine environments that make up the designated area, and discusses the function of the PBFs that are essential for the conservation of the species.

One factor affecting the status of ESA-listed species considered in this opinion, and aquatic habitat at large, is climate change. Climate change is likely to play an increasingly important role in determining the abundance and distribution of ESA-listed species, and the conservation value of designated critical habitats, in the Pacific Northwest. These changes will not be spatially homogeneous across the Pacific Northwest. Major ecological realignments are already occurring in response to climate change (IPCC, 2022). Long-term trends in warming have continued at global, national and regional scales. Global surface temperatures in the last decade (2010s) were estimated to be 1.09 °C higher than the 1850-1900 baseline period, with larger increases over land ~1.6 °C compared to oceans ~0.88 (IPCC 2021). The vast majority of this warming has been attributed to anthropogenic releases of greenhouse gases (IPCC 2021). Globally, 2014-2018 were the 5 warmest years on record both on land and in the ocean (2018 was the 4th warmest) (NOAA NCEI, 2022). Events such as the 2013-2016 marine heatwave (Jacox *et al*., 2018) have been attributed directly to anthropogenic warming in the annual special issue of Bulletin of the American Meteorological Society on extreme events (Herring *et al*., 2018). Global warming and anthropogenic loss of biodiversity represent profound threats to ecosystem functionality (IPCC 2022). These two factors are often examined in isolation, but likely have interacting effects on ecosystem function.

Updated projections of climate change are similar to or greater than previous projections (IPCC 2021). NMFS is increasingly confident in our projections of changes to freshwater and marine systems because every year brings stronger validation of previous predictions in both physical and biological realms. Retaining and restoring habitat complexity, access to climate refuges (both flow and temperature) and improving growth opportunity in both freshwater and marine environments are strongly advocated in the recent literature (Siegel and Crozier, 2020a).

Climate change is systemic, influencing freshwater, estuarine, and marine conditions. Other systems are also being influenced by changing climatic conditions. Literature reviews on the impacts of climate change on Pacific salmon (Crozier, 2011; Crozier, 2012; Crozier, 2013; Crozier, 2014; Crozier, 2015; Crozier, 2016; Crozier, 2017; Crozier *et al*., 2019; Crozier and Siegel, 2018; Siegel and Crozier, 2019; Siegel and Crozier, 2020b) have collected hundreds of papers documenting the major themes relevant for salmon. Here we describe habitat changes

relevant to Pacific salmon and steelhead, prior to describing how these changes result in the varied specific mechanisms impacting these species in subsequent sections.

Forests

Climate change will impact forests of the western U.S., which dominate the landscape of many watersheds in the region. Forests are already showing evidence of increased drought severity, forest fire, and insect outbreak (Halofsky, Peterson and Harvey, 2020). Additionally, climate change will affect tree reproduction, growth, and phenology, which will lead to spatial shifts in vegetation. Halofsky *et al*. (2018) projected that the largest changes will occur at low- and high-elevation forests, with expansion of low-elevation dry forests and diminishing high-elevation cold forests and subalpine habitats.

Forest fires affect salmon streams by altering sediment load, channel structure, and stream temperature through the removal of canopy. Holden *et al*. (2018) examined environmental factors contributing to observed increases in the extent of forest fires throughout the western U.S. They found strong correlations between the number of dry-season rainy days and the annual extent of forest fires, as well as a significant decline in the number of dry-season rainy days over the study period (1984-2015). Consequently, predicted decreases in dry-season precipitation, combined with increases in air temperature, will likely contribute to the existing trend toward more extensive and severe forest fires and the continued expansion of fires into higher elevation and wetter forests (Alizadeh *et al*., 2021).

Agne *et al*. (2018) reviewed literature on insect outbreaks and other pathogens affecting coastal Douglas-fir forests in the Pacific Northwest and examined how future climate change may influence disturbance ecology. They suggest that Douglas-fir beetle and black stain root disease could become more prevalent with climate change, while other pathogens will be more affected by management practices. Agne *et al*. (2018) also suggested that due to complex interacting effects of disturbance and disease, climate impacts will differ by region and forest type.

Freshwater Environments

The following is excerpted from Siegel and Crozier (2019), who present a review of recent scientific literature evaluating effects of climate change, describing the projected impacts of climate change on instream flows:

Cooper *et al*. (2018) examined whether the magnitude of low river flows in the western U.S., which generally occur in September or October, are driven more by summer conditions or the prior winter's precipitation. They found that while low flows were more sensitive to summer evaporative demand than to winter precipitation, interannual variability in winter precipitation was greater. Malek *et al*. (2018), predicted that summer evapotranspiration is likely to increase in conjunction with declines in snowpack and increased variability in winter precipitation. Their results suggest that low summer flows are likely to become lower, more variable, and less predictable.

The effect of climate change on ground water availability is likely to be uneven. Sridhar *et al*. (2018) coupled a surface-flow model with a ground-flow model to improve predictions of surface water availability with climate change in the Snake River Basin. Projections using RCP 4.5 and 8.5 emission scenarios suggested an increase in water table heights in downstream areas of the basin and a decrease in upstream areas.

As cited in Siegel and Crozier (2019), Isaak *et al*. (2018), examined recent trends in stream temperature across the Western U.S. using a large regional dataset. Stream warming trends paralleled changes in air temperature and were pervasive during the low-water warm seasons of 1996-2015 (0.18-0.35°C/decade) and 1976-2015 (0.14-0.27°C/decade). Their results show how continued warming will likely affect the cumulative temperature exposure of migrating sockeye salmon *O. nerka* and the availability of suitable habitat for brown trout *Salmo trutta* and rainbow trout *O. mykiss*. Isaak *et al*. (2018) concluded that most stream habitats will likely remain suitable for salmonids in the near future, with some becoming too warm. However, in cases where habitat access is currently restricted by dams and other barriers salmon and steelhead will be confined to downstream reaches typically most at risk of rising temperatures unless passage is restored (FitzGerald *et al*., 2020; Myers *et al*., 2018).

Streams with intact riparian corridors and that lie in mountainous terrain are likely to be more resilient to changes in air temperature. These areas may provide refuge from climate change for a number of species, including Pacific salmon. Krosby *et al*. (2018), identified potential stream refugia throughout the Pacific Northwest based on a suite of features thought to reflect the ability of streams to serve as such refuges. Analyzed features include large temperature gradients, high canopy cover, large relative stream width, low exposure to solar radiation, and low levels of human modification. They created an index of refuge potential for all streams in the region, with mountain area streams scoring highest. Flat lowland areas, which commonly contain migration corridors, were generally scored lowest, and thus were prioritized for conservation and restoration. However, forest fires can increase stream temperatures dramatically in short time-spans by removing riparian cover (Koontz *et al*. 2018), and streams that lose their snowpack with climate change may see the largest increases in stream temperature due to the removal of temperature buffering (Yan *et al*. 2021). These processes may threaten some habitats that are currently considered refugia.

Marine and Estuarine Environments

Along with warming stream temperatures and concerns about sufficient groundwater to recharge streams, a recent study projects nearly complete loss of existing tidal wetlands along the U.S. West Coast, due to sea level rise (Thorne *et al*. 2018). California and Oregon showed the greatest threat to tidal wetlands (100%), while 68% of Washington tidal wetlands are expected to be submerged. Coastal development and steep topography prevent horizontal migration of most wetlands, causing the net contraction of this crucial habitat.

Rising ocean temperatures, stratification, ocean acidity, hypoxia, algal toxins, and other oceanographic processes will alter the composition and abundance of a vast array of oceanic species. In particular, there will be dramatic changes in both predators and prey of Pacific salmon, salmon life history traits and relative abundance. Siegel and Crozier (2019) observe that

changes in marine temperature are likely to have a number of physiological consequences on fishes themselves. For example, in a study of small planktivorous fish, Gliwicz *et al*. (2018) found that higher ambient temperatures increased the distance at which fish reacted to prey. Numerous fish species (including many tuna and sharks) demonstrate regional endothermy, which in many cases augments eyesight by warming the retinas. However, Gliwicz *et al*. (2018) suggest that ambient temperatures can have a similar effect on fish that do not demonstrate this trait. Climate change is likely to reduce the availability of biologically essential omega-3 fatty acids produced by phytoplankton in marine ecosystems. Loss of these lipids may induce cascading trophic effects, with distinct impacts on different species depending on compensatory mechanisms (Gourtay *et al*. 2018). Reproduction rates of many marine fish species are also likely to be altered with temperature (Veilleux *et al*. 2018). The ecological consequences of these effects and their interactions add complexity to predictions of climate change impacts in marine ecosystems.

Perhaps the most dramatic change in physical ocean conditions will occur through ocean acidification and deoxygenation. It is unclear how sensitive salmon and steelhead might be to the direct effects of ocean acidification because of their tolerance of a wide pH range in freshwater (although see Ou *et al*. 2015 and Williams *et al*. 2019), however, impacts of ocean acidification and hypoxia on sensitive species (e.g., plankton, crabs, rockfish, groundfish) will likely affect salmon indirectly through their interactions as predators and prey. Similarly, increasing frequency and duration of harmful algal blooms may affect salmon directly, depending on the toxin (e.g., saxitoxin vs domoic acid), but will also affect their predators (seabirds and mammals). The full effects of these ecosystem dynamics are not known but will be complex. Within the historical range of climate variability, less suitable conditions for salmonids (e.g., warmer temperatures, lower streamflows) have been associated with detectable declines in many of these listed units, highlighting how sensitive they are to climate drivers (Ford 2022, Lindley *et al*. 2009, Williams *et al*. 2016, Ward *et al*. 2015). In some cases, the combined and potentially additive effects of poorer climate conditions for fish and intense anthropogenic impacts caused the population declines that led to these population groups being listed under the ESA (Crozier *et al*. 2019).

Climate change effects on salmon and steelhead

In freshwater, year-round increases in stream temperature and changes in flow will affect physiological, behavioral, and demographic processes in salmon, and change the species with which they interact. For example, as stream temperatures increase, many native salmonids face increased competition with more warm-water tolerant invasive species. Changing freshwater temperatures are likely to affect incubation and emergence timing for eggs, and in locations where the greatest warming occurs may affect egg survival, although several factors impact intergravel temperature and oxygen (e.g., groundwater influence) as well as sensitivity of eggs to thermal stress (Crozier *et al*. 2020). Changes in temperature and flow regimes may alter the amount of habitat and food available for juvenile rearing, and this in turn could lead to a restriction in the distribution of juveniles, further decreasing productivity through density dependence. For migrating adults, predicted changes in freshwater flows and temperatures will likely increase exposure to stressful temperatures for many salmon and steelhead populations, and alter migration travel times and increase thermal stress accumulation for ESUs or DPSs with early-returning (i.e. spring- and summer-run) phenotypes associated with longer freshwater

holding times (Crozier *et al*. 2020, FitzGerald *et al*. 2021). Rising river temperatures increase the energetic cost of migration and the risk of *en route* or pre-spawning mortality of adults with long freshwater migrations, although populations of some ESA-listed salmon and steelhead may be able to make use of cool-water refuges and run-timing plasticity to reduce thermal exposure (Keefer *et al*. 2018, Barnett *et al*. 2020).

Marine survival of salmonids is affected by a complex array of factors including prey abundance, predator interactions, the physical condition of salmon within the marine environment, and carryover effects from the freshwater experience (Burke *et al*., 2013; Holsman *et al*., 2012). It is generally accepted that salmon marine survival is size-dependent, and thus larger and faster growing fish are more likely to survive (Gosselin *et al*., 2021). Furthermore, early arrival timing in the marine environment is generally considered advantageous for populations migrating through the Columbia River. However, the optimal day of arrival varies across years, depending on the seasonal development of productivity in the California Current, which affects prey available to salmon and the risk of predation (Chasco *et al*., 2021). Siegel and Crozier (2019) point out the concern that for some salmon populations, climate change may drive mismatches between juvenile arrival timing and prey availability in the marine environment. However, phenological diversity can contribute to metapopulation-level resilience by reducing the risk of a complete mismatch. Carr-Harris *et al*. (2018), explored phenological diversity of marine migration timing in relation to zooplankton prey for sockeye salmon *O. nerka* from the Skeena River of Canada. They found that sockeye migrated over a period of more than 50 days, and populations from higher elevation and further inland streams arrived in the estuary later, with different populations encountering distinct prey fields. Carr-Harris *et al*. (2018) recommended that managers maintain and augment such life-history diversity.

Synchrony between terrestrial and marine environmental conditions (e.g., coastal upwelling, precipitation and river discharge) has increased in spatial scale causing the highest levels of synchrony in the last 250 years (Black *et al*. 2018). A more synchronized climate combined with simplified habitats and reduced genetic diversity may be leading to more synchrony in the productivity of populations across the range of salmon (Braun *et al*., 2016). For example, salmon productivity (recruits/spawner) has also become more synchronized across Chinook populations from Oregon to the Yukon (Dorner *et al*. 2018, Kilduff *et al*. 2014). In addition, Chinook salmon have become smaller and younger at maturation across their range (Ohlberger *et al*., 2018). Other Pacific salmon species (Stachura el al. 2014) and Atlantic salmon (Olmos *et al*. 2020) also have demonstrated synchrony in productivity across a broad latitudinal range.

At the individual scale, climate impacts on salmon in one life stage generally affect body size or timing in the next life stage and negative impacts can accumulate across multiple life stages (Healey 2011; Wainwright and Weitkamp 2013, Gosselin *et al*. 2021). Changes in winter precipitation will likely affect incubation and/or rearing stages of most populations. Changes in the intensity of cool season precipitation, snow accumulation, and runoff could influence migration cues for fall, winter and spring adult migrants, such as coho and steelhead. Egg survival rates may suffer from more intense flooding that scours or buries redds. Changes in hydrological regime, such as a shift from mostly snow to more rain, could drive changes in life history, potentially threatening diversity within an ESU (Beechie *et al*. 2006). Changes in summer temperature and flow will affect both juvenile and adult stages in some populations,

especially those with yearling life histories and summer migration patterns (Crozier and Zabel 2006; Crozier *et al*. 2010, Crozier *et al*. 2019).

At the population level, the ability of organisms to genetically adapt to climate change depends on how much genetic variation currently exists within salmon populations, as well as how selection on multiple traits interact, and whether those traits are linked genetically. While genetic diversity may help populations respond to climate change, the remaining genetic diversity of many populations is highly reduced compared to historic levels. For example, Johnson *et al*. (2018), compared genetic variation in Chinook salmon from the Columbia River Basin between contemporary and ancient samples. A total of 84 samples determined to be Chinook salmon were collected from vertebrae found in ancient middens and compared to 379 contemporary samples. Results suggest a decline in genetic diversity, as demonstrated by a loss of mitochondrial haplotypes as well as reductions in haplotype and nucleotide diversity. Genetic losses in this comparison appeared larger for Chinook from the mid-Columbia than those from the Snake River Basin. In addition to other stressors, modified habitats and flow regimes may create unnatural selection pressures that reduce the diversity of functional behaviors (Sturrock *et al*. 2020). Managing to conserve and augment existing genetic diversity may be increasingly important with more extreme environmental change (Anderson *et al*. 2015), though the low levels of remaining diversity present challenges to this effort (Freshwater 2019). Salmon historically maintained relatively consistent returns across variation in annual weather through the portfolio effect (Schindler *et al*., 2015), in which different populations are sensitive to different climate drivers. Applying this concept to climate change, Anderson *et al* (2015) emphasized the additional need for populations with different physiological tolerances. Loss of the portfolio increases volatility in fisheries, as well as ecological systems, as demonstrated for Fraser River and Sacramento River stock complexes (Freshwater *et al*., 2019; Munsch *et al*., 2022).

2.2.1 Status of the Species

Table 2, below, provides a summary of listing and recovery plan information, status summaries and limiting factors for the species addressed in this opinion. More information can be found in recovery plans and status reviews for these species. Acronyms appearing in the table include DPS (Distinct Population Segment), ESU (Evolutionarily Significant Unit), ICTRT (Interior Columbia Technical Recovery Team), MPG (Major Population Group), NWFSC (Northwest Fisheries Science Center), TRT (Technical Recovery Team), and VSP (Viable Salmonid Population).

Table 2. Listing classification and date, recovery plan reference, most recent status review, status summary, and limiting factors for each species considered in this opinion.

Species	Listing Classification and Date	Recovery Plan Reference	Most Recent Status Review	Status Summary	Limiting Factors
Lower Columbia River Chinook salmon	Threatened 6/28/05	NMFS 2013	NMFS 2022a; Ford 2022	This ESU comprises 32 independent populations. Relative to baseline VSP levels identified in the recovery plan (Dornbusch 2013), there has been an overall improvement in the status of a number of fall-run populations although most are still far from the recovery plan goals; Spring-run Chinook salmon populations in this ESU are generally unchanged; most of the populations are at a "high" or "very high" risk due to low abundances and the high proportion of hatchery-origin fish spawning naturally. Many of the populations in this ESU remain at "high risk," with low natural-origin abundance levels. Overall, we conclude that the viability of the Lower Columbia River Chinook salmon ESU has increased somewhat since 2016, although the ESU remains at "moderate" risk of extinction	• Reduced access to spawning and rearing habitat • Hatchery-related effects • Harvest-related effects on fall Chinook salmon • An altered flow regime and Columbia River plume • Reduced access to off-channel rearing habitat • Reduced productivity resulting from sediment and nutrient-related changes in the estuary • Contaminant
Upper Columbia River spring-run Chinook salmon	Endangered 6/28/05	Upper Columbia Salmon Recovery Board 2007	NMFS 2022b; Ford 2022	This ESU comprises four independent populations. Current estimates of natural-origin spawner abundance decreased substantially relative to the levels observed in the prior review for all three extant populations. Productivities also continued to be very low, and both abundance and productivity remained well below the viable thresholds called for in the Upper Columbia Salmon Recovery Plan for all three populations. Based on the information available for this review, the Upper Columbia River spring-run Chinook salmon ESU remains at high risk, with viability largely unchanged since 2016.	• Effects related to hydropower system in the mainstem Columbia River • Degraded freshwater habitat • Degraded estuarine and nearshore marine habitat • Hatchery-related effects • Persistence of non-native (exotic) fish species • Harvest in Columbia River fisheries

Species	Listing Classification and Date	Recovery Plan Reference	Most Recent Status Review	Status Summary	Limiting Factors
Snake River spring/summer-run Chinook salmon	Threatened 6/28/05	NMFS 2017a	NMFS 2022c; Ford 2022	This ESU comprises 28 extant and four extirpated populations. There have been improvements in abundance/productivity in several populations relative to the time of listing, but the majority of populations experienced sharp declines in abundance in the recent five-year period Overall, at this time we conclude that the Snake River spring/ summer-run Chinook salmon ESU continues to be at moderate-to-high risk.	• Degraded freshwater habitat • Effects related to the hydropower system in the mainstem Columbia River, • Altered flows and degraded water quality • Harvest-related effects • Predation
Upper Willamette River Chinook salmon	Threatened 6/28/05	NMFS 2011	NMFS 2024; Ford 2022	This ESU comprises seven populations. Abundance levels for all but Clackamas River DIP remain well below their recovery goals. The Clackamas River DIP currently exceeds its abundance recovery goal and its pHOS goal (<10% hatchery-origin fish). While returns to Fall Creek Dam number in the low hundreds, prespawn mortality rates are very high in the basin, and the effects of fires and high summer temperatures resulted in a recruitment failure in 2021. Overall, there has likely been a declining trend in the viability of the Upper Willamette River Chinook salmon ESU since the last review. In order to meet the biological recovery criteria for viability, the UWR Chinook salmon ESU must have four out of seven viable populations. The magnitude of this change is not sufficient to suggest a change in risk category, however, so the Upper Willamette River Chinook salmon ESU remains at “moderate” risk of extinction.	• Degraded freshwater habitat • Degraded water quality • Increased disease incidence • Altered stream flows • Reduced access to spawning and rearing habitats • Altered food web due to reduced inputs of microdetritus • Predation by native and non-native species, including hatchery fish • Competition related to introduced salmon and steelhead • Altered population traits due to fisheries and bycatch

Species	Listing Classification and Date	Recovery Plan Reference	Most Recent Status Review	Status Summary	Limiting Factors
Snake River fall-run Chinook salmon	Threatened 6/28/05	NMFS 2017b	NMFS 2022e; Ford 2022	This ESU has one extant population The single extant population in the ESU is currently meeting the criteria for a rating of "viable" developed by the ICTRT, but the ESU as a whole is not meeting the recovery goals described in the recovery plan for the species, which require the single population to be "highly viable with high certainty" and/or will require reintroduction of a viable population above the Hells Canyon Complex (NMFS 2017b). The Snake River fall-run Chinook salmon ESU therefore is considered to be at a moderate-to-low risk of extinction.	• Degraded floodplain connectivity and function • Harvest-related effects • Loss of access to historical habitat above Hells Canyon and other Snake River dams • Impacts from mainstem Columbia River and Snake River hydropower systems • Hatchery-related effects • Degraded estuarine and nearshore habitat.
Columbia River chum salmon	Threatened 6/28/05	NMFS 2013	NMFS 2022a; Ford 2022	This species has 17 populations divided into 3 MPGs. 3 populations exceed the recovery goals established in the recovery plan (Dornbusch 2013). The remaining populations have unknown abundances. Abundances for these populations are assumed to be at or near zero. The viability of this ESU is relatively unchanged since the last review (moderate to high risk), and the improvements in some populations do not warrant a change in risk category, especially given the uncertainty regarding climatic effects in the near future.	• Degraded estuarine and nearshore marine habitat • Degraded freshwater habitat • Degraded stream flow as a result of hydropower and water supply operations • Reduced water quality • Current or potential predation • An altered flow regime and Columbia River plume • Reduced access to off-channel rearing habitat in the lower Columbia River • Reduced productivity resulting from sediment and nutrient-related changes in the estuary • Juvenile fish wake strandings • Contaminants

Species	Listing Classification and Date	Recovery Plan Reference	Most Recent Status Review	Status Summary	Limiting Factors
Lower Columbia River coho salmon	Threatened 6/28/05	NMFS 2013	NMFS 2022a; Ford 2022	Of the 24 populations that make up this ESU only six of the 23 populations for which we have data appear to be above their recovery goals. Overall abundance trends for the Lower Columbia River coho salmon ESU are generally negative. Natural spawner and total abundances have decreased in almost all DIPs, and Coastal and Gorge MPG populations are all at low levels, with significant numbers of hatchery-origin coho salmon on the spawning grounds. Improvements in spatial structure and diversity have been slight, and overshadowed by declines in abundance and productivity. For individual populations, the risk of extinction spans the full range, from "low" to "very high." Overall, the Lower Columbia River coho salmon ESU remains at "moderate" risk, and viability is largely unchanged since 2016.	• Degraded estuarine and near-shore marine habitat • Fish passage barriers • Degraded freshwater habitat: Hatchery-related effects • Harvest-related effects • An altered flow regime and Columbia River plume • Reduced access to off-channel rearing habitat in the lower Columbia River • Reduced productivity resulting from sediment and nutrient-related changes in the estuary • Juvenile fish wake strandings • Contaminants
Snake River sockeye salmon	Endangered 6/28/05	NMFS 2015	NMFS 2022d; Ford 2022	This single population ESU is at remains at "extremely high risk," although there has been substantial progress on the first phase of the proposed recovery approach—developing a hatchery-based program to amplify and conserve the stock to facilitate reintroductions. Current climate change modeling supports the "extremely high risk" rating with the potential for extirpation in the near future (Crozier *et al*. 2020). The viability of the Snake River sockeye salmon ESU therefore has likely declined since the time of the prior review, and the extinction risk category remains "high."	• Effects related to the hydropower system in the mainstem Columbia River • Reduced water quality and elevated temperatures in the Salmon River • Water quantity • Predation

Species	Listing Classification and Date	Recovery Plan Reference	Most Recent Status Review	Status Summary	Limiting Factors
Upper Columbia River steelhead	Threatened 1/5/06	Upper Columbia Salmon Recovery Board 2007	NMFS 2022b; Ford 2022	This DPS comprises four independent populations. The most recent estimates (five year geometric mean) of total and natural-origin spawner abundance have declined since the last report, largely erasing gains observed over the past two decades for all four populations (Figure 12, Table 6). Recent declines are persistent and large enough to result in small, but negative 15-year trends in abundance for all four populations. The overall Upper Columbia River steelhead DPS viability remains largely unchanged from the prior review, and the DPS is at high risk driven by low abundance and productivity relative to viability objectives and diversity concerns.	• Adverse effects related to the mainstem Columbia River hydropower system • Impaired tributary fish passage • Degraded floodplain connectivity and function, channel structure and complexity, riparian areas, large woody debris recruitment, stream flow, and water quality • Hatchery-related effects • Predation and competition • Harvest-related effects
Lower Columbia River steelhead	Threatened 1/5/06	NMFS 2013	NMFS 2022a; Ford 2022	This DPS comprises 23 historical populations, 17 winter-run populations and 6 summer-run populations. 10 are nominally at or above the goals set in the recovery plan (Dornbusch 2013); however, it should be noted that many of these abundance estimates do not distinguish between natural- and hatchery- origin spawners. The majority of winter-run steelhead DIPs in this DPS continue to persist at low abundance levels (hundreds of fish), with the exception of the Clackamas and Sandy River DIPs, which have abundances in the low 1,000s. Although the five-year geometric abundance means are near recovery plan goals for many populations, the recent trends are negative. Overall, the Lower Columbia River steelhead DPS is therefore considered to be at "moderate" risk.	• Degraded estuarine and nearshore marine habitat • Degraded freshwater habitat • Reduced access to spawning and rearing habitat • Avian and marine mammal predation • Hatchery-related effects • An altered flow regime and Columbia River plume • Reduced access to off-channel rearing habitat in the lower Columbia River • Reduced productivity resulting from sediment and nutrient-related changes in the estuary • Juvenile fish wake strandings • Contaminants

Species	Listing Classification and Date	Recovery Plan Reference	Most Recent Status Review	Status Summary	Limiting Factors
Upper Willamette River steelhead	Threatened 1/5/06	NMFS 2011b	NMFS 2024; Ford 2022	This DPS has four demographically independent populations. Populations in this DPS have experienced long-term declines in spawner abundance. Although the recent magnitude of these declines is relatively moderate, continued declines would be a cause for concern. Overall, the Upper Willamette River steelhead DPS continued to decline in abundance. Although the most recent counts at Willamette Falls and the Bennett Dams in 2019 and 2020 suggest a rebound from the record 2017 lows, it should be noted that current "highs" are equivalent to past lows. In the absence of substantial changes in accessibility to high-quality habitat, the DPS will remain at "moderate-to-high" risk. Overall, the Upper Willamette River steelhead DPS is therefore at "moderate-to-high" risk, with a declining viability trend.	• Degraded freshwater habitat • Degraded water quality • Increased disease incidence • Altered stream flows • Reduced access to spawning and rearing habitats due to impaired passage at dams • Altered food web due to changes in inputs of microdetritus • Predation by native and non-native species, including hatchery fish and pinnipeds • Competition related to introduced salmon and steelhead • Altered population traits due to interbreeding with hatchery origin fish
Middle Columbia River steelhead	Threatened 1/5/06	NMFS 2009b	NMFS 2022f; Ford 2022	This DPS comprises 17 extant populations. Recent (five-year) returns are declining across all populations, the declines are from relatively high returns in the previous five-to-ten year interval, so the longer-term risk metrics that are meant to buffer against short-period changes in abundance and productivity remain unchanged. The Middle Columbia River steelhead DPS does not currently meet the viability criteria described in the Middle Columbia River steelhead recovery plan.	• Degraded freshwater habitat • Mainstem Columbia River hydropower-related impacts • Degraded estuarine and nearshore marine habitat • Hatchery-related effects • Harvest-related effects • Effects of predation, competition, and disease
Snake River basin steelhead	Threatened 1/5/06	NMFS 2017a	NMFS 2022g; Ford 2022	This DPS comprises 24 populations. Based on the updated viability information available for this review, all five MPGs are not meeting the specific objectives in the draft recovery plan, and the viability of many individual populations remains uncertain. Of particular note, the updated, population-level abundance estimates have made very clear the recent (last five years) sharp declines that are extremely worrisome, were they to continue.	• Adverse effects related to the mainstem Columbia River hydropower system • Impaired tributary fish passage • Degraded freshwater habitat • Increased water temperature • Harvest-related effects, particularly for B-run steelhead • Predation • Genetic diversity effects from out-of-population hatchery releases

Species	Listing Classification and Date	Recovery Plan Reference	Most Recent Status Review	Status Summary	Limiting Factors
Southern DPS of green sturgeon	Threatened 4/7/06	NMFS 2018	NMFS 2021	The Sacramento River contains the only known green sturgeon spawning population in this DPS. The current estimate of spawning adult abundance is 17,500 individuals. Telemetry data and genetic analyses suggest that Southern DPS green sturgeon generally occur from Graves Harbor, Alaska to Monterey Bay, California and, within this range, most frequently occur in coastal waters of Washington, Oregon, and Vancouver Island and near San Francisco and Monterey bays. Within the nearshore marine environment, tagging and fisheries data indicate that Northern and Southern DPS green sturgeon prefer marine waters of less than a depth of 110 meters.	• Reduction of its spawning area to a single known population • Lack of water quantity • Poor water quality • Poaching
Southern DPS of eulachon	Threatened 3/18/10	NMFS 2017c	NMFS 2022h	The Southern DPS of eulachon includes all naturally-spawned populations that occur in rivers south of the Nass River in British Columbia to the Mad River in California. Sub populations for this species include the Fraser River, Columbia River, British Columbia and the Klamath River. In the early 1990s, there was an abrupt decline in the abundance of eulachon returning to the Columbia River. Despite a brief period of improved returns in 2001-2003, the returns and associated commercial landings eventually declined to the low levels observed in the mid-1990s. Although eulachon abundance in monitored rivers has generally improved, especially in the 2013-2015 return years, recent poor ocean conditions and the likelihood that these conditions will persist into the near future suggest that population declines may be widespread in the upcoming return years.	• Changes in ocean conditions due to climate change, particularly in the southern portion of the species' range where ocean warming trends may be the most pronounced and may alter prey, spawning, and rearing success. • Climate-induced change to freshwater habitats • Bycatch of eulachon in commercial fisheries • Adverse effects related to dams and water diversions • Water quality, • Shoreline construction • Over harvest • Predation

Species	Listing Classification and Date	Recovery Plan Reference	Most Recent Status Review	Status Summary	Limiting Factors
Southern resident killer whale	Endangered 11/18/05	NMFS 2008	NMFS 2022i	The Southern Resident killer whale DPS is composed of a single population that ranges as far south as central California and as far north as southeast Alaska. While some of the down-listing and delisting criteria have been met, the biological down-listing and delisting 63 criteria, including sustained growth over 14 and 28 years, respectively, have not been met. The SRKW DPS has not grown; the overall status of the population is not consistent with a healthy, recovered population. Considering the status and continuing threats, the Southern Resident killer whales remain in danger of extinction.	• Quantity and quality of prey • Exposure to toxic chemicals • Disturbance from sound and vessels • Risk from oil spills

Status of Blue Whales. The Endangered Species Conservation Act of 1969 listed blue whales as endangered worldwide and they remained on the list of threatened and endangered species after the passage of the ESA in 1973 (35 FR 8491; June 2, 1970). The entire species remains endangered under the ESA (NMFS 2020a). There is no designated critical habitat for blue whales.

Spatial structure and diversity. The Eastern North Pacific Stock of blue whales includes animals found in the eastern north Pacific from the northern Gulf of Alaska to the eastern tropical Pacific (Carretta *et al*., 2017). Most blue whale sightings are in nearshore and continental shelf waters but blue whales frequently migrate through deep oceanic waters to spend their summers feeding in productive waters near the higher latitudes of the Gulf of Alaska and the Aleutian Islands and their winters in the warmer waters at lower latitudes from Southern California to Costa Rica (Calambokidis and Barlow, 2013; Calambokidis *et al*., 2009b). None of the nine feeding areas for blue whales off the U.S. West Coast areas are within the Action Area (Calambokidis *et al*., 2015). There was one sighting of a blue whale (Oleson and Hildebrand, 2012) during 42 small boat surveys from Grays Harbor out to the 1,000 meter isobath off Quinault between 2004 and 2009. Aerial surveys conducted in waters off southern Washington, Oregon, and Northern California in the spring, summer, and fall of 2011 and 2012, encountered a total of 16 blue whales during the fall (Adams *et al*., 2014). Figure 4 shows their general distribution of the Eastern Pacific coast. Acoustic monitoring in waters off the coast of Washington show a yearly seasonal pattern of blue whale presence from summer through winter (Oleson and Hildebrand, 2012).

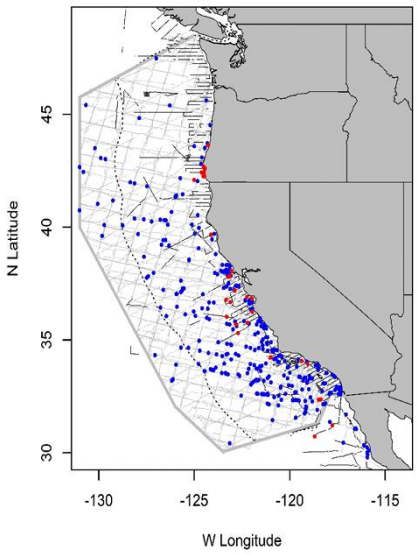


Figure 4. Blue whale sightings based on shipboard surveys off California, Oregon, and Washington, 1991 - 2018 (NMFS 2024b).

Abundance and productivity. Minimum population estimates of the Eastern North Pacific stock of blue whales is 1,551 individuals and show trends that numbers are increasing, although the mark-recapture estimates show there is no evidence of growth in global populations since the early 1990s (NMFS 2020b). The Eastern Pacific blue whale population may have reached a

stable level at 97 percent of carrying capacity in 2013 following the cessation of commercial whaling in 1971 (Monnahan *et al*., 2015).
Limiting factors. Threats to blue whales are vessel strikes, entanglement in fishing gear, habitat degradation, pollution and climate change (Redfern *et al*. 2019; NMFS 2020a; NMFS 2020b). As noted in the Revised Recovery Plan for the blue whale (NMFS 2020b), some blue whale populations are likely more vulnerable than others to ship strikes, largely based on differences in distribution relative to shipping traffic (NMFS 2020). However, some blue whale populations are vulnerable to ship strikes due in large part to coastal populations which seasonally reside in feeding grounds that overlap with shipping routes, such as off southern California (NMFS 2020b). In waters off California between 1991 and 2010 there were 14 ship strikes involving blue whales (Calambokidis, 2012; Calambokidis *et al*., 2009a; Monnahan, Branch and Punt, 2015) and 10 blue whales died from vessel strikes between 2007 and 2011 in waters of the U.S. West Coast (Carretta *et al*., 2017; Carretta *et al*., 2013). There was one blue whale ship strike death reported in 2016 (Carretta *et al*., 2017).

Status of Fin Whales. The Endangered Species Conservation Act of 1969 listed fin whales as endangered worldwide and they remained on the list of threatened and endangered species after the passage of the ESA in 1973 (35 Fed. Reg. 8491) (June 2, 1970) (codified at 50 C.F.R. § 17.11(h)) and subsequent 5-year reviews (NMFS 2019b). There is no designated critical habitat for fin whales. The fin whales most likely to be observed within the proposed action area are identified as the CA/OR/WA stock.

Spatial Structure and Diversity. In the North Pacific, populations off the U.S. west coast and in Alaskan waters (Kenai Peninsula to Shumagin Islands) are increasing. Although, information is sparse on other demographic parameters, reasonable annual population growth rates have been reported to range from 4-7.5%, indicating threats acting on these populations are not limiting growth (NMFS 2019b). Fin whales prefer temperate and polar waters making long-range movements along the entire U.S. West Coast (Falcone *et al*., 2011) following prey off the continental shelf (Azzellino *et al*., 2008). There was one sighting of a group of three fin whales during 42 small boat surveys from Grays Harbor out to the 1,000 meters (m) isobath off Quinault conducted over a five-year period in the summer between 2004 and 2009, (Oleson and Hildebrand, 2012). During aerial surveys within the 2,000 m isobath off southern Washington, Oregon, and Northern California in the spring, summer, and fall of 2011 and 2012, there were six sightings of 13 fin whales during winter and summer 2012 in offshore waters over the continental slope (Adams *et al*., 2014). Figure 5 shows the distribution of fin whales off the Eastern Pacific Coast. Acoustic monitoring has indicated a yearly seasonal pattern of fin whale calls in the Action Area with the absence of calls from approximately May through July (Oleson and Hildebrand, 2012).

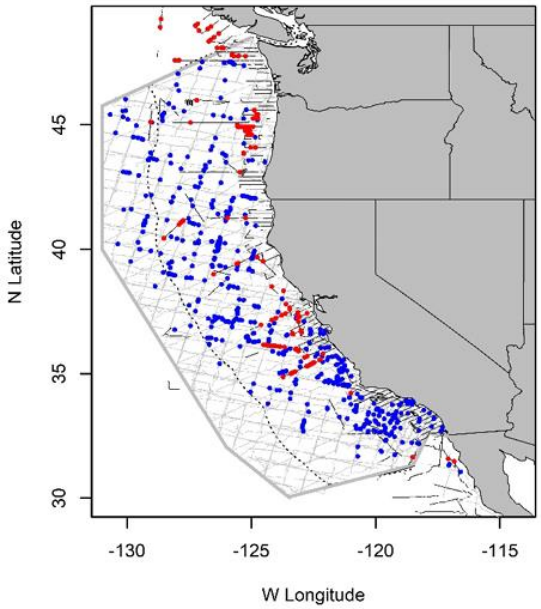


Figure 5. Fin whale sightings based on shipboard surveys off California, Oregon, and Washington, 1991 - 2018 (Barlow 2016, Henry et al. 2020).

Abundance and Productivity. The best estimate of fin whale abundance in California, Oregon, and Washington waters out to 300 nautical miles is 9,029 whales, generated from a trend-model analysis of line-transect data from 1991 through 2014 (Nadeem *et al*., 2016). Removal of the threat of commercial whaling has allowed increased recruitment in global populations and expected to grow.

Limiting factors. Fin whales are susceptible to both ship strikes and entanglement in fishing gear (Carretta *et al*., 2017; NOAA, 2017g). Between 1991 and 201 there were 20 reported ship strikes of fin whales along the U.S. West Coast. From 2010 to 2014 along the U.S West Coast there were nine reported ship strikes to fin whales (Carretta *et al*., 2017). Since 2002, 10 out of the 12 stranded fin whales in Washington have showed evidence attributed to a large ship strike (Carretta *et al*., 2017). Four fin whales were seriously injured by entanglement in fishing gear off the U.S. West Coast between 2007 and 2014 (Carretta *et al*., 2017; Carretta *et al*., 2013).

Status of Sei Whale. The Endangered Species Conservation Act of 1969 listed sei whales was as endangered worldwide and they remained on the list of threatened and endangered species after the passage of the ESA in 1973 (35 FR 8491; June 2, 1970). The North Pacific population is threatened under the ESA (NMFS 2021b). There is no designated critical habitat for sei whales.

Spatial structure and diversity. Sei whales migrate to spend the summer months feeding in the subpolar higher latitudes and return to lower latitudes as far south as Southern California to calve in the winter (Horwood, 2009). They are found feeding along the California Current, preferring deep water habitat along the continental shelf (Perry *et al*., 1999).

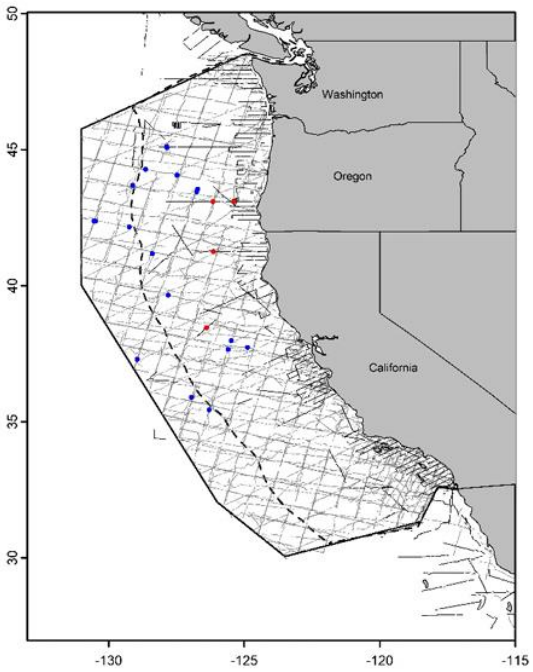


Figure 6. Sei whale sighting locations from shipboard surveys off California, Oregon, and Washington, 1991 – 2018 (NMFS 2024c).

Abundance and productivity. Abundance estimates for the two most recent line transect surveys of California, Oregon, and Washington waters in 2008 and 2014 out to 300 nautical miles are 311 (CV=0.76) and 864 (CV=0.40) sei whales, respectively (Barlow 2016). The best estimate of abundance for California, Oregon, and Washington waters out to 300 nautical miles is the unweighted geometric mean of the 2008 and 2014 estimates, or 519 (CV=0.40) sei whales (Barlow 2016).

Limiting factors. Sei whales, because of their offshore distribution and relative scarcity in U.S. Atlantic and Pacific waters, probably have a lower incidence of fishing gear entanglement than fin whales. One sei whale was killed in a collision with a vessel off the coast of Washington in 2003 (NMFS, 2017e).

Status of Humpback Whales. The Endangered Species Conservation Act listed humpback whales as endangered under in June 1970 (35 FR 18319) and they remained on the list of threatened and endangered species after the passage of the ESA in 1973 (35 FR 8491).

In 2016, NOAA Fisheries revised the listing status of the humpback whale under the Endangered Species Act (ESA). The globally listed endangered species was divided into 14 distinct population segments (DPSs), the species-level listing was removed, and NOAA Fisheries listed four DPSs as endangered and one DPS as threatened (81 FR 62260, September 8, 2016). Central America DPS humpback whales are listed as endangered. Mexico DPS humpback whales are listed as threatened. We designated critical habitat on April 21, 2021 (86 FR 21082). The ESA

generally requires recovery plans for the conservation and survival of listed endangered and threatened species.

The DPSs are considered new listings under the ESA, so NOAA Fisheries is developing a DPS-specific recovery plan for the Central America, Mexico, and Western North Pacific DPSs. This new plan will replace the species-wide recovery plan that was published in 1991. Until the new recovery plan is complete, this recovery outline will serve as an interim guidance document and, with the existing species-wide recovery plan, direct recovery efforts, including recovery planning, for the Central America, Mexico, and Western North Pacific DPSs of humpback whales (NMFS 2022j).

Spatial structure and diversity. Humpback whales are in all major oceans and most seas. They typically spend the summer on high-latitude nearshore feeding grounds and the winter in the tropics and subtropics around islands, over shallow banks, and along continental coasts, where calving occurs (Barlow *et al*., 2011; Bettridge *et al*., 2015; Calambokidis *et al*., 2017; Calambokidis *et al*., 2009b). Visual surveys and acoustic monitoring studies detect some humpbacks along the Washington coast year-round (Cogan, 2015; Emmons *et al*., 2019; Oleson *et al*., 2009). The Central America DPS is composed of humpback whales that breed along the Pacific coast of Costa Rica, Panama, Guatemala, El Salvador, Honduras and Nicaragua and feed almost exclusively offshore of California and Oregon with only a few individuals identified at the northern Washington – southern British Columbia feeding grounds (81 FR 62259). The Mexico DPS consists of humpback whales that breed along the Pacific coast of mainland Mexico, and the Revillagigedos Islands and transit through the Baja California Peninsula coast. The DPS feeds across a broad geographic range from California to the Aleutian Islands, with concentrations in California-Oregon, northern Washington – southern British Columbia, northern and western Gulf of Alaska and Bering Sea feeding grounds (81 FR 62259).

Three biologically important humpback whale feeding areas are off of the Washington Oregon coast (Calambokidis *et al*., 2015); (1) Point St. George off Crescent City, Oregon from July to November (2) Stonewall and Heceta Bank off Newport, Oregon from May to November, and (3) Northern Washington from May–November. Surveys of the Northern Washington feeding area found that humpback whale sightings were concentrated around the edge of what appears to be the semi-permanent eddy associated with the outflow from the Strait of Juan de Fuca (Dalla Rosa, Ford and Trites, 2012). Figure 7 shows the distribution of humpback whale sightings off the Eastern Pacific Coast. Satellite tag location data from humpback whales indicate a preference for water less than 200 meters deep (Barlow *et al*., 2011; Becker *et al*., 2016; Campbell *et al*., 2015).

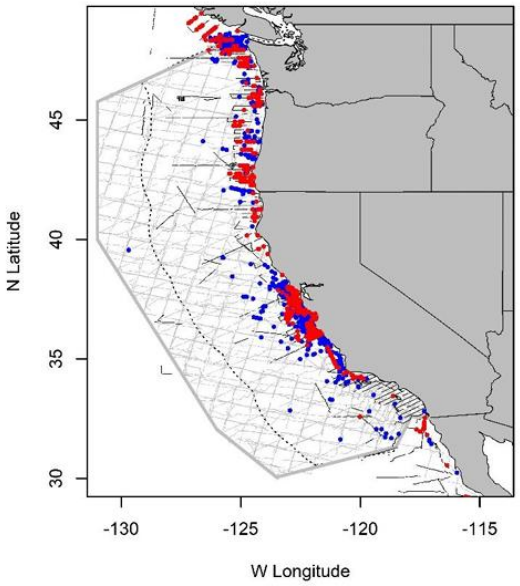


Figure 7. Humpback whale sightings based on shipboard surveys off California, Oregon, and Washington, 1991-2018 (NMFS 2022l).

Abundance and productivity. Current abundance of the Central America DPS is 411 (81 FR 62259). A population growth rate is currently unavailable for these DPS. The current abundance of the Mexico humpback whale DPS is 3,264 (81 FR 62259). Current estimates of abundance for the CA/OR/WA stock is 1918 individuals with 1729 feeding off California and Oregon and 189 feeding off Washington (NMFS 2019).

Limiting factors. The most common source of injury to humpback whales along the U.S. Pacific coast is entanglement in pot and trap fisheries (Carretta *et al*., 2018). Humpback whales continue to be the predominant species reported as entangled in recent years. There were 54 separate entanglement cases reported for humpback whales along the U.S West Coast in 2016 NOAA, 2017). Fewer humpback whales were entangled in 2023 where 16 whales were entangled, including 3 off Oregon and Washington coasts (NMFS 2023b). For the five-year period between 2011 and 2015 there were 34 cases of entanglement involving pot/trap fisheries and an additional 26 cases of reported interactions with other fisheries (Carretta *et al*., 2017).

Available data from NMFS indicate that along the U.S. Pacific coast between 2011 and 2015, there were nine ship strikes involving humpback whales (Carretta *et al*., 2018). Humpback whales are also potentially affected by loss of habitat, loss of prey (for a variety of reasons including climate variability), underwater noise, jet skis and similar fast waterborne tourist-related traffic disturbance and vessel strike, and pollutants (Muto *et al*., 2017).

***Status of sperm whales*.** Sperm whales are listed as endangered under the ESA, but there is no designated critical habitat for this species. Sperm whales in Alaska are from the North Pacific stock. Sperm Whales in the Action Area are from the California, Oregon, Washington stock (Carretta *et al*., 2017; Carretta *et al*., 2018).

Spatial structure and diversity. Sperm whales are typically found in temperate and tropical waters of the Pacific (Rice, 1989) but they are also found in areas of higher latitudes in the northern Pacific including Alaska (Whitehead, 2009; Whitehead *et al*., 2008). Sperm whales have a preference for deep water areas of high productivity, generally near drop offs and areas with strong currents and steep topography (Gannier and Praca, 2007). The semi-permanent the Strait of Juan de Fuca eddy is one such area (MacFadyen *et al*., 2008). Sperm whales are somewhat migratory. No sperm whales were detected during systematic surveys of waters between the British Columbia border with Alaska and Washington (Williams *et al*., 2007). Sperm whales were observed twice in deep water off the coast from Grays Harbor in aerial surveys of waters off Washington, Oregon, and Northern California in the spring, summer, and fall of 2011 and 2012 (Adams *et al*., 2014). Figure 8 shows the distribution of sperm whales off the Eastern Pacific Coast from 1991 – 2018. There were a total of five sperm whale sightings during the NMFS 2014 summer shipboard survey off the coast of Washington (Barlow, 2016).

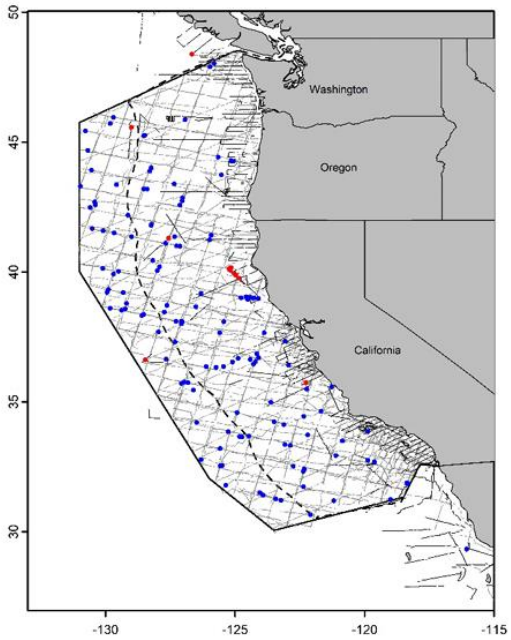


Figure 8. Sperm whale sightings based on shipboard surveys off California, Oregon, and Washington, 1991-2018 (NMFS 2024d).

Abundance and productivity. Estimates of sperm whale total global abundance range from 300,000 and 450,000 individuals (Whitehead, 2009). The California/Oregon/Washington stock abundance is 2,106 individuals (N_{min}=1,332), and the Hawaii stock abundance is 3,354 individuals (N_{min}=2,539) (Carretta *et al*., 2019).

Limiting factors. In waters off the U.S. Pacific West Coast between 2011 and 2015, there was one reported ship strike involving a sperm whale in 2012 (Carretta *et al*., 2017). From 2010 to 2014, a total of five sperm whales were entangled in fishing gear off the U.S. Pacific West Coast (Carretta *et al*., 2016). Between 1982 – 2017, fourteen sperm whales were reported as entangled

to the NMFS West Coast Region. The reports originated from southern California, primarily between September and December in gill or drift net fisheries (Saez et al., 2021).

Status of Leatherback Turtles.

Sea turtles are difficult to study across all life stages due to their extensive distribution, certain cryptic life stages, complex life history, and remote habitats. As a result, status and trends of sea turtle populations are usually based on data collected on nesting beaches (e.g., number of adult females, number of nests, nest success, etc.). The spatial structure of male sea turtles and their fidelity to specific coastal areas is unknown; however, we describe the status of sea turtle populations based on the nesting beaches that females return to when they mature. We make inferences about the growth or decline of leatherback populations based on numbers of nests and trends in numbers of nests.

West Pacific Leatherback Population: Distribution and Population Structure

We define the West Pacific population as leatherback turtles originating from the West Pacific Ocean, with the following boundaries: south of 71° N, north of 47° S latitudes and east of 120° E, and west of 117.124° W longitudes (NMFS and USFWS, 2020) . Indonesia, Papua New Guinea and Solomon Islands have been identified as the core nesting areas for this population Figure 9 (Benson *et al*., 2007a; Benson *et al*., 2011; Benson *et al*., 2007b; Benson *et al*., 2018).

Low levels of nesting are also reported in Vanuatu and the Philippines (NMFS and USFWS, 2020) . Recently, a new leatherback turtle nesting area was identified at Buru Island, Maluku province of Indonesia where approximately 200 nests are laid annually (NMFS and USFWS, 2020; WWF, 2019) . However, long-term monitoring data for this population is geographically limited to the Bird's Head Peninsula in West Papua at Jamursba Medi and Wermon nesting beaches which represent an estimated 50 to 75 percent of all nesting in the West Pacific (NMFS and USFWS, 2020).

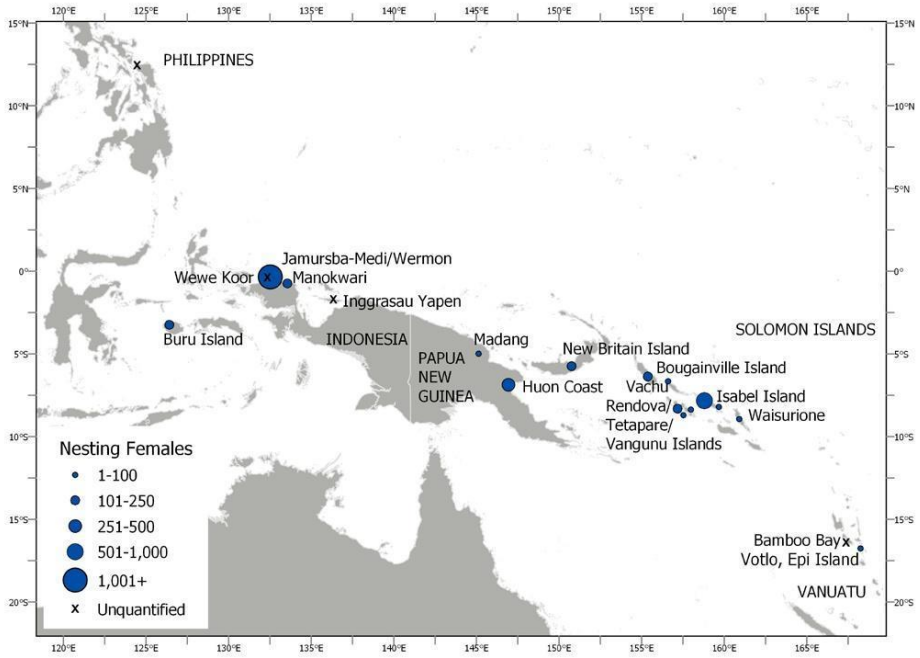


Figure 9. Nesting sites of the West Pacific leatherback population (NMFS and USFWS 2020).

The West Pacific population exhibits metapopulation dynamics and genetic population structure (NMFS and USFWS, 2020). While mtDNA analyses of 106 samples from Indonesia, Papua New Guinea, and Solomon Islands did not detect genetic differentiation among nesting aggregations (Dutton *et al*., 2007), microsatellite DNA analyses indicate fine-scale genetic structure (Dutton *et al*., 2007) (NMFS SWFSC, unpublished data). While we often consider these different nesting aggregations separately, together they comprise the Western Pacific population (NMFS and USFWS, 2020).

Two life history strategies are documented in the West Pacific leatherback population: winter boreal nesters and summer boreal nesters. The most consistent monitoring effort has been at Jamursba-Medi beach, and its nesting females are primarily summer nesters. Wermon beach has a stronger bimodal pattern of nesting, with summer and winter nesters in roughly equal proportions. There is historical evidence to suggest a similar bimodal nesting strategy in other nesting aggregations, but data is lacking to quantify the current extent of summer nesting activity in the Solomon Islands and Papua New Guinea where the majority of nesting activity occurs during winter months (NMFS and USFWS, 2020).

Migration and foraging strategies vary based on these life history strategies, likely due to prevailing offshore currents and, for hatchlings, seasonal monsoon-related effects experienced as hatchlings (Benson *et al*., 2011; Gaspar *et al*., 2012). Summer nesting females forage in Northern Hemisphere foraging habitats in Asia and the North Pacific Ocean, while winter nesting females migrate to tropical waters of the Southern Hemisphere in the South Pacific Ocean (Benson *et al*., 2011; Harrison *et al*., 2018) (Figure 10). The lack of crossover among seasonal nesting populations suggests that leatherback turtles develop fidelity for specific foraging regions likely

based on juvenile dispersal patterns (Benson *et al*., 2011; Gaspar *et al*., 2012; Gaspar and Lalire, 2017). Stable isotopes, linked to particular foraging regions, confirm nesting season fidelity to specific foraging regions (Seminoff *et al*., 2012).

West Pacific Leatherback Population: Abundance, Status, and Trends
Our ability to estimate leatherback population abundance is complicated by the life history of the species. Data collected at nesting beaches are often the best available data but do not provide information on life stages away from the nesting beaches (i.e., immature and mature males and immature females). Additionally, standardized nesting surveys are difficult to maintain over many, consecutive years and at all nesting beaches. Here we provide data that have been consistently collected using a standardized monitoring approach over the most recent available remigration interval, providing reasonable certainty that such data are representative of recent nesting at the identified beach. Although some data may have been collected at other nesting beaches, monitoring has not been recent, consistent, or standardized, thus limiting our certainty of these data; therefore data from those nesting beaches cannot be used to calculate abundance.

Using the best available data for the West Pacific leatherback population (Fitry Pakiding, University of Papua, pers. comm. 2020) and a Bayesian steady-state model (Martin *et al*., 2020) provided a median estimate of the total number of nesting females (i.e., over one, 3-year, remigration interval) at Jamursba Medi and Wermon beaches of 790 females, with a 95 percent credible interval of 666 to 942 females, as a snapshot of current abundance in 2017. We consider this the best available estimate of total adult female abundance at these two nesting beaches in 2017 (based on data from 2014 through 2017). To estimate the total number of nesting females from all nesting beaches in the West Pacific, we need to consider nesting at unmonitored or irregularly monitored beaches. As noted above, an estimated 50 to 75 percent of West Pacific leatherback nesting occurs at Jamursba-Medi and Wermon beaches (Dutton *et al*., 2007; NMFS and USFWS, 2020). Applying the conservative estimate of 75 percent to the Martin *et al*. (2020) estimate of 790 nesting females at Jamursba Medi and Wermon beaches, the total number of nesting females in the West Pacific population would be 1,054 females with an overall 95 percent credible interval of 888 to 1,256 females. It should be noted that this estimate (*i.e*., 1,054) of nesting females for the West Pacific population based on more recent available information is an update of the NMFS and USFWS (2020) estimate (*i.e.*, 1,277), which was based on a simple calculation that did not provide confidence or credible intervals.

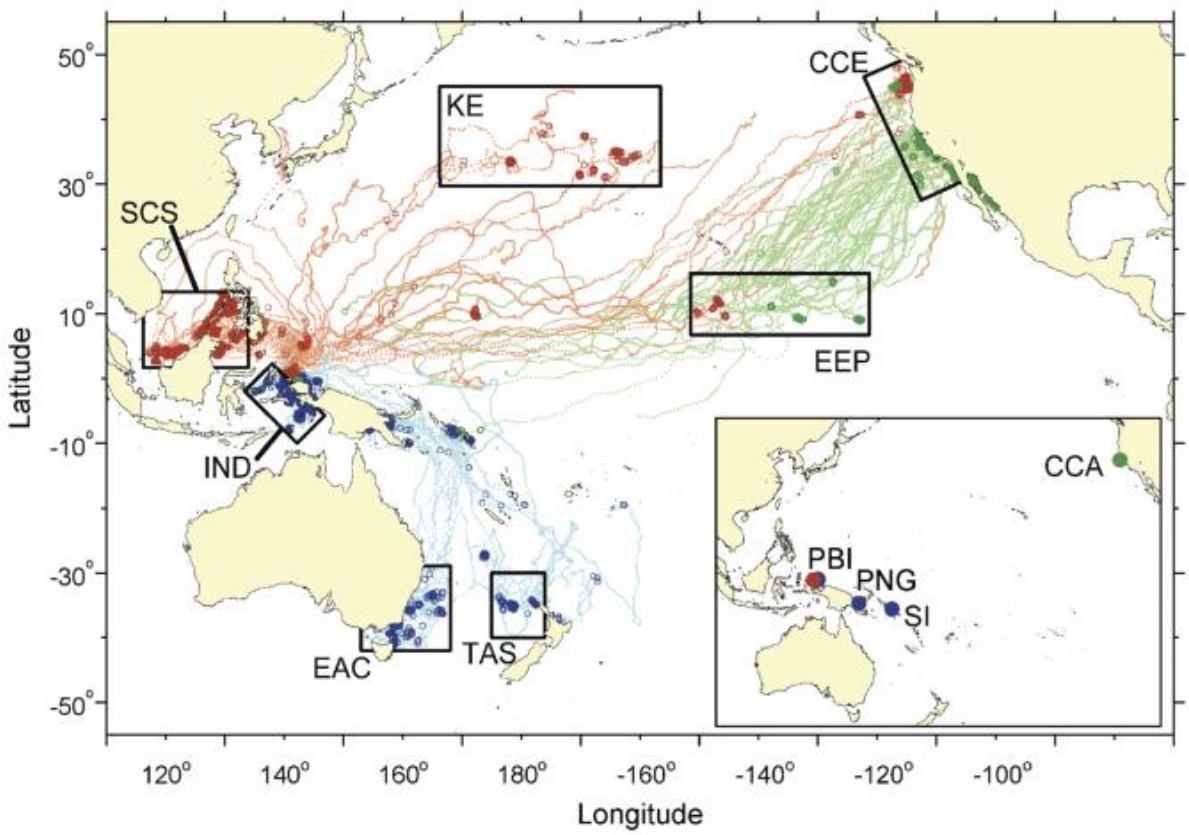


Figure 10. Satellite tracks from 126 West Pacific leatherbacks. Color of track indicates deployment season: red = summer nesters, blue = winter nesters, green = deployments at central California foraging grounds. Inset shows deployment locations; PBI = Papua Barat, Indonesia, PNG = Papua New Guinea, SI = Solomon Islands, CCA = central California. Black boxes represent ecoregions for which habitat associations were quantitatively examined: SCS = South China, Sulu and Sulawesi Seas, IND = Indonesian Seas, EAC = East Australia Current Extension, TAS = Tasman Front, KE = Kuroshio Extension, EEP = equatorial eastern Pacific, and CCE = California Current Ecosystem (Benson *et al*. 2011).

Based on the estimates presented in Jones *et al*. (2012) for all Pacific populations, NMFS inferred an estimated West Pacific leatherback total population size (i.e., juveniles and adults) of 250,000 (95 percent confidence interval 97,000 to 535,000) in 2004. Based on the relative change in the estimates derived from Jones *et al*. (2012) and the more recent Martin *et al*., (2020), NMFS estimates the current juvenile and adult population size of the West Pacific leatherback population is around 100,000 sea turtles (95 percent confidence interval 47,000 to 195,000 individuals).

The Western Pacific population exhibits low hatching success and decreasing nesting population trends due to past and current threats, which are likely to further lower abundance and increase the risk of extinction (NMFS and USFWS 2020). The low estimated nesting female abundance of the West Pacific population places it at elevated risk for environmental variation, genetic

complications, demographic stochasticity, negative ecological feedback, and catastrophes (NMFS and USFWS 2020). These processes, working alone or in concert, place small populations at a greater extinction risk than large populations, which are better able to absorb impacts to habitat or losses in individuals (NMFS and USFWS 2020). Low site fidelity, which is characteristic of the species, results in the dispersal of nests among various beaches (NMFS and USFWS 2020). This may help to reduce population level impacts from threats which may disproportionately affect one area over another, but may also place nests in locations that are likely unmonitored and not protected from human poaching or predation, thereby increasing threats to the population. Due to its small size, this population has restricted capacity to buffer such losses (NMFS and USFWS 2020).

The median trend in annual nest counts estimated for Jamursba Medi nesting beaches from data collected from 2001-2017 was -5.7 percent annually (NMFS and USFWS 2020). The median trend in annual nest counts estimated for Wermon nesting beaches from data collected from 2006 to 2017 (excluding 2013–2015 due to low or insufficient effort) was -2.3 percent annually (NMFS and USFWS 2020). In the absence of population trend data on other leatherback life history stages, we consider these trends in annual nest counts an index of the population's growth rate.

Martin *et al*. (2020) estimated the mean and median time until the West Pacific population declines to 50 percent, 25 percent, and 12.5 percent of its current estimated abundance. Results of this modeling effort indicate that the adult female portion of West Pacific leatherbacks nesting at Jamursba-Medi and Wermon beaches are predicted to decline to 50 percent of their current abundance in a mean of about 13 years (95 percent CI from 5 to 26 years) and to 25 percent of their current abundance in a mean of about 24 years (95 percent CI from 13 to 42 years).

Pacific Population Abundance Relative to the Global Leatherback Population
The greatest genetic divergence within leatherback sea turtles is evident between Atlantic and Indo-Pacific populations (NMFS and USFWS 2020). At least two populations occur within the Pacific Ocean, the West Pacific and the East Pacific, and it has long been considered likely that individuals from the Northeast Indian Ocean population may also occur in the Pacific Ocean. The West Pacific, East Pacific, and Northeast Indian Ocean leatherback populations have all experienced severe and continuing declines. While the West Pacific population is arguably the most robust of the three Pacific populations, our best estimate for the total index of nesting female abundance is only 1,054 females, and at its current rate of decline is predicted to reach half of its current abundance in only 13 years (Martin *et al*., 2020). The Northeast Indian Ocean has exhibited a drastic population decline with the extirpation of its largest nesting aggregation in Terengganu, Malaysia (Tiwari and Wallace, 2013). NMFS and FWS (2020) calculated an index of nesting female abundance, defined as the estimated number of nesting females over one (3-year) remigration interval, for each of the Pacific populations. Based on this index, the Northeast Indian Ocean is the smallest of the three populations, with an estimated total index of nesting female abundance of 109 females. The minimum estimated total index of nesting female abundance for the East Pacific population is 755 females. Pacific leatherback recovery is defined, in part, when each population (stock) averages 5,000 females nesting annually over 6 years, and all nesting populations are either stable or increasing over a 25-year monitoring period

(NMFS and USFWS, 1998). The Pacific populations are not on a trajectory to meet these, or other relevant recovery criteria.

The conservation biology principles of resiliency, redundancy, and representation (collectively known as the "3Rs") can be used as a lens for evaluating the current and future status of a species based on an assessment of its reproductive potential, numbers, and distribution. Resiliency describes the ability of the species to withstand stochastic disturbance events, which is associated with population size, growth rate, and habitat quality. Redundancy describes the ability of a species to withstand catastrophic events, which is related to the number, distribution, and resilience of populations. Representation describes the ability of a species to adapt to changing environmental conditions, which is related to distribution within the species' ecological settings. The spatial distribution of a species' populations determines, among other things, whether the same natural and anthropogenic stressors affect all of a species' populations, or whether some populations occur in protected areas or are at least protected from stressors that affect other populations. Changes in the spatial distribution of the populations (or subpopulations) that comprise a globally-listed entity are also important indicators of the species' status and health, as they provide insight into how the species is responding to long-term changes in its environment (for example, to climate change).

Based on the best available information presented above, the Pacific leatherback population is characterized by low resiliency and redundancy. With low abundance estimates in all countries where the species nests in both the Western Pacific and Eastern Pacific, leatherback sea turtles are at an extremely high risk of being extirpated from the Pacific Ocean. While leatherback abundance estimates are higher for other portions of its global range (e.g., Northwest Atlantic), all seven leatherback populations are currently at a high risk of extinction (NMFS and USFWS 2020).

2.2.2 Status of the Critical Habitat

This section describes the status of designated critical habitat affected by the proposed action by examining the condition and trends of the essential physical and biological features of that habitat throughout the designated areas. These features are essential to the conservation of the ESA-listed species because they support one or more of the species' life stages (e.g., sites with conditions that support spawning, rearing, migration and foraging).

For most salmon and steelhead, NMFS's critical habitat analytical review teams (CHARTs) ranked watersheds within designated critical habitat at the scale of the fifth-field hydrologic unit code (HUC5) in terms of the conservation value they provide to each ESA-listed species that they support (NMFS 2005). The conservation rankings were high, medium, or low. To determine the conservation value of each watershed to species viability, the CHARTs evaluated the quantity and quality of habitat features, the relationship of the area compared to other areas within the species' range, and the significance to the species of the population occupying that area. Even if a location had poor habitat quality, it could be ranked with a high conservation value if it were essential due to factors such as limited availability, a unique contribution of the population it served, or is serving another important role.

For southern DPS green sturgeon, a team similar to the CHARTs — a critical habitat review team (CHRT) — identified and analyzed the conservation value of particular areas occupied by southern green sturgeon, and unoccupied areas necessary to ensure the conservation of the species. The CHRT did not identify those particular areas using HUC nomenclature, but did provide geographic place names for those areas, including the names of freshwater rivers, the bypasses, the Sacramento-San Joaquin Delta, coastal bays and estuaries, and coastal marine areas (within 110 m depth) extending from the California/Mexico border north to Monterey Bay, California, and from the Alaska/Canada border northwest to the Bering Strait; and certain coastal bays and estuaries in California, Oregon, and Washington.

For southern DPS eulachon, critical habitat includes portions of 16 rivers and streams in California, Oregon, and Washington (USDC 2011). We designated all of these areas as migration and spawning habitat for this species.

A summary of the status of critical habitats, considered in this opinion, is provided in Table 3, below.

Table 3. Critical habitat, designation date, federal register citation, and status summary for critical habitat considered in this opinion.

Species	Designation Date and Federal Register Citation	Critical Habitat Status Summary
Lower Columbia River Chinook salmon	9/02/05 70 FR 52630	Critical habitat encompasses 10 subbasins in Oregon and Washington containing 47 occupied watersheds, as well as the lower Columbia River rearing/migration corridor. Most HUC5 watersheds with PCEs for salmon are in fair-to-poor or fair-to-good condition (NMFS 2005). However, most of these watersheds have some, or high potential for improvement. We rated conservation value of HUC5 watersheds as high for 30 watersheds, medium for 13 watersheds, and low for four watersheds.
Upper Columbia River spring-run Chinook salmon	9/02/05 70 FR 52630	Critical habitat encompasses four subbasins in Washington containing 15 occupied watersheds, as well as the Columbia River rearing/migration corridor. Most HUC5 watersheds with PCEs for salmon are in fair-to-poor or fair-to-good condition. However, most of these watersheds have some, or high, potential for improvement. We rated conservation value of HUC5 watersheds as high for 10 watersheds, and medium for five watersheds. Migratory habitat quality in this area has been severely affected by the development and operation of the dams and reservoirs of the Federal Columbia River Power System.
Snake River spring/summer-run Chinook salmon	10/25/99 64 FR 57399	Critical habitat consists of river reaches of the Columbia, Snake, and Salmon rivers, and all tributaries of the Snake and Salmon rivers (except the Clearwater River) presently or historically accessible to this ESU (except reaches above impassable natural falls and Hells Canyon Dam). Habitat quality in tributary streams varies from excellent in wilderness and roadless areas, to poor in areas subject to heavy agricultural and urban development (Wissmar *et al*. 1994). Reduced summer stream flows, impaired water quality, and reduced habitat complexity are common problems. Migratory habitat quality in this area has been severely affected by the development and operation of the dams and reservoirs of the Federal Columbia River Power System.
Upper Willamette River Chinook salmon	9/02/05 70 FR 52630	Critical habitat encompasses 10 subbasins in Oregon containing 56 occupied watersheds, as well as the lower Willamette/Columbia River rearing/migration corridor. Most HUC5 watersheds with PCEs for salmon are in fair-to-poor or fair-to-good condition. However, most of these watersheds have some, or high, potential for improvement. Watersheds are in good to excellent condition with no potential for improvement only in the upper McKenzie River and its tributaries (NMFS 2005). We rated conservation value of HUC5 watersheds as high for 22 watersheds, medium for 16 watersheds, and low for 18 watersheds.
Snake River fall-run Chinook salmon	10/25/99 64 FR 57399	Critical habitat consists of river reaches of the Columbia, Snake, and Salmon rivers, and all tributaries of the Snake and Salmon rivers presently or historically accessible to this ESU (except reaches above impassable natural falls, and Dworshak and Hells Canyon dams). Habitat quality in tributary streams varies from excellent in wilderness and roadless areas, to poor in areas subject to heavy agricultural and urban development (Wissmar *et al*. 1994). Reduced summer stream flows, impaired water quality, and reduced habitat complexity are common problems. Migratory habitat quality in this area has been severely affected by the development and operation of the dams and reservoirs of the Federal Columbia River Power System.

Species	Designation Date and Federal Register Citation	Critical Habitat Status Summary
Columbia River chum salmon	9/02/05 70 FR 52630	Critical habitat encompasses six subbasins in Oregon and Washington containing 19 occupied watersheds, as well as the lower Columbia River rearing/migration corridor. Most HUC5 watersheds with PCEs for salmon are in fair-to-poor or fair-to-good condition (NMFS 2005). However, most of these watersheds have some or a high potential for improvement. We rated conservation value of HUC5 watersheds as high for 16 watersheds, and medium for three watersheds.
Lower Columbia River coho salmon	2/24/16 81 FR 9252	Critical habitat encompasses 10 subbasins in Oregon and Washington containing 55 occupied watersheds, as well as the lower Columbia River and estuary rearing/migration corridor. Most HUC5 watersheds with PCEs for salmon are in fair-to-poor or fair-to-good condition (NMFS 2005). However, most of these watersheds have some or a high potential for improvement. We rated conservation value of HUC5 watersheds as high for 34 watersheds, medium for 18 watersheds, and low for three watersheds.
Snake River sockeye salmon	10/25/99 64 FR 57399	Critical habitat consists of river reaches of the Columbia, Snake, and Salmon rivers; Alturas Lake Creek; Valley Creek; and Stanley, Redfish, Yellow Belly, Pettit and Alturas lakes (including their inlet and outlet creeks). Water quality in all five lakes generally is adequate for juvenile sockeye salmon, although zooplankton numbers vary considerably. Some reaches of the Salmon River and tributaries exhibit temporary elevated water temperatures and sediment loads that could restrict sockeye salmon production and survival (NMFS 2015b). Migratory habitat quality in this area has been severely affected by the development and operation of the dams and reservoirs of the Federal Columbia River Power System.
Upper Columbia River steelhead	9/02/05 70 FR 52630	Critical habitat encompasses 10 subbasins in Washington containing 31 occupied watersheds, as well as the Columbia River rearing/migration corridor. Most HUC5 watersheds with PCEs for salmon are in fair-to-poor or fair-to-good condition (NMFS 2005). However, most of these watersheds have some or a high potential for improvement. We rated conservation value of HUC5 watersheds as high for 20 watersheds, medium for eight watersheds, and low for three watersheds.
Lower Columbia River steelhead	9/02/05 70 FR 52630	Critical habitat encompasses nine subbasins in Oregon and Washington containing 41 occupied watersheds, as well as the lower Columbia River rearing/migration corridor. Most HUC5 watersheds with PCEs for salmon are in fair-to-poor or fair-to-good condition (NMFS 2005). However, most of these watersheds have some or a high potential for improvement. We rated conservation value of HUC5 watersheds as high for 28 watersheds, medium for 11 watersheds, and low for two watersheds.
Upper Willamette River steelhead	9/02/05 70 FR 52630	Critical habitat encompasses seven subbasins in Oregon containing 34 occupied watersheds, as well as the lower Willamette/Columbia River rearing/migration corridor. Most HUC5 watersheds with PCEs for salmon are in fair-to-poor or fair-to-good condition (NMFS 2005). However, most of these watersheds have some or a high potential for improvement. Watersheds are in good to excellent condition with no potential for improvement only in the upper McKenzie River and its tributaries (NMFS 2005). We rated conservation value of HUC5 watersheds as high for 25 watersheds, medium for 6 watersheds, and low for 3 watersheds.

Species	Designation Date and Federal Register Citation	Critical Habitat Status Summary
Middle Columbia River steelhead	9/02/05 70 FR 52630	Critical habitat encompasses 15 subbasins in Oregon and Washington containing 111 occupied watersheds, as well as the Columbia River rearing/migration corridor. Most HUC5 watersheds with PCEs for salmon are in fair-to-poor or fair-to-good condition (NMFS 2005). However, most of these watersheds have some or a high potential for improvement. We rated conservation value of occupied HUC5 watersheds as high for 80 watersheds, medium for 24 watersheds, and low for 9 watersheds.
Snake River basin steelhead	9/02/05 70 FR 52630	Critical habitat encompasses 25 subbasins in Oregon, Washington, and Idaho. Habitat quality in tributary streams varies from excellent in wilderness and roadless areas, to poor in areas subject to heavy agricultural and urban development (Wissmar *et al*. 1994). Reduced summer stream flows, impaired water quality, and reduced habitat complexity are common problems. Migratory habitat quality in this area has been severely affected by the development and operation of the dams and reservoirs of the Federal Columbia River Power System.
Southern DPS of green sturgeon	10/09/09 74 FR 52300	Critical habitat has been designated in coastal U.S. marine waters within 60 fathoms depth from Monterey Bay, California (including Monterey Bay), north to Cape Flattery, Washington, including the Strait of Juan de Fuca, Washington, to its United States boundary; the Sacramento River, lower Feather River, and lower Yuba River in California; the Sacramento-San Joaquin Delta and Suisun, San Pablo, and San Francisco bays in California; tidally influenced areas of the Columbia River estuary from the mouth upstream to river mile 46; and certain coastal bays and estuaries in California (Humboldt Bay), Oregon (Coos Bay, Winchester Bay, Yaquina Bay, and Nehalem Bay), and Washington (Willapa Bay and Grays Harbor), including, but not limited to, areas upstream to the head of tide in various streams that drain into the bays. Several activities threaten the PBFs in coastal bays and estuaries and need special management considerations or protection. The application of pesticides, activities that disturb bottom substrates/ adversely affect prey resources/ degrade water quality through re-suspension of contaminated sediments, commercial shipping and activities that discharge contaminants and result in bioaccumulation of contaminants in green sturgeon; disposal of dredged materials that bury prey resources; and bottom trawl fisheries that disturb the bottom/prey resources for green sturgeon.
Southern DPS of eulachon	10/20/11 76 FR 65324	Critical habitat for eulachon includes portions of 16 rivers and streams in California, Oregon, and Washington. All of these areas are designated as migration and spawning habitat for this species. In Oregon, we designated 24.2 miles of the lower Umpqua River, 12.4 miles of the lower Sandy River, and 0.2 miles of Tenmile Creek. We also designated the mainstem Columbia River from the mouth to the base of Bonneville Dam, a distance of 143.2 miles. Dams and water diversions are moderate threats to eulachon in the Columbia and Klamath rivers where hydropower generation and flood control are major activities. Degraded water quality is common in some areas occupied by southern DPS eulachon. In the Columbia and Klamath river basins, large-scale impoundment of water has increased winter water temperatures, potentially altering the water temperature during eulachon spawning periods. Numerous chemical contaminants are also present in spawning rivers, but the exact effect these compounds have on spawning and egg development is unknown. Dredging is a low to moderate threat to eulachon in the Columbia River. Dredging during eulachon spawning would be particularly detrimental.

Species	Designation Date and Federal Register Citation	Critical Habitat Status Summary
Southern resident killer whale	08/02/21 86 FR 41668	Critical habitat includes approximately 2,560 square miles of marine inland waters of Washington: 1) the Summer Core Area in Haro Strait and waters around the San Juan Islands; 2) Puget Sound; and 3) the Strait of Juan de Fuca. Six additional areas include 15,910 square miles of marine waters between the 20-feet (ft) (6.1-meter (m)) depth contour and the 656.2-ft (200-m) depth contour from the U.S. international border with Canada south to Point Sur, California. We have excluded the Quinault Range Site. Based on the natural history of the Southern Residents and their habitat needs, NMFS identified three PCEs, or physical or biological features, essential for the conservation of Southern Residents: 1) Water quality to support growth and development; 2) prey species of sufficient quantity, quality, and availability to support individual growth, reproduction and development, as well as overall population growth; and 3) passage conditions to allow for migration, resting, and foraging Water quality in Puget Sound, in general, is degraded. Some pollutants in Puget Sound persist and build up in marine organisms including Southern Residents and their prey resources, despite bans in the 1970s of some harmful substances and cleanup efforts. The primary concern for direct effects on whales from water quality is oil spills, although oil spills can also have long-lasting impacts on other habitat features In regards to passage, human activities can interfere with movements of the whales and impact their passage. In particular, vessels may present obstacles to whales' passage, causing the whales to swim further and change direction more often, which can increase energy expenditure for whales and impacts foraging behavior. Reduced prey abundance, particularly Chinook salmon, is also a concern for critical habitat.
Central America DPS Humpback Whales	4/21/2021 86 FR21082	Specific areas designated as occupied critical habitat for the Central America DPS of humpback whales contain approximately 48,521 nmi^2 of marine habitat in the North Pacific Ocean within the portions of the California Current Ecosystem off the coasts of Washington, Oregon, and California. The nearshore boundary is defined by the 50-m isobath, and the offshore boundary is defined by the 1,200-m isobath relative to MLLW. The Columbia River Area was rated with medium/low conservation value. The PBF for this species is prey species of sufficient quality, abundance, and accessibility to support feeding and population growth.
Mexico DPS Humpback Whales	4/21/2021 86 FR21082	Specific areas designated as critical habitat for the Mexico DPS of humpback whales contain approximately 116,098 nmi^2 of marine habitat in the North Pacific Ocean, including areas within portions of the eastern Bering Sea, Gulf of Alaska, and California Current Ecosystem. The PBF for this species is The PBF for this species is prey species of sufficient quality, abundance, and accessibility to support feeding and population growth.

Status of Designated Critical Habitat for Leatherback Sea Turtles

On January 26, 2012, NMFS issued a final rule to revise the critical habitat for the leatherback sea turtle by designating areas within the Pacific Ocean (77 FR 4169; effective February 27, 2012). Previous critical habitat for this species was limited to the island of St. Croix, U.S. Virgin Island for the Northwest Atlantic leatherback population. The critical habitat designation for Pacific leatherbacks includes approximately 16,910 mi^2 (43,798 km^2) stretching along the California coast from Point Arena to Point Arguello east of the 3,000 meters depth contour; and 25,004 mi^2 (64,760 km^2) stretching from Cape Flattery, Washington to Cape Blanco, Oregon east of the 2,000 meters depth contour (Figure 11).

The leatherback sea turtle Critical Habitat Review Team identified one essential physical and biological feature (PBF) that is essential for the conservation of leatherbacks in marine waters of the U.S. West Coast: The occurrence of prey species, primarily *scyphomedusae* of the order *Semaeostomeae* (e.g., *Chrysaora, Aurelia, Phacellophora, and Cyanea*), of sufficient condition, distribution, diversity, abundance and density necessary to support individual as well as population growth, reproduction, and development of leatherbacks.

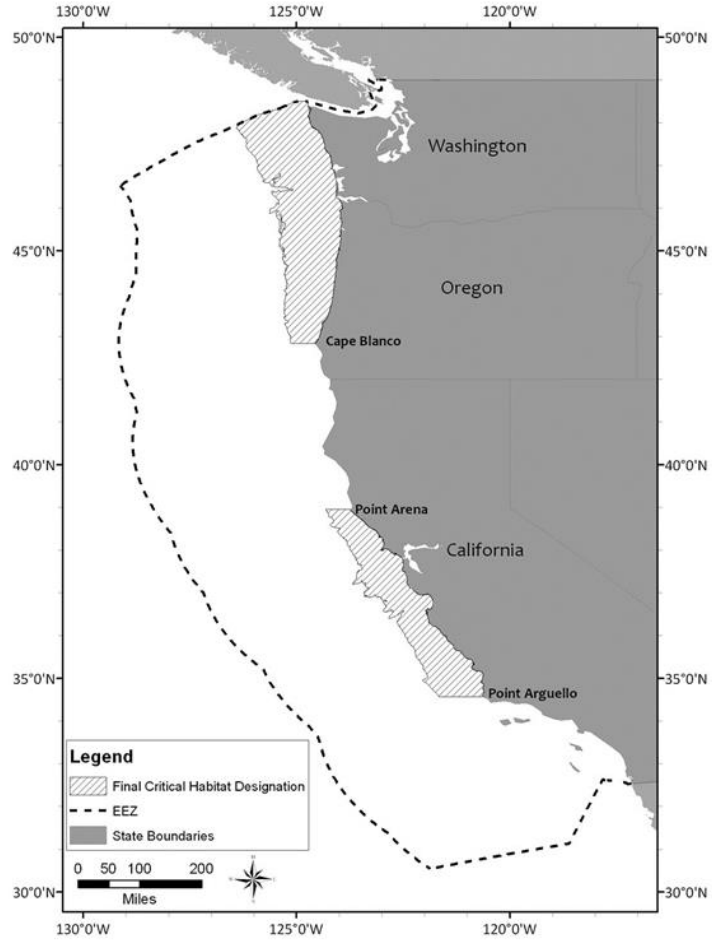


Figure 11. Leatherback sea turtle designated critical habitat along the Pacific Coast.

2.3. Action Area

"Action area" means all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action (50 CFR 402.02).

For this consultation, the action area encompasses the facility, including the activities associated with construction and operation of the proposed facility and management of the associated stormwater, and the restoration site of approximately 466 acres located 0.25 miles south of the facility parcel.

The action area also includes the Columbia River starting at the Port Westward Industrial Park outfall in the Bradbury Slough side channel and the Clatskanine River starting at the McLean Slough confluence. It extends downstream, through the mouth of the Columbia River and into the Pacific Ocean, where it expands into a fan shape as defined by OGV travel routes, until it reaches the continental shelf approximately 40 nautical miles offshore. The northern border of this fan is N 46° 57′, W 125° 18′ and the southern border is N 45° 01′, W 125° 18′ (approximately 117 nautical miles) (Figure 12). Within this fan area, encounters, including vessel collisions and impact from ship noise, are reasonably certain to occur between OGVs and marine mammals and leatherback sea turtles. Although the OGVs that travel through this area are likely to continue along the West Coast of the United States and Canada, their exact destinations and routes are not known at this time and the density of marine mammals and leatherback sea turtles is substantially lower beyond the continental shelf. Beyond this area in the Pacific Ocean, the risk of a ship strike with a marine mammal or sea turtle becomes unlikely. Therefore, this action area delimits the geographic location where the proposed action is likely to result in effects on listed species and critical habitat.

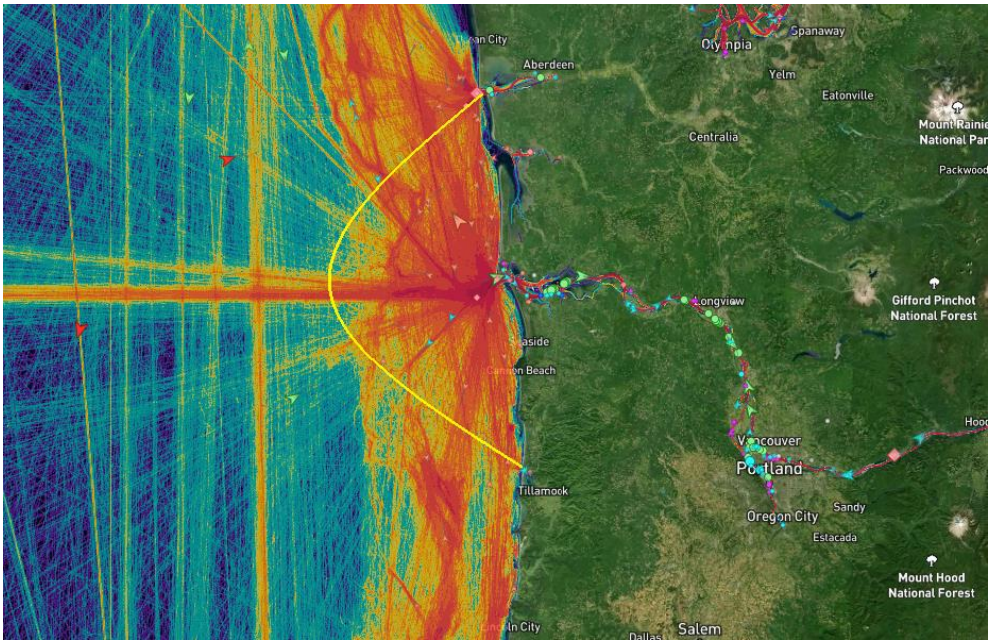


Figure 12. Approximate Pacific Ocean portion of the action area for OGV traffic from NEXT (Data/Image from www.marinetraffic.com, Feb. 27, 2025).

2.4. Environmental Baseline

The "environmental baseline" refers to the condition of the listed species or their designated critical habitat in the action area, without the consequences to the listed species or designated critical habitat caused by the proposed action. The environmental baseline includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultations, and the impact of State or private actions which are contemporaneous with the consultation in process. The consequences to listed species or designated critical habitat from ongoing agency activities or existing agency facilities that are not within the agency's discretion to modify are part of the environmental baseline (50 CFR 402.02).

The Columbia River is the largest river system in the Pacific Northwest, originating in the Canadian Rockies at Columbia Lake and flowing 1,253 miles downstream to its confluence with the Pacific Ocean. In all, the Columbia River drains an area of 258,000 square miles. Discharges range between 80,000 cubic feet per second (cfs) and 400,000 cfs seasonally, with higher flow pulses occurring in the spring and lower flow periods between July and October (USGS 2024). The flow regime of the mainstem Columbia River has been significantly altered by dams and flow control structures that divert water for hydropower, flood control, irrigation, and transportation. 40 percent of all U.S. hydropower is derived from the Columbia and Snake Rivers, and the Columbia River is used to irrigate more than 6 million acres of agricultural land (LCREP 2023).

On the mainstem of the Columbia River, hydropower projects including the Federal Columbia River Hydropower System (FCRPS) have significantly degraded salmon and steelhead habitats (Bottom *et al*. 2005; Fresh *et al*. 2005; NMFS 2011; NMFS 2013; NMFS 2020c). The series of dams and reservoirs that make up the FCRPS block an estimated 12 million cubic yards of debris and sediment that would otherwise naturally flow down the Columbia River and replenish shorelines along the Washington and Oregon coasts. Hydroelectric development modified natural flow regimes, resulting in higher water temperatures, changes in fish community structure leading to increased rates of piscivorous and avian predation on juvenile salmon and steelhead, and delayed migration for both adult and juvenile salmonids. Physical features of dams such as turbines also kill migrating fish. In-river survival is inversely related to the number of hydropower projects encountered by emigrating juvenile fish.

The Columbia River Estuary extends from the mouth of the river to its furthest extent of tidal influence at the Bonneville Dam (RM 146). The estuary includes three physiographic subsystems based on salinity: the euryhaline region, which is subject to large fluctuations in salinity, extending from the mouth of the river to RM 18, the brackish mixing zone between RM 18 and RM 34, and the tidal freshwater zone between RM 34 and RM 146 (Weitkamp *et al*. 2014; Bottom *et al*. 2005). The flow regimes, physical composition, and sediment input of each of these zones have been significantly altered by upriver activities over the last 150 years, resulting in degraded conditions for fish (Bottom *et al*. 2005). These impacts have been particularly harmful for juvenile emigrating salmon. While historical Columbia River salmon returns averaged between 11 and 16 million annually (with a much larger number of juveniles

emigrating), these rates have declined to less than 12% of predevelopment levels (Bottom *et al*. 2005).

The Federal Navigation Channel and adjacent Port berths have been subject to over a century of channel deepening activities to facilitate vessel traffic. In this time, the depth of the river has doubled, altering the hydrologic regime within the reach and reducing the complexity of the river system (Helaire *et al*. 2019). Industrial harbor and port development are also significant influences on the Lower Willamette and Lower Columbia rivers (Bottom *et al*. 2005; Fresh *et al*. 2005; NMFS 2011; NMFS 2013).

The most extensive urban development in the LCR subbasin has occurred in the Portland/Vancouver area. Along the western bank of the Columbia River, the City of Portland has constructed 45 miles of levees, cutting off the river from its floodplain and channelizing flow. These activities, along with the upstream dam operations, have reduced productivity and foraging habitat for salmonids as well as the distribution of sediment and nutrients from floodplain habitat. Habitat complexity is a key factor related to the success of species after floods (Pearsons *et al*. 1992). The extensive levee system in the LCR inhibits habitat forming processes, thereby reducing the availability of rearing habitat and forage opportunities for salmonids.

Virtually the entire LCR channel and riparian zone has been degraded by the effects of forest management, agriculture, mining, transportation, and urbanization, as well as the use of LCR water for hydropower, consumption, irrigation, heat transfer, transportation and recreation. These economic activities contribute to; degraded water quality, changes in channel morphology, reduced instream roughness and cover, degraded riparian functions, and lost estuarine rearing habitats such as wetlands, and floodplains. Climate change is likely to play an increasingly important role in determining the fate of ESA-listed species and the conservation value of their designated critical habitats in the LCR as described in Section 2.2.

Birds, other fish and marine mammals prey on juvenile or adult salmon in the Columbia River. Caspian terns, double-crested cormorants, glaucous-winged/western gull hybrids, California gulls, and ring-billed gulls are the main avian predators. Avian predators congregate near hydroelectric dams and nest in the LCR on islands made from dredged sediment and other man-made structures. They benefit from dams and reservoirs because low flow velocity increases smolt migration time and suspended sediment deposition in reservoirs reduces turbidity below the dam. Smolt bypass systems in dams concentrate fish at the bypass entry points making them easier for avian predators to catch. The Columbia River Basin also has native and introduced fish species that prey on salmon and steelhead. The primary piscine predators of salmonids are northern pikeminnow (native), smallmouth bass (introduced), and walleye (introduced). Other predatory resident fish are channel catfish (introduced), yellow perch (introduced), largemouth bass (introduced), and bull trout (native). Seals and sea lions have learned to hunt returning adult salmon and steelhead in the LCR, especially in the constricted passages past Bonneville Dam and Willamette Falls.

The environmental baseline includes the anticipated impacts of all Federal actions in the action area that have already undergone formal consultation. The USACE, Bonneville Power Administration (BPA), and Bureau of Reclamation have consulted on large water management

actions, such as operation of the Federal Columbia River Power System, the Umatilla Basin Project, and the Deschutes Project. The U.S. Bureau of Indian Affairs (BIA), U.S. Bureau of Land Management, and the U.S. Forest Service (USFS) have consulted on Federal land management throughout Oregon and Washington, including restoration actions, forest management, livestock grazing, and special use permits. The BPA, NOAA Restoration Center, and USFWS have also consulted on large restoration programs that consist of actions designed to address species limiting factors or make contributions that would aid in species recovery.

The project area is on Columbia River floodplain that has been converted to uplands by system of levees (Figure 13). About 10,000 linear feet of waterways operated and maintained by the Beaver Drainage Improvement Company drain floodwater and supply irrigation water to farms. These waterways drain south through McLean Slough and Beaver Slough for approximately six miles to a pump station near the Clatskanie River that discharges water back over the levee. Pump-station floats have a summertime setting of 8.5 feet below sea level, and wintertime setting of 6.5 feet below sea level. Any water surface above these elevations triggers the three pumps to turn on at the pump station.

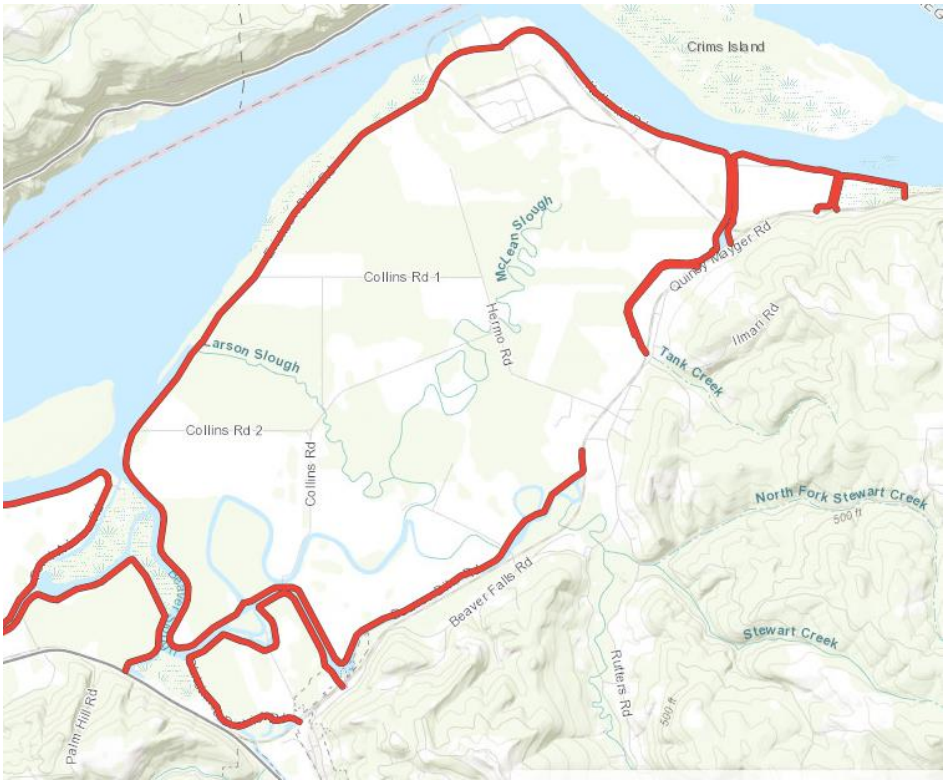


Figure 13. Levees around the Port Westward Industrial Park.

Baseline effects in the action area

Water withdrawal

Port Westward has an Oregon Water Resources Department (OWRD) water right for 30 cubic feet per second (13,465 gpm) at their Columbia River intake. The intake is a Cook Legacy Intake System that has a 21-Inch tee screen with an AirBurst system. The system works together

to allow withdrawal of up to 4,000 gpm per screen at a mean approach velocity of 0.27 feet per second. In 2012, NMFS issued a biological opinion concluding the construction of this water withdrawal and its future operation were not likely to jeopardize the continued existence of any listed species nor adversely modify their critical habitat. The NEXT proposal will not withdraw additional water than that analyzed in the 2012 opinion. As such, the impacts from the withdrawal are part of the environmental baseline for this consultation (NMFS Reference Number NWR 2012-00566).

Contaminants and Temperature

Port Westward has an NPDES permitted (permit number 111746) outfall in the Columbia River that sets discharge limits on pH, excess heat and the concentrations of residual chlorine, free available chlorine, total chromium, total zinc, total suspended solids and oil and grease. The length of the permitted mixing zone is 30 meters. The permit requires that effluent discharged at 27 °C (80.6°F) be cooled to 20 °C (68°F) at the edge of the mixing zone. We've followed the analysis for buoyant jets in Fischer (1979) using temperature as a tracer to estimate that the outfall mixing zone dilution factor is greater than 30 (see Appendix 1).

There are no existing stormwater treatment facilities along Port Westward Industrial Park roadways or railroads but the waterways throughout Port property are slow-flowing and provide some infiltration and runoff treatment from contaminants partitioning to bottom sediments and bank soils. Background stormwater and wastewater contaminant concentrations at Port Westward are in Morace (2006). Columbia River water quality conditions (turbidity, pH, and dissolved oxygen) at the Port Westward are generally within the range needed to support aquatic life but two areas on the Columbia River, upstream from the project site (one at RM 71.9 and one at RM 74) are listed for temperature exceedances. Data published by the U.S. Geological Survey in 2012 indicate that summer water temperatures downstream of Bonneville Dam routinely exceed 70°F.

OGV wake waves and other effects

The action area captures all OGV traffic heading for or leaving the Port Westward facility. From 2013 through 2022 there was an average of 1,376 vessel calls per year at all Columbia River ports. Between 2015 and 2021, Port Westward received a total of 94 ocean going tankers and 17 articulated tug barges, an average of 15.6 ships per year. The main destination of export vessels are California and Washington. The largest percentage of the vessel types that travel in the Columbia River are bulk carriers carrying grain, automobiles, petroleum and soda ash. Barges are the second most common vessel using the Columbia River. Smaller vessels that supply feedstocks are 250 to 450 feet long, 75 to 85 feet wide, and have a draft of 28 to 40 feet when fully loaded and a draft of 15 to 20 feet when empty. The average speed of smaller vessels is 14.4 knots in the ocean and 10.7 knots on the Columbia River. The States of Washington and Oregon require ballast water to be exchanged at sea or treated to eliminate living organisms prior to discharge. In addition, NMFS developed a biological opinion addressing the USCG's national ballast water management program and initial numerical standard. NMFS found that the discharge of ballast water using the initial numerical standard in not likely to jeopardize the continued existence of endangered or threatened species in the Columbia River (NMFS 2012).

Long period wake waves from OGVs strand juvenile salmon on low slope beaches of the Columbia River (Bauersfeld 1977, Hinton and Emmett 1994, Ackerman 2002, Pearson *et al.*, 2006). Wake wave stranding occurs every year, mostly during spring months when juvenile salmonids are at their highest density in the LCR. The Wapato Conservation Bank monitored wake wave stranding at the mouth of the Lewis River (Columbia River mile 87) and documented wake stranding of ESA-listed salmonids from both OGVs and smaller watercraft. Pearson *et al*. (2006) found that wake wave stranding is a function of: beach slope, shielding, and distance from the shipping lane; tide stage and amplitude; river flow and velocity; vessel type, size, direction, speed, and load; and fish density. They observed that ships moving slower than 8 nautical miles per hour did not cause wake stranding. Juveniles of every population of every ESA-listed Snake River, Willamette River and Columbia River salmon and steelhead ESU/DPS will be exposed to wake/wave stranding from OGVs in the Lower Columbia River moving to and from Port Westward. Ocean-type life history Chinook, and chum salmon, subyearlings that migrate in shallow water along the shoreline, are most vulnerable to being stranded by OGV wake waves. Pearson *et al*. (2006) also monitored fish wake stranding from 126 deep-draft OGVs at three Lower Columbia River 'sentinel' beaches, Sauvie Island, Barlow Point and County Line Park, in the summer of 2004 and the winter and spring of 2005. Wake wave stranding occurred at all three sites over all three seasons, ranging from a low of 15 percent of OGVs at Sauvie Island to a high of 53 percent of OGVs at Barlow Point. Fifteen percent of OGVs passing County Line Park in the winter, spring or summer stranded an average of 7.3 fish per pass. Pearson and Skalski (2011) conducted a GIS search for beaches that might be susceptible to wake wave stranding based on channel confinement, beach distance from the navigation channel, beach shielding features, beach slope, submerged berms in the navigational channel, and fine scale beach features. They determined that stranding is likely or highly likely at about 33 miles of the 208 miles (104 Washington miles and 104 Oregon miles) of shoreline they analyzed.

Marine mammal and turtle collisions

The action area overlaps humpback whale and leatherback sea turtle designated critical habitat. Blue whales, sei whales, fin whales, and sperm whales also migrate through and forage in the action area every year. Collisions with commercial ships are a threat to marine mammals and turtles where shipping lanes cross breeding and feeding habitats and migratory routes. Between 2013 and 2022, an average of 1376 ocean going vessels (OGVs (cargo and passenger vessels 300 gross tons or larger, tankers, tank barges and articulated tug barges)) entered the Columbia River with a standard deviation of 70 OGVs (Table 4).

Table 4. OGVs entering the Columbia River from 2013 to 2022 (WDOE, 2022).

Year	2022	2021	2020	2019	2018	2017	2016	2015	2014	2013
Cargo & Passenger Washington	721	787	764	751	795	734	805	744	762	673
C&P Oregon	525	521	473	436	524	505	496	447	612	620
Tanker Washington	4	11	5	15	30	30	40	42	38	32
Tanker Oregon	73	54	57	62	60	21	32	35	33	31
Tanker Barge or Articulated Tug Barge	31	31	27	37	32	31	37	55	81	1
Total	1354	1404	1326	1301	1441	1321	1410	1323	1526	1357
Average	1376									
Standard Deviation	69.5									

The number of confirmed vessel collisions with ESA-listed species in Oregon and Washington from 2000-2018 are: three sperm whale, three humpback whales, and ten fin whales (Marine Mammal Health and Stranding Response Program database[2]). Additional strikes likely occur and go unnoticed and unreported.

Acoustic Disturbance.

Increasing levels of anthropogenic sound in the world's oceans (Andrew *et al*. 2002), such as those produced by shipping traffic, Acoustic Thermometry of Ocean Climate or Low Frequency Active sonar, have been suggested to be a habitat concern for whales, particularly for baleen whales (fin, sei, humpback, and blue) that may communicate using low frequency sound. Based on vocalizations (Richardson *et al*. 1995; Au *et al*. 2006), reactions to sound sources (Lien *et al*. 1993, 1992; Maybaum 1993), humpback whales also appear to be sensitive to mid-frequency sounds, including those used in active sonar military exercises (Reynolds 2007). We do not have specific information about what types of acoustic disturbance is in the action area; however, we expect noise from vessel activities, including shipping, boating associated with commercial and recreational fishing, and Coast Guard operations.

Use of the action area by listed species

ESA-listed salmonids

Despite degraded habitat conditions, ESA-listed species migrate through and rear in the action area. Numerous early life history strategies of Columbia River salmonids have been lost as a result of past management actions such as channel deepening and loss of floodplain habitat connectivity (Bottom *et al*. 2005). In addition to variations in outmigration timing, juvenile ESA-listed species also have a wide horizontal and vertical distribution in the Columbia River related to size and life history stage. Generally speaking, juvenile salmonids would occupy the action

[2] https://www.fisheries.noaa.gov/national/marine-life-distress/marine-mammal-health-and-stranding-response-program

area across the width of the river, and to average depths of up to 35 feet (Carter *et al*., 2009). Smaller-sized fish use the shallow inshore habitats and larger fish would use the channel margins and main channel. The pattern of use generally shifts between day and night. Juvenile salmon occupy different locations within the Columbia River, and are typically in shallower water during the day, avoiding predation by larger fish that are more likely to be in deeper water. These juveniles venture into the deeper areas of the river away from the shoreline, towards the navigation channel and along the bathymetric break (channel margin) and would be closer to the bottom of the channel (Carter *et al*., 2009). The smaller sub-yearling salmonids typically congregate along the nearshore areas in shallow water and extend into the channel margins (Bottom *et al*., 2011). Yet, as Carlson *et al*. (2001) indicated, there is higher use of the channel margins than previously thought. Considering the parameters above, juvenile and subyearling salmonids are likely to be found in shallower waters such as the flushing channel while adult salmonids are more likely to occupy the deep-water berths and Federal Navigation Channel.

The level of exposure of juvenile salmonids would vary depending on the species, life history, location, migration timing, and water depth occupied. Juvenile salmonids migrate in the vicinity of and may rear in the action area during different times of the year. In general, juvenile salmonids are present in the action area year-round, being most abundant from the late winter through the summer, becoming less abundant in the fall (NMFS, 2017b). Juvenile Chinook salmon are present year-round with timing ranging from spring to early fall, although sub-yearlings are present later into the fall (Dawley *et al*., 1986; NMFS, 2017b). Juvenile chum salmon are present from winter to spring. Juvenile coho salmon and steelhead are present year-round with their primary migration timing ranging from spring to mid-summer. Juvenile sockeye salmon are present during mid-spring to late summer.

Eulachon.

Pacific eulachon are anadromous smelt that spawn within the mainstem LCR and its tributaries. Previous studies have documented the highest densities of out-migrating larvae in the Columbia River upstream of the Port at the confluence of the Cowlitz River and Columbia River, however eulachon do spawn upriver in the mainstem channel and in Sandy River (WDFW 2020). Adult eulachon ascend large tributaries of the Columbia River (i.e., Cowlitz, Elochoman, Grays, Kalama, Lewis, Sandy, etc.) during late winter and spring (Gustafson *et al*., 2016). They produce hundreds of millions of eggs with a sticky exterior covering that adheres to the substrate until larvae hatch and are rapidly transported downstream as free-floating drift throughout early spring (Parente & Snyder, 1970; Smith & Saalfeld, 1955). Eulachon larvae rapidly disperse throughout the water column and are widely distributed as they passively drift downstream (Howell & Uusitalo, 2000).

In the Columbia River, eulachon abundance decreased markedly since the 2016 status review NMFS 2022. The decrease in abundance reflects both changes in biological status and changes in ocean conditions. For the years 2011 through 2015, the 5-year SSB mean was 97.9 million spawners. For the years 2016 through 20214, the 6-year SSB mean was 40.2 million spawners. However, the 2021 estimate (96.4 million spawners) was nearly equivalent to the 2011-2015 mean (NMFS 2022).

The eulachon spawning migration typically begins when river temperatures are between 0°C and 10°C, which usually occurs between January and April in the Columbia River. Spring freshets carry larvae to the Columbia River Estuary, and juveniles will disperse onto the continental shelf within the first year of life (Gustafson 2015). Migration of adults into the Columbia River and its tributaries occurs from December through May, with peak abundances and spawning during February and March over sandy substrates in LCR tributaries. Eggs and larvae are present from February until early June, as they drift in currents downstream to the Columbia River Estuary. Common threats to eulachon are described in Table 5.

Table 5. Physical and biological threats to eulachon and their relative level of severity (NMFS 2022h).

Threats	**Level of Severity**
Climate change impacts on ocean conditions	High
Dams / water diversions	Moderate
Eulachon by-catch	High
Climate change impacts on freshwater habitat	Moderate
Predation	Moderate
Water quality	Moderate
Catastrophic events	Low
Disease	Very low
Competition	low
Shoreline construction	Moderate
Tribal fisheries	Very low
Non-indigenous species	Very low
Recreational harvest	low
Commercial harvest	low
Scientific monitoring	Very low
Dredging	Moderate

Green Sturgeon

Green sturgeon utilize the action area during the summer and early fall months and are likely to be present in the action area during project construction and operations (Moser & Lindley, 2007; Moser *et al.*, 2016). Commercial catches of green sturgeon peak in October in the Columbia River estuary, and records from other estuarine fisheries (Willapa Bay and Grays Harbor, Washington) support the conclusion that sturgeon are present in these estuaries from June until October (Moser & Lindley, 2007). Green sturgeon spawn in freshwater portions of southern Oregon and central California rivers, and they spend most of their lives migrating in coastal marine waters and spending time in estuaries from the Sacramento River, California to Alaska. Green sturgeon and their prey are associated with substrates in estuarine and coastal marine environments. Adults and subadults, the only life history stages known in the Columbia River, migrate in the Pacific Ocean and use the Columbia River estuary in the summer and fall months for foraging and to optimize growth (Moser and Lindley 2007). Their presence in the Columbia River typically occurs from June through October. Green sturgeon can live to 60 years old and grow to approximately 256-270 cm.

Leatherback Sea Turtles.

Along the coast of Washington, past and present population status is difficult to quantify, but research using satellite telemetry indicates that the Washington's outer coast (especially the area near the Columbia River plume) is an important foraging area for the species (Benson *et al.* 2011). Leatherback sea turtles regularly occur off the coast of Washington, especially off the mouth of the Columbia River (i.e., within the action area) during the summer and fall when large aggregations of jellyfish form (WDFW 2012). The NMFS Pacific Leatherback Sea Turtle Work Group tracks the total annual authorized incidental take in past biological opinions for inclusion in the Environmental Baseline of new biological opinions. This information is summarized in table 6 below.

Table 6. Summary of annual authorized take of Pacific leatherback sea turtles in NMFS Incidental Take Statements by life stage and type of take (last updated January, 2021).

Life Stage	**Annual Authorized Take (based on rounded up numbers above)**		
	Sublethal (minor injury)	**Sublethal (behavioral harassment or TTS)**	**Dead or serious injury**
Juvenile (includes one juvenile/subadult from HMS Deep-set Longline BiOp)	23	0	27
Subadult/Adult (includes not specified)	310	207	11

Blue Whales

Blue whales are very rare in the action area. The Eastern North Pacific population feeds off California in the summer and fall. Vessel surveys conducted in Washington waters in 1996 and 2001 did not find any blue whales (Carretta *et al*. 2013) however some individuals have been sighted in recent years off the coasts of Oregon and Washington. The Eastern North Pacific population is stable and includes about 1,900 individuals (WDFW 2025).

Sei Whales

Sei whales are rare off the coast of Washington. The Eastern North Pacific population is quite small, including about 500 animals (WDFW 2025). Trends in abundance are unknown.

Fin Whales

Fin whales along the coasts of California, Oregon, and Washington are composed of a single population with about 9,000 individuals. Trends in abundance have increased in recent years (WDFW 2025). They are common off the Washington coast.

Humpback Whales

Humpback whales are common off the Washington coast during summer months. They are highly migratory. The Central America DPS is listed as federally endangered, and the Mexico DPS is federally threatened. Population trends have been increasing.

Sperm Whales

Most of the sperm whales in Washington coastal waters belong to the California/ Oregon/ Washington population, which has approximately 2,000 whales, and slowly increasing in abundance. Sperm whales are most likely to be found in deeper water off the continental shelf.

SRKW

Southern Resident killer whales are common in the action area. Three pods (J,K, and L) make up the Southern Resident DPS. There are 73 SRKW remaining (newly born calves are not counted before they are at least 6 months old due to high calve mortality rates).

Critical habitat in the action area

This section of the environmental baseline examines the designated critical habitat affected by the proposed action by examining the current condition and trends of essential physical and biological features throughout the designated areas. These features are essential to the conservation of the listed species because they support one or more of the species' life stages (e.g., sites with conditions that support spawning, rearing, migration and foraging).

To determine the conservation value of each watershed to species viability, NMFS's critical habitat analytical review teams (CHARTs) evaluated the quantity and quality of habitat features (for example, spawning gravels, wood and water condition, side channels), the relationship of the area compared to other areas within the species' range, and the significance to the species of the population occupying that area (NOAA Fisheries 2005). Thus, even a location that has poor quality of habitat could be ranked with a high conservation value if it were essential due to factors such as limited availability (e.g., one of a very few spawning areas), a unique contribution of the population it served (e.g., a population at the extreme end of geographic distribution), or if it serves another important role (e.g., obligate area for migration to upstream spawning areas).

For each recovery domain, the CHART assessed biological information pertaining to occupied by listed salmon and steelhead, determine whether those areas contained PCEs essential for the conservation of those species and whether unoccupied areas existed within the historical range of the listed salmon and steelhead that are also essential for conservation. A complete review of all primary constituent elements ((PCEs) or physical and biological features (PBFs) and associated scoring for each fifth-field hydrologic unit code (HUC5) is available at NOAA Fisheries (2005). Below, we describe generally describe the environmental baseline for critical habitat in the action area.

On the mainstem of the Columbia River, hydropower projects, including the Federal Columbia River Hydropower System (FCRPS), have significantly degraded salmon and steelhead habitats (Bottom *et al*. 2005, Fresh *et al.* 2005, NMFS 2011, NMFS 2013). The series of dams and reservoirs that make up the FCRPS block an estimated 12 million cubic yards of debris and

sediment that would otherwise naturally flow down the Columbia River and replenish shorelines along the Washington and Oregon coasts.

Industrial harbor and port development are also significant influences on the Lower Willamette and Lower Columbia rivers (Bottom *et al*. 2005, Fresh *et al*. 2005, NMFS 2011, NMFS 2013). Since 1878, 100 miles of river channel within the mainstem Columbia River, its estuary, and Oregon's Willamette River have been dredged as a navigation channel by the USACE. Originally dredged to a 20-foot minimum depth, the Federal navigation channel of the Lower Columbia River is now maintained at a depth of 43 feet and a width of 600 feet. The Lower Columbia River supports five ports on the Washington State side: Kalama, Longview, Skamania County, Woodland, and Vancouver. In addition to loss of riparian habitat, and disruption of benthic habitat due to dredging, high levels of several sediment chemicals — such as arsenic and polycyclic aromatic hydrocarbons — have been identified in Lower Columbia River watersheds in the vicinity of the ports and associated industrial facilities.

The most extensive urban development in the Lower Columbia River subbasin has occurred in the Portland/Vancouver area. Outside of this major urban area, the majority of residences and businesses rely on septic systems. Common water quality issues with urban development and residential septic systems include higher water temperatures, lowered dissolved oxygen, increased fecal coliform bacteria, and increased chemicals associated with pesticides and urban runoff.

The Columbia River estuary has lost a significant amount of the tidal marsh and tidal swamp habitats that are critical to juvenile salmon and steelhead, particularly small or ocean-type species (Bottom *et al*. 2005, Fresh *et al*. 2005, NMFS 2011, NMFS 2013). Edges of marsh areas provide sheltered habitats for juvenile salmon and steelhead where food, in the form of amphipods or other small invertebrates which feed on marsh detritus, is plentiful, and larger predatory fish can be avoided. Historically, floodwaters of the Columbia River inundated the margins and floodplains along the estuary, allowing juvenile salmon and steelhead access to a wide expanse of low-velocity marshland and tidal channel habitats. In general, the riverbanks were gently sloping, with riparian and wetland vegetation at the higher elevations of the river floodplain becoming habitat for salmon and steelhead during flooding river discharges or flood tides. Sherwood *et al*. (1990) estimated that the Columbia River estuary lost 20,000 acres of tidal swamps, 10,000 acres of tidal marshes, and 3,000 acres of tidal flats between 1870 and 1970. This study further estimated an 80 percent reduction in emergent vegetation production and a 15 percent decline in benthic algal production.

Habitat and food-web changes within the estuary, and other factors affecting salmon population structure and life histories, have altered the estuary's capacity to support juvenile salmon (Bottom *et al*. 2005, Fresh *et al*. 2005, NMFS 2011, NMFS 2013). Diking and filling have reduced the tidal prism and eliminated emergent and forested wetlands and floodplain habitats. These changes have likely reduced the estuary's salmon-rearing capacity. Moreover, water and sediment in the Lower Columbia River and its tributaries have toxins that are harmful to aquatic resources (LCREP 2007). Contaminants of concern include dioxins and furans, heavy metals, polychlorinated biphenyls (PCBs) and organochlorine pesticides such as DDT. Simplification of the population structure and life-history diversity of salmon possibly is yet another important

factor affecting juvenile salmon viability. Restoration of estuarine habitats, particularly diked emergent and forested wetlands, reduction of avian predation by terns, and flow manipulations to restore historical flow patterns have likely begun to enhance the estuary's capacity to support salmon, although historical changes in population structure and salmon life histories may prevent salmon from making full use of estuarine habitats.

A team similar to the CHARTs, referred to as a Critical Habitat Review Team (CHRT), identified and analyzed the conservation value of particular areas occupied by southern green sturgeon, and unoccupied areas they felt are necessary to ensure the conservation of the species (USDC 2009). The CHRT identified several activities that threaten the PCEs in coastal bays and estuaries and necessitate the need for special management considerations or protection. The application of pesticides is likely to adversely affect prey resources and water quality within the bays and estuaries, as well as the growth and reproductive health of Southern DPS green sturgeon through bioaccumulation. Other activities of concern include those that disturb bottom substrates, adversely affect prey resources, or degrade water quality through re-suspension of contaminated sediments. Of particular concern are activities that affect prey resources. Prey resources are affected by: commercial shipping and activities generating point source pollution and non-point source pollution that discharge contaminants and result in bioaccumulation of contaminants in green sturgeon; disposal of dredged materials that bury prey resources; and bottom trawl fisheries that disturb the bottom (but result in beneficial or adverse effects on prey resources for green sturgeon). In addition, petroleum spills from commercial shipping and proposed hydrokinetic energy projects are likely to affect water quality or hinder the migration of green sturgeon along the coast (USDC 2009).

2.5. Effects of the Action

Under the ESA, "effects of the action" are all consequences to listed species or critical habitat that are caused by the proposed action, including the consequences of other activities that are caused by the proposed action but that are not part of the action. A consequence is caused by the proposed action if it would not occur but for the proposed action and it is reasonably certain to occur. Effects of the action may occur later in time and may include consequences occurring outside the immediate area involved in the action (see 50 CFR 402.2).

For this consultation, we consider climate change where relevant to status of the species or environmental baseline, but do not consider any potential future impacts from climate change on listed species in the action area to be effects of the action. It is true that greenhouse gasses (GHGs) would be emitted when biofuel or SAF produced under the proposed action are later used.

However, we cannot show a causal connection between such emissions of GHGs and specific localized climate change as it impacts listed species or critical habitat with reasonable certainty for the following reasons:

1. The ultimate fate of the biofuel and SAF developed or produced is unknown. Depending on market conditions, biofuel could be blended with crude oil and refined into gasoline or diesel and burned in automobiles. Also, it could be synthesized into other consumer products including plastics. These products could be used anywhere in the world after

production. Due to this high degree of uncertainty, we cannot identify any specific effect from the burning or processing of these biofuels that is reasonably certain to occur.

2. We cannot make the requisite causal connections between the emissions of greenhouse gasses from the proposed action and specific localized climate change as it impacts the listed species or critical habitat. By some standards, biofuel and SAF production is itself carbon-neutral after considering the sequestration of carbon by plants used in the feedstock.

3. Additionally, even if we assume that all of the biofuel and SAF would be burned to produce energy, and this is a step in a causal chain toward a change in temperature in the area where listed species occur, the magnitude of that effect pathway is likely to be too small to constitute an effect on the listed species or critical habitat. The amount of GHGs produced would be a small fraction of GHGs produced world-wide. Even if it were possible to make such an attribution, the global temperature change attributable to such emissions would be miniscule and we are unable to meaningfully analyze any resulting impacts on ESA-listed species and critical habitat.

2.5.1 Effects on Listed Species

Effects of the proposed action on species are based, in part, on habitat effects as described in detail below. Because no in-water work is proposed, there are no in-water work windows. The proposed action will result in temporary effects from the construction of the facility (i.e., water quality effects from turbidity, vessel noise associated with off-loading equipment, and migration obstruction effects due to vessel presence at the docks) which will affect juvenile salmonids and eulachon; and enduring effects from the ongoing operations of the facility (i.e., water quality effects [waste water and stormwater runoff], wake stranding, and migration obstruction effects). Enduring effects will affect juvenile and adult salmonids, all life stages of eulachon, and adult and sub-adult green sturgeon. Additionally, enduring effects will include effects associated with increased ship traffic to and from the NEXT facility on some marine mammals and turtles as described below.

Short-term Effects

Water Quality

Turbidity

The proposed bio-refinery will result in the development of 122.5 acres, and expose upland soil as a result of construction activities. Despite the use of erosion control measures, including silt fencing, fine sediment delivery to the drainage waterways and ultimately to the Columbia River will increase until soils stabilize. Suspended fine sediment has the potential to harm juvenile fishes, including ESA-listed juvenile salmonids and adult and larval eulachon. The source of elevated turbidity will largely occur with the construction of the drainage ponds and associated waterways. We anticipate that most of the fine sediment suspended in the ponds and waterways will remain there until the ponds require maintenance. However, some suspended sediment will escape the ponds and route to McLean Slough and ultimately, the Columbia River.

Juvenile salmonids and adult eulachon exposed to elevated turbidity would react by moving into deeper water from the shoreline and avoiding the area. Due to juveniles mainly occupying shallow water habitat, the risk of exposure to turbidity is greater for sub-yearlings than yearling salmonids. According to Wilber and Clarke (2001), juveniles exposed to 10–100 milligrams per liter of suspended sediment for 8 hours would experience sub-lethal physiological effects. These effects include reduced feeding and behavioral effects such as startle responses followed by relocation. Elevated levels of suspended sediment also reduce the ability of juvenile salmonids to seek refugia (Korstrom and Birtwell 2006). Given the dispersed area of the constructed ponds and the lengthy catchments for suspended sediment to settle, the expected short duration of suspended sediment expected during construction, and the capacity of the fishes to avoid turbid areas, we expect effects among juvenile salmon and eulachon exposed to turbidity to be minor.

Adult salmonids will typically be in the main river channel at depths of 10 to 20 feet below the water surface and off the bottom (Johnson *et al*. 2005). This suggests that the potential for adults to encounter areas of high suspended sediment is low. Studies show that salmonids are able to detect and distinguish turbidity and other water quality gradients (Bisson and Bilby 1982), and adult salmon have swimming abilities to more easily avoid waters affected by suspended sediment to find refuge and/or passage conditions within unaffected adjacent areas. We anticipate adult salmonids will pass through the action area without experiencing adverse effects due to the brevity of exposure and therefore should not experience reduced fitness.

We anticipate very minor effects to green sturgeon as they are often associated with turbid conditions on the benthos where similar species, Atlantic (*A. oxyrinchus)* and shortnose (*A. brevirostrum)* sturgeon, show little to no obvious turbidity effects (Johnson 2018).

Noise

Noise from ships and barges off-loading equipment in preparation for construction are temporary but would occur periodically until construction is complete (one to two years). This would occur whenever vessels moor or travel from the NEXT facilities to deliver and remove construction related equipment. In response to ship moorage and traffic with such high frequency, fish behaviors will be altered. Nicholes *et al*. (2015) found that boat noise can induce stress responses via increased cortisol concentration in fishes. Behaviors affected include rearing, feeding, flight responses, and migration. It is highly likely that moorage and traffic of tankers and barges will coincide with juvenile salmonid or adult eulachon presence, and it is likely to temporarily disrupt normal fish behavior. However, vessel noise is likely to last only for one to two hours per vessel as they will likely stop their engines (ships) or to drop off barges (tug boats) to load and off-load equipment. The number of vessels is expected to include less than 10 vessels during construction. Therefore, the number of fish affected will be very small and effects to them will be short in duration and limited to small avoidance behaviors. Effects from short term noise related to ship and barge traffic during construction will be minor.

Migration obstruction

While construction-related vessels are moored at the NEXT facility to load and off-load equipment, they may remain at the dock for weeks or months. The presence of barges or ships at the dock will increase over-water shade. Shade effects on fish are well known. The moored vessels would create areas of cover that decrease water velocity and create shade. These

conditions may create favorable habitat for predators such as the Northern pikeminnow, smallmouth bass, and largemouth bass (Faler *et al*., 1988; Isaak & Bjornn, 1996). The Northern pikeminnow and smallmouth bass have consistently been shown to use low-velocity habitats (Faler *et al*., 1988; Isaak & Bjornn, 1996; Martinelli & Shively, 1997). In Columbia River reservoirs, their preference for low velocity habitats associated with overwater structures places them in the paths of the out-migrating juveniles (Carrasquero, 2001). In the McNary reservoir, smallmouth bass have also been found to prefer low velocity habitats (Tabor *et al*., 1993). Additional studies cited by Rondorf *et al*. (2010) found similar findings on these juvenile salmonid and eulachon predators. These studies found that pikeminnow and smallmouth bass actively search for low velocity habitats, prefer shaded areas, and utilize overwater structures such as moored vessels at the NEXT facility. Shade can delay migration as individual fish will stall active migration when confronted with over-water shade and deeper water.

It is highly likely that moorage and traffic of ships and barges will coincide with juvenile salmonid and eulachon presence, and it is likely to temporarily disrupt normal fish behavior. Vessels (barges and ships) are anticipated to remain moored at the NEXT dock facility for weeks to months at a time as equipment is used to construct the NEXT facility. Additionally, the number of vessels is expected to include up to 10 vessels during construction. Therefore, the number of juvenile salmonids and all life histories of eulachon affected will be in the thousands or tens of thousands. Most individuals will delay their migrations but will ultimately pass the moored vessels. Adult eulachon are likely to respond to permanent habitat effects by slightly adjusting their migration pathway. Adult eulachon are typically 6–8 inches in size, which is beyond the gape limit of all but the largest piscine predators in the LCR (NMFS, 2017a). However, hundreds of individual juvenile salmonids and egg and larval life history stages of eulachon will be consumed by lie-in-wait predators associated with moored vessels over the duration of construction activities lasting months. Therefore, individual juvenile salmonids and larval eulachon will be harmed because predation caused by the migration obstruction of moored ships during construction will harbor known predators.

Enduring Effects

Water Quality Effects

Contaminants produced by the NEXT facility Discharge at NEXT processing facility (wastewater and some stormwater) will be treated differently than the surrounding landscape (stormwater), as described in more detail below. The NEXT facility will produce and route wastewater and stormwater containing toxic chemicals (contaminants), which are incompletely removed by treatment processes. The facility's main wastewater system is designed to route wastewater produced from converting 50,000 barrels per day of vegetable oil and animal fats to renewable fuel and SAF. Wastewater would be collected and treated based on various chemicals in the waste stream. Once treated, the wastewater and stormwater would be comingled and processed through the tertiary filters before routing through a heat exchanger for cooling prior to entering the existing Port Westward wastewater collection system (in Ditch 1) for eventual discharge at the Port's outfall to the Columbia River. Treated water (discharge) would be released continuously throughout the year.

Runoff sources from the surrounding landscape (i.e., not the main NEXT processing facility) would include bare soil, aggregate, asphalt, and concrete from multiple areas surrounding the

main facility. Stormwater runoff will be routed by sheet flow through multiple drainage ditches, waterways, and constructed wetlands prior to release into McLean Slough and ultimately routed to the Clatskanie and Columbia rivers. All stormwater runoff will be routed to the ditches and drainage ponds described in the Proposed Action, above (Section 1.3). Runoff would mobilize small amounts of contaminated sediments, which would settle onto the top layer of the waterway and wetland substrates where the contaminants would remain biologically available for years. Detention ponds are sized to release stored water over 10 days following a 100-year, 24-hour storm. NEXT detention ponds are designed with an inverted elbow outlet so that particles floating on the surface of the pond would remain in the pond and trapped on or near the bottom when the pond drains. Nevertheless, stormwater with a large and complex mix of contaminants will escape the drainage ponds to the Columbia and Clatskanie rivers daily and when large storm events occur.

As described in the proposed action (Section 1.3), the NEXT facility will generate 72.6 acres of new PGIS. Additionally, the industrial complex will facilitate 667 new vehicle trips daily with the capacity for 3,000 additional vehicles trips. The proposed action also adds 60 semi-trucks and 1,220 rail cars monthly (ELS 2023). The addition of impervious surfaces with vehicles will generate increased toxic contaminants above the environmental baseline. Stormwater runoff, combined stormwater / wastewater from the NEXT facility, and accidental spills will route these the contaminants to drainage ponds and ditches. ESA-listed species in the Clatskanie and Columbia rivers would be exposed to concentrations of discharge and stormwater constituents that escape from the detention ponds. Many of the fuels, lubricants, and other fluids commonly used in motorized vehicles and construction equipment are petroleum-based hydrocarbons that contain Polycyclic Aromatic Hydrocarbons (PAHs), which are known to be injurious to fish. Other contaminants likely to result from the proposed action at the NEXT facility include 6PPD-Q, metals, herbicides, Polychlorinated Biphenyls (PCBs), and other organic compounds. Below, we describe the delivery and toxicity of NEXT facility contaminants, followed by the likely effects to listed species.

PAHs comprise a large fraction of the total cumulative toxic load present in stormwater runoff (treated or untreated) and are often bound or complexed with or carried by sediments (Grant et al. 2003). Petroleum-based contaminants include more than 100 different chemicals, and usually occur as complex mixtures in the environment (Ecology 2021). NEXT-facility sources of PAHs released to the environment would be from vehicle emissions, plastics including tire wear particles, improper motor oil disposal, leaks, and asphalt sealants (ELS 2023; Ecology 2021). PAHs are lipophilic, persistent, interact synergistically with bio-accumulative and redox-active metals and other contaminants, and may disperse long-distances in water (Gauthier et al. 2014, 2015; Arkoosh et al. 2011; Ecology 2021). PAHs at the NEXT facility are likely to accumulate in drainage ponds and persist for weeks to years in sediments.

The 6PPD chemical acts as a preservative in tires. As tires wear with age and road-wear, tire particles, in the presence of ozone, transform into 6PPD-Quinone (6PPD-Q) and are transported from roads and parking lots to rivers and streams in stormwater runoff. The optimum treatment BMP for 6PPD and 6PPD-Q removal is infiltration (WDEQ 2022; Fardel et al. 2020), which is unavailable at this site because of the high groundwater level. Large tire particles have negative buoyancy and sink to the bottom of the detention pond but microscopic tire particles have large

surface area to volume ratios and can have neutral or positive buoyancy due to the surface tension of water. Particles on the surface are likely to remain trapped in the pond for extended periods because the outlet is an inverted elbow and 6PPD-Q does not biodegrade rapidly without biofiltration (Challis et al. 2021; Johannessen et al. 2021). 6PPD and 6PPD-Q have low solubility so the dissolved fraction is low. Instead, 6PPD and 6PPD-Q molecules released from microscopic tire particles partition to organic matter in suspended sediment and over time, settle. Thus, the effectiveness of 6PPD and 6PPD-Q removal by detention ponds is rated medium by Ecology (2022).

Metals, such as copper, zinc, cadmium, or mercury, can have a range of acute and chronic physiological and behavior effects on fish. There are three known physiological pathways of metal exposure and uptake within salmonids: (1) gill surfaces can uptake metal ions which are then rapidly delivered to biological proteins (Niyogi et al. 2004); (2) olfaction (sense of smell) receptor neurons (Baldwin et al. 2003), and; (3) dietary uptake. For dissolved metals, the most direct pathway to fish and other aquatic organisms is through the gills. Relative toxicity of metals can be altered by hardness, water temperature, pH, suspended solids, and presence of other metals. Water hardness affects the bio-available fraction of metals from gill surfaces; as hardness increases; metals are less bio-available, and therefore less toxic (Hansen et al. 2002; Niyogi et al. 2004). However, Baldwin et al. (2003) did not find any influence of water hardness on the inhibiting effect of copper on salmon olfactory functions. Copper is a neurotoxicant that directly damages the sensory capabilities of salmonids at low concentrations. These effects are generally among the more sensitive fish responses and underlie important behaviors involved in growth, reproduction, and survival (Hecht et al. 2007).

Herbicide applications are proposed for the NEXT project. NMFS identified three pathways for the analysis of herbicide application effects: (1) Runoff from riparian application; (2) application within perennial ponds, wetlands, waterways, and intermittent channels; and (3) runoff from impervious surfaces, ponds and ditches. Surface water contamination with herbicides can occur when herbicides are applied intentionally or accidentally into ditches, drainage ponds or other bodies of water, or when soil-applied herbicides are carried away in runoff to surface waters. Accidental contamination of surface waters can occur when drainage ponds are sprayed with herbicides or when buffer zones around water sources are not wide enough. Glyphosate is proposed to be used to prevent regrowth of weeds after the bio-refinery site is stripped and graded to control weeds competing with native plants at the mitigation site, and to control weeds along roads and the railway. It is degraded by soil microorganisms and has a field half-life of 2-197 days.

Even though PCBs were banned in the United States in 1979, they persist at high concentrations in sediments and aquatic foodwebs in the Columbia River. The influx and transport of cleaner sediments, the flushing of flows, and the dredging and disposal of sediments through time was expected to reduce and bury these contaminants below biologically available access; however, PCBs still occur at very high concentrations in surface sediment and are biologically available to fish and their prey (Counihan et al. 2014). Lower Columbia River sediments are composed of primarily sand and silt. These fine-grained materials are not uniformly distributed in the river, which is important because fine-grained material frequently contains more organic carbon, and organic material is most frequently associated with contaminants, such as PCBs. Total organic

carbon is also important for invertebrate production, which can lead to bioaccumulation of PCB concentration in the higher trophic levels of salmon, and green sturgeon. In the lower Columbia River, PCBs increased inversely with RM, although the Longview reach had the highest concentration of PCBs in sediment samples (Counihan *et al*. 2014), although see Hermann (2008) for very high concentrations observed in the Hanford reach, upstream of the action area.

Effects to listed species from contaminants

The proposed action would result in increased PGIS at the Port Westward area which would degrade water quality in the action area. All stormwater discharge from the NEXT facility is expected to contain concentration levels of constituents and chemical mixtures that are toxic to fish and aquatic life. Depending on the contaminant, its concentration, and/or the duration of exposure, exposed fish may experience effects that can range from avoidance of an affected area, to reduced growth, altered immune function, and mortality (Beitinger and Freeman 1983; Brette *et al*. 2014; Feist *et al*. 2011; Gobel *et al*. 2007; Incardona *et al*. 2004, 2005, and 2006; McIntyre *et al*. 2012; Meadore *et al*. 2006; Sandahl *et al*. 2007; Spromberg *et al*. 2015). Fish can uptake contaminants directly through their gills, and through dietary exposure (Karrow *et al*. 1999; Lee and Dobbs 1972; McCain *et al*. 1990; Meador *et al*. 2006; Neff 1982; Varanasi *et al*. 1993).

The incremental addition of contaminants over time are a source of adverse effects to salmonids. Adverse effects occur even when the source load cannot be distinguished from ambient levels because many contaminants bioaccumulate in the tissues of aquatic organisms and in benthic sediments. Adult and juvenile fishes will be exposed to stormwater contaminants during migration, spawning, and rearing life history stages.

Lipophilic chemicals such as PAH's tend to bioaccumulate in the tissues of aquatic organisms, particularly those at the top of trophic food chains such as salmonids and SRKW's. Increased levels of PAHs, oils, and other contaminants would be widely dispersed, and can have detrimental effects at very low levels of exposure either directly or indirectly through the consumption of contaminated prey or exposure to contaminants in the water column. As the concentration of these constituents increases in the environment the likelihood that organisms such as SRKW are harboring dangerous chemical loads increase concurrently. Environmental and biological accumulation of these chemicals can result in adverse long-term ecosystem impacts including altering species behavior, reproduction, and growth. PAHs and their metabolites are acutely toxic to salmonids and may cause lethal narcosis at low levels of exposure, can bioaccumulate through food webs (water, groundwater, soil, and plants; Bravo *et al*. 2011; Zhang *et al*. 2017), and can also cause chronic sub-lethal effects to aquatic organisms at very low levels (Neff 1985; Varanasi *et al*. 1985; Meador *et al*. 1995).

6PPD-Q is among the most toxic chemicals known for aquatic organisms, especially to coho salmon (LC_{50} 0.08 µg/L) (Tian *et al*. 2022) and ranks as among the most potently acute aquatic toxicants when compared to chemicals with existing Clean Water Act Aquatic Life Ambient Water Quality Criteria (Ecology 2022). Toxicity of 6PPD-Q does not follow a phylogenetic relationship. Species within the *Oncorhynchus* genus show radically different acute toxicities, from an LC_{50} as low as 0.040 µg/L in coho fry to no mortality observed in sockeye at 50 µg/L (Lo *et al*. 2023; Greer *et al*. 2023). 6PPD-Q is also highly toxic to *O. mykiss* (LC_{50fry} 0.47 – $LC_{50juvenile}$ 2.26 µg/L), and moderately toxic to Chinook salmon (LC_{50} 67.3 µg/L) (Roberts *et al.*

2024; Lo *et al.* 2023). Sublethal concentrations of 6PPD-Q can disrupt aerobic metabolism, swimming performance, and cardiovascular function in *O. mykiss* (steelhead) and lake trout (*Salvelinus namaycush*), potentially affecting fish survival (Selinger 2025).

Exposure to metal mixtures may result in sublethal effects that reduce growth or immune system functions that could persist after juvenile Chinook salmon leave their natal streams. Arkoosh *et al.* (1998) determined that alteration in disease resistance was sustained even after Chinook salmon were removed from the source of contaminants for 2 months and concluded that immune alteration in early life stages could persist into their early marine residency. Individual metal concentrations, and some mixture concentrations and combinations, have been tested with Chinook and coho salmon and steelhead. Results range from lethal to sublethal effects, which include reduced growth, fecundity, avoidance, reduced stamina, and neurophysiological and histological effects on the olfactory system (Eisler 1998; Playle 2004).

Glyphosate is practically non-toxic to fish (Solomon and Thompson 2003) with an LC_{50} to rainbow trout of 55 mg/L. Stehr *et al.* (2009) found that the low levels of herbicide delivered to surface waters are unlikely to be toxic to the embryos of ESA-listed salmon, steelhead and trout. However, mortality or sub-lethal effects such as reduced growth and development, decreased predator avoidance, or modified behavior are likely to occur with some surfactants, which are mixed with glyphosate. Toxicity studies, particularly acute aquatic toxicity studies, show that formulated products can be more toxic than the glyphosate active ingredient alone. For example, one class of surfactants used in glyphosate formulations are the polyethoxylated tallow amines (POEA) and this class has been shown to be more toxic to aquatic animals than glyphosate alone (USEPA 2015; USEPA 2020).

PCBs are highly toxic to juvenile salmon (Meador et al. 2010). Meador *et al*. (2002) estimated 2,400 ng ∑PCBs/g lipid as the adverse health threshold for PCBs based on a broad range of toxicological studies on juvenile salmonids with effects ranging from enzyme induction to mortality. Johnson *et al*. (2013) observed concentrations of 22 to 6,900 ng/g lipid in juvenile Chinook salmon in the lower Columbia River. Subyearling life history types had the highest concentration due to their extended rearing in the lower river. Johnson *et al*. (2007) observed that high concentrations of PCBs in the stomach contents of juvenile Chinook and coho salmon indicates that they were accumulating these contaminants through their prey. In both whole body and stomach concentrations, Chinook salmon had higher concentrations of PCBs than coho salmon, which may indicate that juvenile Chinook salmon were consuming prey at higher trophic levels (Johnson *et al*. 2007). Exposure to PCBs may lead to altered immune function and increased disease susceptibility (Arkoosh *et al*. 1994, 1998, 2001; Bravo et al. 2011), poor growth, or metabolic dysfunction (Meador *et al*. 2002, 2006) and altered behavior (Scholz *et al*. 2000; Sandahl *et al*. 2005), all of which increase the risk of mortality in juvenile salmon.

Juvenile and adult salmonids and eulachon, and sub-adult green sturgeon would be exposed to the outfalls of the drainage ponds at the NEXT facility. The exact number of years that detectable amounts of operations-related contaminants would be biologically available at the site is uncertain, but is expected to persist for 50 years or more. Similarly, the annual numbers of juvenile salmon and eulachon that may be exposed to operations-related contaminated forage are uncertain. However, the best available information about the number of populations and number

of individuals from those populations suggest that the number of individual fish that annually move through the project area would be very high. There is a reasonable likelihood that some coho salmon and steelhead fry that reside for short periods of time near the NEXT facility will die from acute exposure to 6PPD-Q and PAHs. However, most stormwater contaminants that escape the detention ponds will coincide with large rain events in the fall, which is when juvenile salmonids and eulachon are least likely to be abundant. There is also a reasonable likelihood that many individual juvenile salmonids and eulachon will be exposed to sublethal effects from contaminants.

Similarly, the amounts of contaminated prey that individual fish may consume, or the intensity of effects that exposed individuals may experience are uncertain and likely to be highly variable. However, the number of contaminants that would be mobilized suggests that the number of prey subject to consumption by juvenile salmonids or eulachon would be moderately high, especially with PAHs, which do not degrade quickly and are likely to persist well downstream of the facility outfalls. This suggests that the probability of trophic connectivity to the contamination would be moderate for any individual fish.

Green sturgeon are also susceptible to contaminants. There have been reports identifying concentrations of metals and pesticides in the blood plasma of green sturgeon from Grays Harbor (Layshock *et al*., 2022). Copper and selenium concentrations ranged from 100 to 1000 nanograms per milliliter and 200 to 400 nanograms per milliliter respectively. Pesticide concentrations ranged from 2–10 nanograms per milliliter of blood plasma (Layshock *et al*., 2022). Although metals and pesticides have known toxic effects in green sturgeon, the toxicity threshold for blood plasma concentrations of these compounds is unknown for green sturgeon. Nevertheless, there is a reasonable likelihood that contaminants escaping into the Columbia River would expose green sturgeon to the toxics remaining after treatment from the detention ponds that bioaccumulate to their blood plasma concentrations and increase toxicity. We anticipate that individual green sturgeon may be harmed or injured by this contamination.

Water quality would be impaired as a consequence of the development and operation of the NEXT facility. Contaminants including PAHs, 6PPD-Q, herbicides, heavy metals, PCBs, and other toxic chemicals would be produced and delivered to the Columbia and Clatskanie Rivers by escaping from drainage ponds and ditches. These contaminants will harm individual salmonids, eulachon, and green sturgeon directly and through trophic interactions daily for at least the next 50 years. Fall freshets are likely to carry the highest concentration of chemicals released due to stormwater on the landscape, whereas wastewater/stormwater discharge from the main facility would likely be continuous throughout the life of the NEXT facility. Therefore, we do not anticipate that contaminants in the water column would return to pre-NEXT facility levels. Additionally, some contaminants will accumulate in the benthos, which will impair forage opportunities of green sturgeon at least 25 miles downstream of the NEXT facility. The swift currents of the Columbia River will likely disperse some chemicals in the water column as they drift downstream, and some will accumulate in substrates. Degraded water quality will persist into the foreseeable future. Additionally, many individual fish will be affected by sublethal effects (such as swimming impairment) and become susceptible to increased predation. Some individual fish are likely to die from direct and indirect exposure to contaminants produced as a consequence of the proposed action.

Migration Obstruction

The presence of barges or ships at the dock to load or unload biofuel will increase over-water shade. Shade effects on fish are well known. The moored vessels would create areas of cover that decrease water velocity and create shade. These conditions may create favorable habitat for predators such as the Northern pikeminnow, smallmouth bass, and largemouth bass (Faler *et al*., 1988; Isaak & Bjornn, 1996). The Northern pikeminnow and smallmouth bass have consistently been shown to use low-velocity habitats (Faler *et al*., 1988; Isaak & Bjornn, 1996; Martinelli & Shively, 1997). In Columbia River reservoirs, their preference for low velocity habitats associated with overwater structures places them in the paths of the out-migrating juveniles (Carrasquero, 2001). In the McNary reservoir, smallmouth bass have also been found to prefer low velocity habitats (Tabor *et al*., 1993). Additional studies cited by Rondorf *et al*. (2010) found similar findings on these juvenile salmonid and eulachon predators. These studies found that pikeminnow and smallmouth bass actively search for low velocity habitats, prefer shaded areas, and utilize overwater structures such as moored vessels at the NEXT facility. Shade can delay migration as individual fish will stall active migration when confronted with over-water shade and deeper water. When juvenile fish encounter areas of diminished prey, competition for those limited resources increases, and less competitive individuals are forced into suboptimal foraging areas (Auer *et al*. 2020). Further, individuals with an inherently higher metabolism tend to be bolder and competitively dominant, and may outcompete other individuals for resources within a microhabitat, potentially increasing interspecific mortality (Biro and Stamps 2010).

It is highly likely that moorage and traffic of ships and barges will coincide with juvenile salmonid and eulachon presence, and it is likely to temporarily disrupt normal fish behavior. The NEXT facility will facilitate 171 new OGV trips each year. Vessels (barges and ships) are anticipated to moor at the NEXT dock facility for 2 – 3 days to load and off-load product. Thus, for about 342 days/year, the NEXT dock will obstruct the migration and rearing habitat of juvenile salmonids and eulachon. The number of juvenile salmonids and all life histories of eulachon affected will be in the thousands or tens of thousands. Most individuals will delay their migrations but will ultimately pass the moored vessels. Adult eulachon are likely to respond to permanent habitat effects by slightly adjusting their migration pathway. Adult eulachon are typically 6–8 inches in size, which is beyond the gape limit of all but the largest piscine predators in the LCR (NMFS 2017a). However, hundreds of individual juvenile salmonids and egg and larval life history stages of eulachon will be consumed by lie-in-wait predators associated with moored vessels.

Feedstock or biofuel spills

Biodiesel is likely to harm or kill fish, whales, and turtles in the event of a large biodiesel fuel spill. Pure "neat" biodiesel does not contain complex hydrocarbons as petroleum products do, and is typically less toxic to fish and other aquatic organisms. However, pure biodiesel is subject to degradation through time, and additives, including petroleum-based diesel, are frequently added ("blended") to stabilize the product. In laboratory experiments conducted by Khan *et al.* (2007), neat biodiesel was found to have half the toxicity as petroleum-based diesel. However, biodiesel remains toxic and in small concentrations (< 4 ppm) kills 50% (LC_{50}) of a zooplankton (*Daphnia magna*) within 24 hours, and 50% of rainbow trout (*O. mykiss*) in 1073 ppm concentrations within 24 hours (Khan *et al.* 2007). Additionally, effects to three species of microalgae as a result of biodiesel exposure revealed that pure diesel was more toxic than

petroleum-based diesel (Pikula *et al.* 2018). The potential harm to listed species from an oil spill is dependent on the size of the spill, the availability of protection measures (which differs between the Columbia River and the Pacific Ocean), and exposure to individual species. Below, we differentiate between the risks and effects to listed species from large oceanic and Columbia River biofuel or feedstock spills.

Oceanic feedstock or biofuel spill risk

Oceanic biofuel or feedstock spills have the potential to affect whales and turtles. Tanker ships and barges will deliver raw oil feedstocks such as vegetable oils, used cooking oil, animal tallow, and inedible corn oil to the storage tanks at the NEXT facility. The NEXT facility will convert the feedstocks to non-petroleum biodiesels and sustainable aviation fuel where they will again be transported to the Pacific Ocean by ship or barge (ELS 2023). Large spills from commercial vessels are considered in general terms to be "low probability/high consequence events" (WDOE 2015). There is inherent risk of transiting through the action area where an accident could be caused by a multitude of factors from mechanical failure, human error, bad weather, or an unfortunate chain of events. Risk mitigation measures i.e., best management practices (BMPs), industry standards, traffic separation schemes, mechanical inspections, etc., partially reduce overall risk among all vessel traffic. The most basic assumption that NMFS is making regarding risk in this opinion is that more feedstock or biofuel-carrying ships per year above the baseline equates to more risk associated with the proposed action. Each additional ship transiting the action area contributes to an incremental increase in the risk profile of NEXT individually and in the overall traffic scheme in the action area.

In the event of an oceanic spill, killer whales appear to not have the wherewithal to avoid oiled waters. Matkin *et al*. (1994) reported that killer whales did not attempt to avoid oil-sheened waters following the Exxon Valdez oil spill in Alaska. After the Exxon Valdez oil spill in 1989, six of the 36 members of the northeastern Pacific AB pod were missing within one week of the spill after being seen in heavily oiled waters and eight more disappeared within two years. These absences were followed by the deaths of two orphaned calves in the winter of 1993-1994, as well as two adult males (including one fairly young individual) in 1994 and 1997 whose dorsal fins collapsed soon after the spill, indicating stress or ill health. AT1 pod lost eight of its 22 members by 1990 and two others by 1992. These mortality rates are unprecedented for the northeastern Pacific (NMFS 2008a). As the direct toxicity effects on SRKW from biodiesel are unknown, it is unclear how a large biofuel spill will affect them in the Pacific Ocean. It is equally unclear how bioaccumulation through the food chain would affect SRKW. However, as discussed below we think the risks to SRKW are low because the likelihood of a spill is low (NMFS 2022i), and they are unlikely to be exposed to oil in the action area.

An oceanic spill on the outer coast could disperse over many, many miles, which could expose more individual whales to spilled biofuel or feedstock, but potentially avoid acute toxic exposure because the product and vapors would rapidly dilute (if the biofuel or feedstock is toxic to whales or turtles). When biofuel of feedstock is spilled in the ocean, it would initially spread primarily on the surface, depending on its relative density and composition. Some of the product would evaporate. An oil slick may remain cohesive, or may break up in rough seas. Waves, currents, and wind can push oil into coastal areas and affect marine and terrestrial habitats in the path of the drift. Over time, oil waste would weather (deteriorate) and disintegrate by means of

photolysis and biodegradation. The rate of biodegradation depends on the availability of nutrients, oxygen, and microorganisms, as well as temperature. Based on the description above, we conclude that risk to individual whales and turtles as a result of an oceanic spill is very low due to the unlikely event of a spill, the dispersal of the oil, and the low abundance and infrequent presence of the whales and turtles in the action area. The effects of an oceanic spill on salmonids, eulachon or green sturgeon is discountable because they are below the surface and highly mobile in the ocean.

Columbia River feedstock or biofuel spill risk

Although there is a risk of a large spill occurring in the Columbia River, the likelihood of a significant spill is low because of CPBR oil spill contingency plans with the EPA, USCG, and ODEQ that quickly mobilize against potential spills in the Columbia River. In addition to the above-mentioned plans, CRC stages over 6,500 feet of containment boom, skimmers, and two deployment vessels at the Port Westward facility. CPBR also pre-booms all OGVs prior to fuel transfer. CPBR stages over 6,500 feet of containment boom, skimmers, and two deployment vessels at the Port Westward facility and pre-booms all OGVs prior to oil transfer. A containment boom is placed around each OGV until the transfer is complete. OGVs approaching and leaving Port Westward are also required to have their own Vessel Response Plan. Once OGVs enter the Columbia River, the Maritime Fire and Safety Association becomes an additional oil spill response organization. In the event that additional resources are needed, CPBR is covered by the Strategic Northwest Area Contingency Plan. EPA administers surprise simulated spills. CPBR received the highest marks for simulated spill response and cleanup. In addition, CPBR contracts with several OSROs that are on-call in the event of a spill. In the event of a spill, CPBR and the OSROs could likely respond to and contain a small-scale spill before it becomes a significant incident. For these reasons, we do not consider a significant spill in the Columbia River as reasonably certain to occur. We do not consider impacts from a significant spill to be effects of the action for the purposes of this analysis.

Stranding on beaches by OGV wake waves.

Ship wakes from vessel traffic transiting to and from the NEXT facility would strand juvenile salmonids and eulachon in the Columbia River. Four studies (Bauersfeld 1977, Hinton and Emmett 1994, Ackerman 2002, Pearson *et al.*, 2006) have indicated that under certain conditions, deep draft vessels can produce wakes that strand juvenile salmon on shallow beaches in the Columbia River. Between 1974 and 1975, Bauersfeld (1977) estimated that 14,500 juvenile Chinook, 1,359 juvenile coho, and 4,771 juvenile chum salmon were stranded (killed) because of ship wakes from 180 deep draft vessels. Pearson *et al*., (2006) monitored 126 deep-draft vessel transits, and stranding occurred at three sites over all three seasons ranging from a low of 15% at Sauvie Island near Portland to a high of 53% at Barlow Point near Longview.

The NEXT facility would be downstream of 2 of the 3 known wake stranding beaches and is likely downstream of 2/3 of the unknown stranding beaches that meet Pearson *et al.* (2011) criteria for slope. The NEXT facility would result in up to 128 (=9/12 of 171) total OGVs up and down the river each year during 9 months of the year when young-of-the-year salmonids are migrating or rearing in shallow water along the margins of the Columbia River. Eulachon juveniles and eggs would be most susceptible to wake stranding from February through April. OGVs to and from the NEXT facility would pass the County Line Park stranding beach, about

two miles downstream from Point Westward, but OGVs approaching or leaving the NEXT facility would be slowing down from 10 nautical miles per hour or accelerating to 10 nautical miles per hour as they pass County Line Park (ELS 2023), which may be a speed that reduces stranding at County Line Park than reported by Pearson *et al.* (2011). Wake stranding will likely occur at about 11 miles of other known stranding beaches downstream of the proposed NEXT facility.

Despite the reduced speed by ships and barges at some known stranding beaches, the increase in the number of vessels arriving and departing the NEXT facility will increase the mortality of juvenile salmonids and larval and egg life stages of eulachon. Ocean-type salmonids (typically, fall Chinook and chum salmon) are susceptible to wake stranding as passing ship wakes displace them from the water onto adjacent beaches. The small size of Chinook and chum salmon fry (35-55mm) obligates them to migrate near the shoreline to avoid piscine predators where they are highly susceptible to ship wake stranding mortality. These fish are incapable of avoiding these events when they swim or drift near shallow slope beaches and ships pass. Hundreds to thousands of individual salmon and eulachon fry are expected to die or be injured annually, especially during early spring, as small fry and large ship wakes co-occur.

OGVs strikes and marine mammals and turtles

Collisions with large ships remain a source of anthropogenic mortality or serious injury for both sea turtles and whales. The action area includes approximately 4,680 square nautical miles of the Pacific Ocean where SRKW, humpback, sei, fin, blue and sperm whales and leatherback sea turtles spend part of the year in sufficient densities that encounters and collisions with OGVs are likely. The proposed NEXT facility will rely upon 115 third party OGVs to supply feedstock and 56 third party OGVs to export bio refinery fuels. Below, we assess the general co-occurrence of ships and animals, and qualitatively consider the degree of additional risk posed to individuals in the action area and the potential consequences to the respective populations.

OGV strikes on killer whales are considered infrequent (NMFS 2022i). When they occur, ship strikes can result in injury or mortality (Gaydos and Raverty 2007). In 2016, an 18-year old male, J34, was found dead near Sechelt, British Columbia. The necropsy indicated that the whale died of blunt force trauma to the head, and Raverty *et al*. (2020) determined this was consistent with a vessel strike. From 2002 to 2016, two Southern Resident killer whales (subadult L98 and adult J34) perished from collisions with vessels[3]. Two others (adult L60 and subadult L112) died of trauma from unknown sources (NMFS 2021). Vessel strikes on killer whales are considered more uncommon than larger whale strikes because killer whale swimming and social behavior is dolphin-like (killer whales are the largest animal in the dolphin family). Because SRKW are highly agile and capable of evading approaching OGVs and because the expanse of the action area decreases the likelihood of ship strikes, we conclude that SRKW are unlikely to be harmed by OGV strikes.

The large whales in the action area are vulnerable to injury and death from vessel collisions (Vanderlaan and Taggart 2007). The occurrence and density is variable for the different species in the action area. In U.S. waters, ship strikes account for tens of large whale deaths per year (Conn and Sibler 2013, Henry *et al.* 2012, Van der Hoop *et al.* 2012). The documented number

[3] SRKW L98 was habituated to boats and humans

of vessel collisions is an underestimate of the actual number of collisions because vessel collisions have a low probability of detection (Laist *et al.* 2001, Conn and Sibler 2013).

Ship strike injuries to whales include propeller wounds characterized by external gashes or severed tail stocks, blunt trauma injuries indicated by fractured skulls, jaws, and vertebrae (Laist *et al.* 2001), and hemorrhaging that sometimes lacks external expression (Conn and Sibler 2013). Vessel size and speed are associated with the number and severity of vessel collisions with whales. In one study, of the known collisions that killed whales, at least 87 percent involved ships more than 250 feet long (Laist *et al.* 2001). There is a significant positive relationship between ship speed and the probability of a lethal injury (Conn and Sibler 2013).

The 2021 Humpback Whale Recovery Plan outline identifies ship strike as a general threat. Of the humpback whales within the action area, NMFS presumes that 9 percent are from the Central America DPS and 28 percent are from the Mexico DPS. Along the entire West Coast range of this stock, the 2019 Humpback Whale Stock assessment (NMFS 2019a) identified 2.2 observed vessel collisions per year from 2013-2017 with total estimated vessel collisions per year of 22 (based on Rockwood el al. 2017). This estimate of 22 vessel collisions per year is for the combined CA/OR/WA stock across its range, of which the action area is a small portion and signals at a low reporting or observation rate of vessel strikes. Carretta *et al*. (2018) estimates an additional 10.8 serious injuries/deaths per year during this same time period. Fourteen vessel strike cases involving humpback whales were observed in CA-OR-WA waters during 2016 - 2020 (8 in CA, 1 in OR, and 5 in WA), or 2.6 whales per year (Carretta et al. 2022). Neilson *et al*. (2012) summarized 108 large whale vessel-strike events in Alaska from 1978 to 2011, 25 of which are known to have resulted in the whale's death. Eighty-six percent of these reports involved humpback whales. Humpback whale strikes by OGVs are vastly underreported (NMFS 2022k), which likely means that the actual number of humpback whale strikes and mortality is much higher. The 2015 Status Review (NMFS 2015b) concludes that vessel collisions are considered likely to moderately reduce the population size or growth rate of the Central America humpback whale DPS. Taking this information into account and considering that the entire population size of the Central America DPS is in the 100's of animals, NMFS concludes that both DPSs of humpback whales use the action area and are susceptible to OGV strikes. Over the course of the 50-year operation of the NEXT facility, and approximately 8,550 vessel trips, it is reasonable that one or more humpback whales could be injured of killed by vessel traffic.

Blue whales are extremely rare in the action area (Figure 4). The Eastern North Pacific population feeds off California in the summer and fall. Vessel surveys conducted in Washington waters in 1996 and 2001 did not find any blue whales (Carretta *et al*. 2013; Figure 39) however some groups and individuals have been sighted in recent years off the coasts of Oregon and Washington. The incremental increase in risk from the proposed action in any given year is likely small, however, over the course of the 50-year operations of the NEXT facility we can reasonably estimate that at least one blue whale from this DPS will be struck as a result of the proposed action.

The risk of ship strikes to fin whales in the action area in any given year is low. The best-estimate of abundance is taken as the estimate from 2018, or 11,065 (CV=0.405) animals (Becker et al. 2020), which is a significant increase from the estimated 2,636 fin whales reported

to occur off the coasts of California, Oregon, and Washington in 2001 and 2005 (NMFS 2010a), with the concentrations of sightings increasing through Oregon and becoming more abundant off Washington. Fin whales typically feed well offshore along the continental slope. Fin whales have been reported struck and killed by large ships along the entire West Coast with an estimated 19 whales struck from 1998-2013 (WCR Stranding Database). Between 1991 and 2001 there were 20 reported ship strikes of fin whales along the U.S. West Coast. From 2010 to 2014 along the U.S West Coast there were nine reported ship strikes to fin whales (Carretta *et al*., 2017). Since 2002, 10 out of the 12 stranded fin whales in Washington have showed evidence attributed to a large ship strike (Carretta *et al*., 2017). The 2010 Fin Whale Recovery Plan identifies vessel collisions as a high threat with a "medium severity, but with high level of uncertainty, the relative impact to recovery of fin whales due to ship strikes is ranked as unknown but potentially high." Although fin whales have been struck in the action area, the main hot spots for fin whale ship strikes are off California. The primary range of fin whales is south of the action area; however, a moderate number of them have been struck by OGVs in recent years. Over the course of the 50-year NEXT facility operations, it is reasonable to assume that at least one fin whale will be struck.

Known ship strikes on sei whales is uncommon in the eastern North Pacific Ocean, but is poorly understood. There are relatively few documented accounts of vessel strikes with sei whales, and it is suspected that strikes on this species are underreported because the whales do not typically strand. One ship strike death was reported in the eastern North Pacific Ocean (off Washington) in 2003 (NMFS 2018). No vessel strikes of sei whales have been documented during the most-recent 5-yr period (2017 - 2021) (Carretta *et al*. 2023). There are approximately 35,000 sei whales in the eastern North Pacific Ocean (NMFS 2021). Sei whales are often observed in the same foraging area for many years and then disappear for prolonged periods of time, only to reappear years later (Jonsgård and Darling 1977; Schilling *et al*. 1992), which complicates efforts to track abundance trends through time. Despite the poor understanding of ship strikes on sei whales, we conclude that ship strikes on these whales is likely in the action area due to their abundance off the Washington Coast, the underreporting of strikes, their tendency to avoid stranding, and the 50-year expected operation of the NEXT facility.

The abundance estimates for sperm whales off California, Oregon, and Washington, out to 300 nautical miles (nm) ranged from 2,000 to 3,000 animals (Moore and Barlow 2014; Becker et al. 2020). For the most recent 5-year period of 2017-2021, no vessel strike deaths or serious injuries were observed, though one was recorded in 2007 (Carretta et al. 2013). Due to the low probability of a sperm whale carcass washing ashore, estimated vessel strike deaths are likely underestimated. The 2010 Sperm Whale Recovery Plan identifies vessel strike as one of several main threats to species recovery (NMFS 2010b). Sperm whales spend long periods of time "rafting" and socializing at the surface after deep dives, typically up to 10 minutes at a time, making them vulnerable to ship strikes. Population trends appear neutral (NMFS 2024d) Although no sperm whales are known to have been struck by OGVs in recent years, vessel strikes are largely unreported or unobserved. They are social animals and are frequently found at the surface, which increases their risk of ship strikes. Over the course of the 50-year license, it is reasonable that at least one sperm whale will be struck by an OGV originating from or going to the NEXT facility.

Because all sea turtles must spend time at the surface to breathe, rest, bask, and feed, these fundamental behaviors make turtles vulnerable to ship strikes. Although a number of (presumably) recreational propeller strikes on leatherback sea turtles are known, ship strikes are not reported. Based on telemetry data for leatherback turtles (n=15) on the northeastern U.S. shelf, leatherback turtles spent over 70 percent of their time in the top 15 m (Dodge *et al.* 2014). Thus, despite the lack of known strikes, vessel strikes pose a threat to the West Pacific DPS. Of leatherback strandings documented in central California between 1981 and 2016, 11 were determined to be the result of vessel strikes (7.3 percent of total; NMFS unpublished data). Leatherback turtles are known to feed off the Washington Coast, including the Columbia River plume; however, the main feeding areas are off California.

The likelihood that leatherback sea turtles will be exposed to collisions with vessels from the project is higher for about 100 days of the year during the summer and fall months because there is an abundance of forage species in the action area during that time. During the cooler approximately 265 days of the year, leatherback turtles are not expected to be present in the action area in enough numbers to result in ship strikes (NMFS and USFWS 2020). The increased risk in some years to any one individual turtle in the action area from ship strikes is small, but not insignificant. During summer, turtles are likely to occur in the action area making the odds of encountering additional NEXT-associated ships likely over the course of the 50-year NEXT operations. At least some leatherback sea turtles are likely to be harmed by OGV strikes.

Noise

Noise and disturbance from the boat/vessel activities associated with the operation of the NEXT facility would occur periodically with ship and vessel traffic. This would occur whenever boats/vessels moor or travel from the NEXT facilities. Moored vessels are anticipated to take approximately 2 days to load and off-load product, which combined with the number of vessels anticipated over the course of a year, amounts to about 350 days (ELS 2023). Elevated in-water noise at levels capable of causing detectable effects in exposed fish would be caused by episodic tugboat and tanker ship operations.

The effects caused by a fish's exposure to noise vary with the hearing characteristics of the fish, the frequency, intensity, and duration of the exposure, and the context under which the exposure occurs. At low levels, effects may include the onset of behavioral disturbances such as acoustic masking (Codarin *et al*. 2009), startle responses and altered swimming (Neo *et al*. 2014), abandonment or avoidance of the area of acoustic effect (Mueller 1980; Picciulin *et al*. 2010; Sebastianutto *et al*. 2011; Xie *et al*. 2008) and increased vulnerability to predators (Simpson *et al*. 2016). At higher intensities and/or longer exposure durations, the effects may rise to include temporary hearing damage (a.k.a. temporary threshold shift or TTS, Scholik and Yan 2002) and increased stress (Graham and Cooke 2008). At even higher levels, exposure may lead to physical injury that can range from the onset of permanent hearing damage (a.k.a. permanent threshold shift or PTS) and mortality. The best available information about the auditory capabilities of the fish considered in this opinion suggest that their hearing capabilities are limited to frequencies below 1,500 Hz, with peak sensitivity between about 200 and 300 Hz (Hastings and Popper 2005; Picciulin *et al*. 2010; Scholik and Yan 2002; Xie *et al*. 2008).

A study found that boat noise can induce stress responses via increased cortisol concentration in fishes (Nicholes *et al.*, 2015). In response to ship moorage and traffic with such high frequency, fish behaviors will be altered. These behaviors include rearing, feeding, sheltering, and migration. It is highly likely that moorage and traffic of tankers and barges will coincide with juvenile salmonid or adult eulachon presence, and it is likely to temporarily disrupt normal fish behavior, resulting in harm to salmonids and eulachon.

Green sturgeon are likely to be affected by vessel noise. Ship traffic will occur year-round at the NEXT facility, and increase the likelihood that green sturgeon will be present in the action area. Senecal *et al*. (2024) observed that Atlantic sturgeon were displaced from ship traffic in the St. Lawrence River from distances over 1 km. from approaching ships. Because the displacement exceeded the visual distance of the sturgeon, the authors attributed the movement of sturgeon to hearing the ships approach. Displacement of the Atlantic sturgeon lasted a median of 31 min. before they were redetected (Senecal *et al*. 2024). Green sturgeon use the lower Columbia River to feed and grow. The displacement of green sturgeon from the action area would likely be over short durations in the lower river as ships and tug boats pass through the area. However, as ships and barges are docked at the NEXT site, running motors could displace sturgeon for extended periods of time as ELS (2023) reports that ships and barges will occupy the site for about 350 days/yr. Thus, although no green sturgeon are likely to be killed by the ships, the NEXT site will likely preclude foraging by green sturgeon for distances of up to 1 km from the site with a recurring frequency of every 2-3 days.

It is well known that anthropogenic sound from a variety of human activities (e.g. seismic surveys, pile driving, use of explosives, high intensity sonar operations, aircraft and ship noise, etc.) can cause detrimental effects to marine mammals. These effects can cause behavioral changes, mask communication sounds, exclude marine mammals from their habitat, and induce auditory injury or death (Southall *et al*. 2014; Pirotta *et al*. 2014; Verfuss *et al*. 2018). Marine mammals and turtles rely on sound to communicate and obtain information about their environment. There is growing concern about the effect of increasing ocean noise levels due to anthropogenic sources on marine organisms, particularly marine mammals. Specific effects of noise exposure on marine organisms can be characterized by the following physical and behavioral responses (Richardson *et al*. 1995):

1. Behavioral reactions such as startle responses, changes or interruptions in feeding, diving, or respiratory patterns, cessation of vocalizations and temporary or permanent displacement from habitat.
2. Reduction in ability to detect communication or other relevant sound signals below elevated levels of background noise.
3. Temporary and fully recoverable reduction in hearing sensitivity caused by exposure to sound.
4. Permanent, irreversible reduction in hearing sensitivity due to damage or injury to ear structures caused by prolonged exposure to sound or temporary exposure to very intense sound.
5. Effects of sound exposure on tissues in non-auditory systems either through direct exposure or as a consequence of changes in behavior, (*e.g.*, resonance of respiratory cavities or growth of gas bubbles in body fluids).

OGVs produce sound at frequencies from 20-10,000 Hz. Blue, humpback, sei, sperm, and fin whales are all known to be sensitive to sounds within the frequency ranges of OGV noise. Blue whales vocalize at frequencies between 12.5-200 Hz (Au 2000). Sperm whales produce loud broad-band clicks from about 100 Hz to 20,000 Hz (Weilgart 2007; Goold and Jones 1995). None of the noise associated with OGV activity is expected to reach levels that would potentially cause direct physical injury *(i.e.,* ear drum damage) to marine mammals but all OGV-related noise is continuous, and has the potential to result in some type of behavioral disturbance or harassment, including displacement, site abandonment (Reeves and Whitehead 1997; Bryant *et al*.1984), and masking (Richardson *et al*. 1995). These disturbances could cause minor, short-term displacement and avoidance behaviors, alteration of diving or breathing patterns, and less responsiveness when feeding. Vessel noise can also cause acoustically induced stress (Miksis-Olds *et al*. 2018; NRC 2003), which can cause changes in hear rate, blood pressure, and gastrointestinal activity. Stress can also involve activation of the pituitary-adrenal axis, which stimulates the release of more adrenal corticoid hormones. Stress-induced changes in the secretion of pituitary hormones have been implicated in failed reproduction (Moberg 1987, Rivest and Rivier 1995) and altered metabolism (Elasser *et al*. 2000), immune competence (Blecha 2000) and behavior.

OGVs will produce sound frequencies in the hearing range of blue, fin, sei, sperm, and humpback whales. The sound pressures levels will be transient and will attenuate to background ambient sound levels a short distance from the OGV; however, even transient noise can affect the ability of whales to communicate, especially when whales may be far apart from each other. Individuals may react to noise generated, or the presence of, OGVs by changing the direction of their movements, decreased communication, or increasing their swimming speed. These reactions could increase an individuals' energy budget. Consequently, the effects of noise are likely to be temporary but recurring. As a result, we anticipate that blue, fin, sei, sperm, and humpback whales will alter their behavior as a result of noise occurring from OGV traffic, but these behavioral effects will be minor and transitory, and won't result in physical injury or mortality of any whales.

Veirs *et al*., 2016, found that noise from large ships extends into frequencies used by SRKW for echolocation. This means that vessels can impair the whales' ability to find food and interact with each other. Recent evidence indicates there is a higher energetic cost of surface-active behaviors and vocal effort resulting from vessel disturbance (Williams *et al*. 2006; Noren *et al*. 2012; Noren *et al*. 2013; Holt *et al*. 2015). Holt et al. (2021a) found that the probability of capturing prey for SRKW increased as salmon abundance increased, but decreased as vessel speed increased. SRKW made longer dives to capture prey and descended more slowly during these foraging dives while vessels emitted navigational sonar, Whales descended more quickly when noise levels were higher and vessel approaches were closer. Further, Holt et al. (2021b) found a sex and vessel distance effect on these foraging dives, suggesting that females and males respond differently to nearby vessels with female killer whales at greater risk to close approaches by vessels. These studies provide evidence of behavioral responses by SRKW resulting from vessels and noise.

SRKW are known to forage off the Columbia River plume (i.e., within the action area). Numerous studies have documented the importance of Columbia River salmon populations

(Chinook salmon, in particular) to SRKW in the action area (Zamon *et al*. 2007; Ward *et al*. 2013; Hanson *et al.* 2021; Couture *et al*. 2022). The NEXT facility's increased tanker traffic (about 171 OGVs per year) would add about one additional vessel to the action area every other day. This increases the likelihood that SRKW will encounter noise from these vessels when the whales are in the area. Thus, the likelihood of OGVs disturbing SRKW feeding and communication is reasonably likely. Although none of the noise generated from NEXT-associated ships is expected to cause direct physical injury (i.e. eardrum damage), NMFS concludes that the proposed action will result in periodic harm to SRKW in the action area. Thus, noise from OGVs is likely to adversely affect individual SRKW over the course of the 50-year NEXT facility operation by disrupting their ability to find and obtain prey in known foraging habitat.

Sea turtles are thought to be far less sensitive to noise effects than marine mammals. Leatherback sea turtles may be exposed to potentially disturbing levels of sound during OGV transit. Temporary, short-term behavioral effects, such as decreased ability to monitor its acoustic environment, cause habituation, or sensitization (decreases or increases in behavioral response) (Piniak *et al.*, 2012), during OGV transit are possible. However, a single individual's exposure to OGV noise is likely to be transient, as all of the turtles in the action area are migratory, and a single individual is not likely to be within the zone of impact year-round. Thus, effects to turtles from noise is insignificant.

Wetland mitigation

The wetland mitigation site will restore approximately 466.1 acres of wetlands and waterways southwest of the proposed facility approximately 0.25 miles south of the impact area on approximately 590 acres that will be owned by the applicant (ELS 2023). Waterway impacts will be mitigated at this site by creating dendritic channels within the restored wetlands. The mitigation plan objective is to offset permanent impacts to wetlands and waterways by restoring hydrology and vegetation at the mitigation site to improve wetland functions. Restoration actions will include riparian plantings with native plants. Wetland mitigation is not anticipated to appreciably benefit or negatively impact the listed species considered in this opinion as there is no planned surficial connection to waterways where these species occur.

2.5.2 Effects on Critical Habitat

As mentioned in Section 2.2, portions of the action area include designated critical habitat for each of the 13 ESA-listed ESUs/DPSs of salmonids within the LCR, the southern DPS of green sturgeon, the southern DPS of eulachon, SRKW, two DPSs of humpback whale, and leatherback turtles. Critical habitat has not been designated for the following species: blue whale, fin whale, sei whale, and sperm whale. Critical habitat includes Physical and Biological Features (PBFs) necessary to support various life stages of salmonid and non-salmonid listed species (i.e., rearing, migration). NMFS reviews effects on critical habitat affected by a proposed action by examining how the PBFs of critical habitat would be altered, and the duration of such changes.

Effects to habitat features include enduring impediments to migration, increased predation, decreased forage opportunities (i.e., prey), and diminishment of water quality upon juvenile

salmonids and eulachon, and diminished prey and water quality upon green sturgeon. Timing, duration, and intensity of the effects on critical habitat are considered in the analysis below.

Effects on critical habitat for salmonids, eulachon, and green sturgeon

Three of the six PBFs established for salmonid critical habitat are present in the action area. Those PBFs are:

1. Freshwater rearing sites with water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; water quality and forage supporting juvenile development; and natural cover such as shade, submerged and overhanging large wood, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks.

2. Freshwater migration corridors free of obstruction with water quantity and quality conditions and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels, and undercut banks supporting juvenile and adult mobility and survival. These features are essential to conservation because without them juveniles cannot use the variety of habitats that allow them to avoid high flows, avoid predators, successfully compete, begin the behavioral and physiological changes needed for life in the ocean, and reach the ocean in a timely manner.

3. Estuarine areas free of obstruction with water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh-and saltwater; natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels; and juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation.

All three of the PBFs established for the southern DPS of eulachon are present within the action area. Those PBFs are:

1. Freshwater spawning and incubation sites with water flow, quality and temperature conditions and substrate supporting spawning and incubation, and with migratory access for adults and juveniles.

2. Freshwater and estuarine migration corridors associated with spawning and incubation sites that are free of obstruction and with water flow, quality and temperature conditions supporting larval and adult mobility, and with abundant prey items supporting larval feeding after the yolk sac is depleted.

3. Nearshore and offshore marine foraging habitat with water quality and available prey, supporting juveniles and adult survival. Eulachon prey on a wide variety of species including crustaceans such as copepods and euphausiids (Hay and McCarter, 2000; WDFW and ODFW, 2001), unidentified malacostracans (Sturdevant, 1999), cumaceans (Smith and Saalfeld, 1955) mysids, barnacle larvae, and worm larvae (WDFW and ODFW, 2001).

Critical habitat for green sturgeon extends within about 25 miles of the proposed NEXT facility. Three freshwater PBFs established for green sturgeon are present in the action area:

1. Abundant prey items for larval, juvenile, subadult, and adult life stages.

2. Water quality, including temperature, salinity, oxygen content, and other chemical characteristics necessary for normal behavior, growth, and viability of all life stages. Suitable water quality would also include water containing acceptably low levels of contaminants. Water with acceptably low levels of such contaminants (i.e., pesticides, organochlorines, elevated levels of heavy metals, etc. would protect green sturgeon from adverse impacts on growth, reproductive development, and reproductive success.

3. Sediment quality (i.e., chemical characteristics) necessary for normal behavior, growth, and viability of all life stages. This includes sediments free of elevated levels of contaminants (e.g., selenium, polyaromatic hydrocarbons (PAHs), and organochlorine pesticides) that may adversely affect green sturgeon. Based on studies of white sturgeon, bioaccumulation of contaminants from feeding on benthic species may adversely affect the growth, reproductive development, and reproductive success of green sturgeon.

Noise

Underwater noise will disrupt normal migration routes of juvenile salmonids and eulachon. Thus, underwater noise will affect PBF #1, #2, and #3 for all salmonid ESUs/DPSs and PBF #1 and #2 for eulachon. Fish can detect and respond to underwater sound greater than 150 dB by altering their behavior, including delaying migration and increasing their susceptibility to predation (NMFS 2023a). Noise from ships and barges off-loading equipment in preparation for construction are temporary but would occur periodically until construction is complete (one to two years). This would occur whenever vessels moor or travel from the NEXT facilities to deliver and remove construction related equipment. Enduring effects of underwater noise would result from about 171 ships and barges to the NEXT facility to process biofuel for at least the next 50 years (the anticipated life of the facility). The effects may include the onset of behavioral disturbances such as acoustic masking (Codarin *et al*., 2009), startle responses and altered swimming (Neo *et al*., 2014), abandonment or avoidance of the area of acoustic effect (Mueller, 1980; Picciulin *et al*., 2010; Sebastianutto *et al*. 2011; Xie *et al*. 2008) and decreased pursuit of prey and increased vulnerability to predators (Simpson *et al*., 2016).

Migration obstruction

The presence of barges or ships at the dock will increase over-water shade impairing critical habitat for all salmonid ESUs/DPSs and the sDPS of eulachon. Thus, over-water shade will affect PBF #1, #2, and #3 for all salmonid ESUs and PBF #1 and #2 for eulachon. Shade effects on fish are well known. The moored vessels would create areas of cover that decrease water velocity and create shade. Shade from the moored vessels can delay migration of juvenile salmonids as individual fish will stall active migration when confronted with over-water shade and deeper water (Heiser and Finn, 1970; Able *et al*., 1998; Simenstad, 1988; Southard *et al*., 2006; Toft *et al*., 2013). One consequence of juvenile salmon avoiding over-water vessels is that some of them will swim around the structure (Nightingale and Simenstad, 2001). Swimming

around structures lengthens the migration distance and is correlated with increased predation (Faler *et al*., 1988; Isaak and Bjornn, 1996; Martinelli & Shively, 1997; Carrasquero, 2001; Tabor *et al*., 1993).

The moorage of ships and barges would coincide with juvenile salmonid and eulachon presence, and it is likely to disrupt normal fish behavior. Harm to this PBF would result from about 171 ships or barges moored at the NEXT facility to process biofuel for at least the next 50 years (the anticipated life of the facility). Most individual juvenile salmonids will delay their migrations but will ultimately pass the moored vessels. We anticipate that tens of thousands of individual juvenile salmon, and egg and larval life history stages of eulachon will be consumed by lie-in-wait predators associated with moored vessels over the duration of NEXT facility operations lasting 50 years or longer. Therefore, we expect that moorage at the NEXT facility would affect the value or function of the migration and predation PBFs for salmonids and eulachon within the action area.

Water Quality
Water quality is an essential element of the PBFs of salmonid, eulachon, and green sturgeon. The water quality effects from wastewater and stormwater are expected to affect the critical habitat of all ESUs/DPSs of salmonid species (PBFs #1, #2, and #3), eulachon (PBFs #1, #2, and #3), and green sturgeon (PBFs #1, #2, and #3). The proposed permit would authorize the NEXT facility to develop a new biofuel processing plant on approximately 122.5 acres. Effects to water quality due to construction and operations can include the generation of turbidity and releases of contaminated stormwater and wastewater, which would include PAHs, 6PPD-Q, heavy metals, herbicides, and other toxic chemicals.

Turbidity - Temporary and localized increases in turbidity are expected in the immediate vicinity of the NEXT facility during initial construction activities (one to two years). However, the contractor will be responsible for monitoring turbidity levels at the point of compliance (300 ft. from activity) as a condition of the Section 401 Water Quality Certification. As a result, the area of effect from construction runoff will be far more localized than the entirety of the action area and will minimize potential impacts. As the currents within the mainstem LCR are swift, turbidity would likely disperse quickly and the function of this PBF element would rapidly return to its existing condition for salmonids and eulachon.

Releases of contaminated stormwater and wastewater - The NEXT facility would produce and route wastewater and stormwater containing toxic chemicals, which are not completely removed by treatment processes. Wastewater would be collected and, once treated, the wastewater and stormwater would be comingled and processed prior to entering the NEXT wastewater collection system. Stormwater runoff will be routed by sheet flow through multiple drainage ditches, waterways, and constructed wetlands. Both wastewater and stormwater would be released into McLean Slough and ultimately routed to the Columbia River. Incompletely treated discharge would be released continuously throughout the year. Wastewater and stormwater discharges would include petroleum hydrocarbons, PAHs, total suspended sediments, heavy metals, 6PPD-q, and glyphosate. Effects could occur in the water, sediments, and most can bioaccumulate in fish and their prey.

Contaminants in sediments and dissolved in-water can have varying levels of toxicity in fish, and the discharge (wastewater) and recurring suspension (stormwater) of these contaminants would degrade the water quality PBF for salmonids, eulachon, and green sturgeon for the time that these toxins were resuspended within large concentrations in the water column. Concentrations of chemicals in suspension would vary with the specific chemical and timing of release. Fall freshets are likely to carry the highest concentration of chemicals released due to stormwater, whereas wastewater discharge would likely be continuous throughout the life of the NEXT facility, an estimated 50 years. Therefore, we do not anticipate that contaminants in the water column would return to pre-NEXT facility levels. Additionally, some contaminants will accumulate in the benthos, which will impair forage opportunities of green sturgeon into their designated critical habitat, 25 miles downstream of the NEXT facility. The swift currents of the Columbia River will likely disperse some chemicals in the water column as they drift downstream, and some will accumulate in substrates. Degraded water quality associated with this PBF element will persist into the foreseeable future.

Herbicide applications - Surface water contamination with herbicides will occur when herbicides are applied intentionally or accidentally into ditches, irrigation channels or other bodies of water, or when soil-applied herbicides are carried away in runoff to surface waters. Under the proposed action, some formulas of herbicide can be applied within the bankfull elevation of ponds and waterways, in some cases up to the water's edge. Any juvenile salmonid or larval eulachon adjacent to the NEXT facility outfalls are more likely to be exposed to herbicides as a result of overspray, inundation of treatment sites, percolation, surface runoff, or a combination of these factors. Stehr *et al.* (2009) found that the low levels of herbicide delivered to surface waters are unlikely to be toxic to the embryos of ESA-listed salmonids. However, mortality or sub-lethal effects such as reduced growth and development, decreased predator avoidance, or modified behavior are likely to occur. The degradation of herbicides is expected to occur prior to reaching green sturgeon critical habitat downstream. Due to the swift current within the LCR, herbicides would likely disperse quickly within the water column, returning this PBF element to its existing condition in a short period of time and in a short distance from the outfall.

Water quality summary - The enduring diminishment of water quality include the chronic and system-wide introduction and extended existence of contaminants from wastewater and stormwater. Increased levels of PAHs, oils, 6-PPD-Q, and other contaminants will be widely dispersed, and can have detrimental effects at very low levels of exposure either directly or indirectly through the consumption of prey contaminated by their own exposure in the water column. This will impair the value of critical habitat for growth and maturation of each of the 13 salmonid ESUs/DPSs, sDPS eulachon, and sDPS green sturgeon. Accordingly, we consider the combined effects of temporary and enduring effects on water quality will create an incremental and chronic diminishment of the water quality PBF for all of the listed species with designated critical habitat in the Columbia River portion of the action area, throughout the new useful life of the NEXT facility (about 50 years).

Effects on critical habitat for SRKW, humpback whales and leatherback turtles

NMFS identified three PBFs essential for the conservation of SRKW:

1. Water quality to support growth and development.

2. Prey species of sufficient quantity, quality, and availability to support individual growth, reproduction and development, as well as overall population growth.

3. Passage conditions to allow for migration, resting, and foraging.

NMFS identified one PBF for the two DPSs of humpback whale and leatherback turtles.

1. Essential prey resources.

Oceanic biofuel or feedstock spill risk - An actual large spill would affect water quality and prey resources in the vicinity of a spill that could indirectly affect SRKW, humpback whales, and leatherback turtles through ingestion of toxics directly through the water column or through contaminated prey. Therefore, the proposed action indirectly adversely affects SRKW PBFs #1 and #2, and humpback whale and leatherback turtle PBF #1 by incrementally increasing biofuel or feedstock spill risk in the action area. The addition of about 171 vessels by NEXT-associated ships and barges in the action area increases the probability of an oil spill. However, the overall risk of a spill is very low. Further, the toxicity of biofuels is far less than crude oil and it disperses more quickly. We conclude that the risk to SRKW PBFs #1 (water quality) and #2 (prey resources), and humpback whale and leatherback turtle PBF #1 are minor.

Vessel noise - Vessel noise associated with the proposed action directly affects SRKW PBF #2 (prey resources) and PBF #3 (passage conditions), and humpback whale PBF #1 (prey resources). The impacts to prey resources are through acoustic masking. SRKW and humpback whales produce a wide variety of clicks, whistles, and pulsed calls (Schevill and Watkins 1966, Ford 2009, Thomsen *et al*. 2001) that are used for communication among individuals. Viers *et al*. (2015) found that noise from large ships extends into frequencies used by SRKW and humpback whales for echolocation. Vessel noise and the physical presence of ships can interrupt SRKW and humpback whale movement, communication, and feeding efficiency. We expect that NEXT tanker traffic would cause high stress and disturbance to feeding because NEXT-associated ship traffic disturbance coincides with whale presence. Therefore, vessel noise adversely affects critical habitat PBF #2 (prey resources) and PBF #3 (passage conditions), but does not adversely modify critical habitat. Vessel noise is not anticipated to diminish leatherback turtle critical habitat.

For SRKW, discharge events from stormwater and wastewater would reduce quality and quantity of prey including juvenile Chinook salmon (PBF #2). As PS Chinook salmon are a PBF of SRKW critical habitat, their repeated/chronic exposure to contaminants in successive cohorts, directly through diminished water quality, and via contaminated prey, both described above, results in a diminishment of the forage PBF of SRKW critical habitat. Both quantity and quality of prey will slightly decline as a result of impacts to water quality, as these effects are likely to

cause latent health effects on salmon that slightly reduce adult abundance, and also reduce the quality of adult salmon that do return and serve as SRKW prey, due to bioaccumulated contaminants.

Given the total quantity of prey available to SRKWs throughout their range numbers in the millions, the reduction in prey related to short-term construction effects from the proposed action is extremely small. Therefore, NMFS anticipates that the short-term reduction of Chinook salmon from temporary effects would have little effect on SRKWs. However, episodic and enduring declines of SRKW's prey as a result of the proposed action is also expected. Sufficient quantity, quality, and availability of prey are an essential feature of the critical habitat designated for Southern Residents. Increasing the risk of a permanent reduction in the quantity and availability of prey, and the likelihood for local depletions in prey populations in multiple locations over time, reduces the conservation value of critical habitat for SRKWs.

2.6. Cumulative Effects

"Cumulative effects" are those effects of future State or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the Federal action subject to consultation [50 CFR 402.02]. Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

Some continuing non-Federal activities are reasonably certain to contribute to climate effects within the action area. However, it is difficult if not impossible to distinguish between the action area's future environmental conditions caused by global climate change that are properly part of the environmental baseline *vs.* cumulative effects. Therefore, all relevant future climate-related environmental conditions in the action area are described earlier in the discussion of Rangewide Status of the Species and Critical Habitat section (Section 2.2).

However, it is reasonably certain that over the operational life of the project, that climate effects such as modified water temperatures, altered river hydrograph, and shifting salinity will collectively exert additional influence on habitat quality and reduce carrying capacity. NMFS expects State and private activities near and upriver from the proposed action will contribute to cumulative effects in the action area. Therefore, our analysis considers 1) effects caused by specific future non-federal activities in the action area; and 2) effects in the action area caused by future non-federal activities in the Columbia basin.

Future upland development activities lacking a federal nexus are expected to result in increased pollution-generating impervious surface, runoff, and non-point source discharges. Human population growth in Clark and Multnomah Counties are likely to remain high, which will require greater infrastructure development to support and sustain this trend. State, county, and city regulations should minimize and mitigate for the adverse effects of this development so that the overall environmental quality of the action area remains constant, albeit degraded relative to its restored condition.

The legacy of resource-based industries (e.g., agriculture, hydropower facilities, timber harvest, fishing, and metal and gravel mining) caused long-lasting environmental changes that harmed

ESA-listed species and their critical habitats. Stream channel morphology, roughness, and cover, estuarine rearing habitats, wetlands, floodplains, riparian areas, water quality, fish passage, and habitat refugia have been degraded throughout the LCR basin. Those changes reduce the ability of populations of ESA-listed species to sustain themselves in the natural environment by altering or interfering with their behavior in ways that reduce their survival throughout their life cycle.

While widespread degradation of aquatic habitat associated with intense natural resource extraction is no longer common, ongoing land management actions are likely to continue to adversely affect the estuary and delay natural recovery of aquatic habitat in the CR basin including the action area. This trend is somewhat countered by non-federal aquatic habitat restoration occurring in the LCR. The Lower Columbia River Estuary Partnership has over 100 regional partners in the LCR and has completed 284 projects with a total of 35,342 acres of habitat restored (LCREP, 2024). Projects include land acquisitions and conservation easements, adding large logs to streams to create fish habitat, planting trees to shade and cool streams, and removing barriers to fish passage. Still, when considered together, the net cumulative effects are likely to have an adverse effect on ESA-listed fish within the action area.

We are reasonably certain that the States of Washington and Oregon will continue to issue and renew NPDES permits to public and private applicants to discharge stormwater and wastewater to tributaries of the Columbia River and to the Columbia River. These permits add contaminants to the lower Columbia River and estuary that are similar or the same as the contaminants discussed above. Likewise, state, local and private parties will continue to increase the area of impervious surfaces that create stormwater that ultimately enters the Columbia River. Ports and industrial facilities on the Columbia River will continue to import and export products delivered by OGVs, which will cause juvenile salmon to be killed on wake wave stranding beaches on the Columbia River and cause marine mammals and turtles to be struck and injured or killed in the Pacific Ocean.

2.7. Integration and Synthesis

The Integration and Synthesis section is the final step in assessing the risk that the proposed action poses to species and critical habitat. In this section, we add the effects of the action (Section 2.5) to the environmental baseline (Section 2.4) and the cumulative effects (Section 2.6), taking into account the status of the species and critical habitat (Section 2.2), to formulate the agency's biological opinion as to whether the proposed action is likely to: (1) reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing its numbers, reproduction, or distribution; or (2) appreciably diminish the value of designated or proposed critical habitat as a whole for the conservation of the species.

2.7.1 ESA Listed Species – Integration and Synthesis

Salmon and steelhead

Eleven of the salmon and steelhead species addressed by this consultation are "threatened." Upper Columbia River spring-run Chinook salmon, and Snake River sockeye salmon are "endangered". The status of the constituent populations range from very high risk to moderate risk of extirpation. The total abundance of all salmon and steelhead species is very low relative to historical levels. Their historic range and spatial structure is curtailed or modified. Multiple

limiting factors prevent natural fish production from significantly increasing productivity, abundance and diversity.

The environmental baseline includes developed urban areas, land use practices, degraded estuarine and nearshore habitat, degraded floodplain connectivity and function, altered streamflow and channel complexity, reduced large wood and substrate recruitment, predation, contaminants, and OGV wake wave stranding. The proposed NEXT facility would likely operate for decades. Climate change is likely to include greater variability in Pacific Northwest river systems, more frequent droughts, larger floods and higher temperatures. Estuaries and oceans will have higher water temperatures, decreased salinity and increased acidity. The (non-federal) cumulative effects in the coming decades are expected to be incrementally negative for habitat conditions, even when recovery actions are considered, based on the widespread costs of degradation relative to the local benefits of restoration.

We added the effects of the proposed action on species and habitat to determine the likely changes in abundance, productivity, spatial structure, and genetic diversity of the affected species and the implication for species viability. Endangered UCR spring-run Chinook salmon and SR sockeye salmon along with threatened SR spring/summer-run Chinook salmon, SR fall-run Chinook salmon, MCR steelhead, UCR steelhead and SRB steelhead will pass through the action area as larger juveniles, use a greater variety of (deeper) habitats, and swim faster than fish that originate in the Lower Columbia River and Willamette River. Still, all salmon species will be affected by the persistent moorage-associated effects of the proposed action, and all species of salmonids, eulachon, and green sturgeon will be affected by the water quality impairments resulting from the NEXT facility. Salmonid fry typically originating from the Willamette and lower Columbia rivers and eulachon larvae and eggs will be subjected to increased wake stranding effects. LCR and UWR Chinook, LCR and WR steelhead, LCR coho and CR chum salmon rely more on the shallow water in the action area and thus have more exposure to the effects of the action, including noise and migration obstruction. The increase in LCR contaminant mass from NEXT wastewater and stormwater outfalls and the increase in wake wave stranding from the OGVs carrying feedstocks to or product from the NEXT facility, added to the environmental baseline and cumulative effects, is likely to reduce the current abundance of SR, CR and UWR salmonid ESU/DPSs, sDPS eulachon, and sDPS green sturgeon.

Columbia River estuary critical habitat has high conservation value because of the critical function it serves to species using it for migration to and from spawning areas and for rearing. The critical habitat quality and quantity is limited by water quality, altered hydrology, lack of floodplain connectivity and shallow-water habitat, and lack of complex habitat to provide forage and cover. Most adverse effects to the quality and function of critical habitat PBFs from this project will take place in a small part of the Columbia River. The effects on water quality from stormwater and wastewater contaminants that escape drainage ponds will accumulate and persist for decades. This adverse effect to water quality does not substantially alter the function of the critical habitat at the action area scale, or at the 5th-level HUC scale.

Marine mammals and turtles
The proposed action affects Central America and Mexico humpback, blue, fin, sperm, and sei whale species (collectively referred to as large whale species) with incrementally increased ship strike risk and SRKW with increased noise. In the Effects of the Action section, we assessed each of these risks individually in light of each species' status in the action area, its range, abundance, life history characteristics, trajectory for recovery, key limiting factors, etc., and vulnerability to the risks. Those analyses were based heavily on information from the species' listings, recovery plans, and 5-year status reviews, if available. Individually, we found that each pathway of effect did not present a significant risk to the population of whales, although some individual large whales are likely to be directly affected as a result of ship strikes and SRKW affected as result of noise in the action area.

For all of the large whale species, ship strikes are identified as threats to varying degrees. For the coastal species, blue whales, humpback whales, and fin whales are most susceptible to ship strikes. For SRKW, vessel noise is identified as a threat. Although effects to individual whales is likely, we found that increased vessel strike risk to large whales and increased vessel noise risk to SRKW within the action area would likely not have bearing on the population trends of these whales, primarily because all of these listed whale species are sparsely distributed in the action area (or the relative numbers of individuals that frequent the action area is small in proportion to the respective populations (e.g. Mexico DPS humpbacks) and the action area is a very small portion of whales' range. Taking all of these threats together, in light of the status of each species, the environmental baseline, the effects of the action, and cumulative effects, we conclude that the proposed action does not appreciably reduce the likelihood of both the survival and recovery of the listed large whale species.

The proposed action results in periodically increased risk of vessel collisions to leatherback turtles. Climate change will continue to threaten leatherbacks with episodic, recurring events in the action area (e.g., ocean cycles, climate change, storms, and natural mortality) will continue to influence leatherback sea turtles and may increase in frequency and/or severity as has been observed in recent years. Cumulative effects associated with increasing human population will also continue to affect leatherbacks (e.g. water quality degradation, increased boating). Because leatherback turtles occur in low abundance in the action area, the limited exposure of individual leatherback turtles to the adverse effects of the proposed action presents an extremely small additional risk the western Pacific leatherback sea turtle population. Given the best available information, we conclude that the proposed action is likely to harm individual leatherback turtles, but is not likely to appreciably reduce the likelihood of survival or recovery of this species at the global scale (and at the West Pacific population scale). This conclusion is made in consideration of the environmental baseline, status of the species, direct and indirect consequences of the proposed action, together with cumulative effects.

2.7.2 Critical Habitat – Integration and Synthesis

Salmon, steelhead, eulachon, and green sturgeon
The environmental baseline for CR, SR, and WR salmon critical habitat in the action area is degraded, primarily from water quality impacts from human development and extensive shoreline armoring on the Columbia River basin. Climate change presents a great threat to the

condition of the riverine and estuarine habitat, as sea level rise and hydrology changes to the basin could bring further loss of shoreline habitat and result in additional shoreline armoring. As described in detail in Section 2.5, the tangible effects of the project on salmonid, eulachon, and to a lesser extent, green sturgeon critical habitat are minor. These include ship noise, migration obstructions, and contaminants (PAHs, 6PPD-Q, heavy metals, herbicides, and other toxic chemicals). Together the effect of the action, when added to the environmental baseline and cumulative effects, does not appreciably diminish the value of critical habitat for the conservation of CR, SR, or WR salmonids. We draw the same conclusions for eulachon and green sturgeon. Despite degraded baseline conditions, uncertainty from climate change, and cumulative effects, the additive effects of the action do not appreciably diminish the value of critical habitat for the conservation of these designated critical habitats in the action area.

SRKW, Mexico and Central America humpback whale, leatherback turtle
The proposed action directly affects passage conditions for SRKW (SRKW PBF #3) from ship noise, and humpback whales and leatherback turtles (PBF #1) from increased ship strike in some years. The physical presence of ships can interrupt SRKW and humpback whale movement, communication, and feeding efficiency. The NMFS expects a general increase of OGV vessels to occur with the proposed action decreasing critical habitat for these species.

Stormwater and wastewater would reduce quality and quantity of prey for SRKW, including Chinook salmon (PBF #2). The repeated and chronic exposure to contaminants in successive juvenile Chinook salmon cohorts, directly through diminished water quality, and via contaminated prey, both described above, results in a diminishment of the forage PBF of SRKW critical habitat. Both quantity and quality of prey will slightly decline as a result of impacts to water quality and these effects are likely to slightly reduce adult salmon abundance, and also reduce the quality of adult salmon that do return and serve as SRKW prey, through bioaccumulated contaminants.

Considering the combined effects of the action together with baseline conditions and cumulative effects, we conclude that the proposed action will not appreciably diminish the value of designated or proposed critical habitat for the conservation of these species.

2.8. Conclusion

After reviewing and analyzing the current status of the listed species and critical habitat, the environmental baseline within the action area, the effects of the proposed action, the effects of other activities caused by the proposed action, and the cumulative effects, it is NMFS' biological opinion that the proposed action is not likely to jeopardize the continued existence of:

1. Lower Columbia River Chinook salmon
2. Upper Willamette River Chinook salmon
3. Upper Columbia River spring Chinook salmon
4. Snake River spring/summer Chinook salmon
5. Snake River fall Chinook salmon
6. Lower Columbia River coho salmon
7. Columbia River chum salmon
8. Snake River Sockeye salmon

9. Lower Columbia River steelhead
10. Middle Columbia River steelhead
11. Upper Columbia River steelhead
12. Upper Willamette River steelhead
13. Snake river Basin steelhead
14. Eulachon sDPS
15. Green sturgeon sDPS
16. Southern Resident killer whale
17. Humpback whale-Central America DPS
18. Humpback whale Mexico DPS
19. Leatherback sea turtle

or destroy or adversely modify their designated critical habitat.

After reviewing and analyzing the current status of the listed species, the environmental baseline within the action area, the effects of the proposed action, the effects of other activities caused by the proposed action, and the cumulative effects, it is NMFS' biological opinion that the proposed action is not likely to jeopardize the continued existence of:

20. Blue whale
21. Fin whale
22. Sei whale
23. Sperm whale

Critical habitat has not been designated or proposed for blue whale, fin whale, sei whale, or sperm whale; therefore, none was analyzed.

2.9. Incidental Take Statement

Section 9 of the ESA and Federal regulations pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without a special exemption. "Take" is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. "Harm" is further defined by regulation to include significant habitat modification or degradation that actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns, including breeding, spawning, rearing, migrating, feeding, or sheltering (50 CFR 222.102). "Harass" is further defined by interim guidance as to "create the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering." "Incidental take" is defined by regulation as takings that result from, but are not the purpose of, carrying out an otherwise lawful activity conducted by the Federal agency or applicant (50 CFR 402.02). Section 7(b)(4) and section 7(o)(2) provide that taking that is incidental to an otherwise lawful agency action is not considered to be prohibited taking under the ESA if that action is performed in compliance with the terms and conditions of this ITS.

This incidental take statement (ITS) provides a take exemption for the action agency and applicant for any take caused by the effects of the action. For salmonids, green sturgeon, and eulachon, those effects include harm and injury caused by water quality impacts from stormwater

and wastewater-associated contaminants, predation impacts from migration obstructions, and prey impacts from noise resulting from ships transiting the action area and moored at the NEXT facility, and injury and death caused by wake stranding.

This ITS provides take exemption for the action agencies and applicants for any incidental take caused by the consequences of the proposed action. This ITS does not include an exemption for incidental take of marine mammals caused by third party activities associated with OGV traffic, such as ship strikes for humpback, blue, fin, sperm, and sei whale species (collectively referred to as large whale species), and vessel noise for SRKW in the Pacific Ocean, from vessels arriving or departing from the NEXT facility. An exemption is not provided for the primary reason that the ESA does not allow NMFS to exempt incidental take of marine mammals unless a permit authorizing the take is requested and obtained under the MMPA.

2.9.1 Amount or Extent of Take

For incidental take of ESA-listed fish, take in the form of harm, injury and death cannot be accurately quantified as a number of individuals, because the presence, distribution, and abundance of the individuals in the action area is highly variable over time, and is influenced by factors that cannot be easily predicted, observed, or monitored. Additionally, the duration of exposure is highly variable based on species behavior patterns, and the wide variability in numbers exposed and duration of exposure creates a range of responses, many of which cannot be observed without research and rigorous monitoring. There is no practicable means to monitor for the number of fish taken through elevated sound levels, increased predation from obstructed migration, and reduced water quality. In these circumstances, we will identify an "extent" of take which is a habitat indicator that will serve as a surrogate for incidental take. The surrogate is proportionally and causally related to the amount of harm that would result, and each surrogate provided below may be effectively monitored for compliance and re-initiation purposes. Thus, they will serve as a meaningful reinitiation trigger.

In addition, the NEXT facility will increase vessel traffic on the Columbia River by up to 171 OGV round trips per year. In turn, the additional OGV trips are expected to proportionally increase wake stranding events and are expected to result in injury and death to juvenile salmonids and eulachon. At this time, there is limited understanding on the variables that contribute to wake stranding events and the limited data associated with wake stranding is considered insufficient to provide an exact take estimate. NMFS' analysis and no jeopardy determination is based on potential wake stranding assuming the maximum number of ship trips associated with the NEXT facility. NMFS is using the number of OGV trips (which translates to potential wake stranding incidents) as a surrogate for quantifying take consistent with 50 CFR § 402.14(i)(1)(i). Using OGV trips as a surrogate establishes a clear standard for determining when the level of anticipated take has been exceeded. For example, if the OGV round trips supported by the NEXT facility exceeds 171 per year then we expect that anticipated effects and resulting take would also be exceeded. Thus, even though the surrogate mirrors the maximum amount of assumed vessel traffic, it nevertheless functions as an effective check on the ongoing validity of the jeopardy analysis (which underpins the take exemption) because it is an annual measurement that can be monitored by the applicant. That means there is an opportunity each year to check whether the assumption of maximum 171 vessels round trips per year has been exceeded. Thus,

we believe that OGV trips is an easily assessed, effective and reliable take surrogate that meets the legal standards as they relate to a reinitiation trigger.

For leatherback sea turtles, NMFS is using the same surrogate as for wake stranding, i.e., a maximum of 171 OGV round trips per year. This surrogate is causally linked to the incidental take because the risk of ship strikes increases as the number of vessel trips does. In addition, for the reasons set out above with respect to wake stranding, this surrogate establishes a clear standard for determining when the level of anticipated take has been exceeded and functions as an effective check on the ongoing validity of the jeopardy analysis, which underpins the take exemption.

For whales in this Opinion, the proposed action is reasonably certain to harm individual large whales by ship strikes and SRKW by noise due to vessel traffic associated with operation of the proposed action. The best available incidental take surrogate associated with shipping is the number of OGV round trips per year, i.e. a maximum of 171 OGV round trips per year. This surrogate is causally linked to the incidental take that will occur because an increase in vessel traffic translates into a proportional increase in the risk of ship strikes to these species. In addition, for the reasons set out above with respect to wake stranding, this surrogate establishes a clear standard for determining when the level of anticipated take has been exceeded and functions as an effective check on the ongoing validity of the jeopardy analysis, which underpins the take exemption. As explained in the introduction to this section, the ITS does not include an exemption for any future incidental take of marine mammals caused by third party activities associated with OGV traffic.

In the biological opinion, NMFS determined that incidental take is reasonably certain to occur and the best available indicators for the extent of take are as follows:

1. Take in the form of harm of ESA-listed salmonids, green sturgeon, and eulachon[4] from underwater noise and migration obstruction during docking and mooring, at the NEXT facility by ships and tug boats with associated barges. The extent of take for underwater noise and migration obstruction for the NEXT facility is a total of 171 vessels annually. This surrogate indicator of take is both easily observable and causally linked to incidental take by hydroacoustic impacts, and physical presence of the vessels because the amount of take increases incrementally with each trip. It functions as meaningful reinitiation trigger because it can be readily monitored, thus reinitiation could be triggered at any time during the operation of the facility.

2. Take in the form of harm and injury of ESA-listed salmonids, eulachon,[5] and green sturgeon from diminished water quality due to water column suspension and benthic settlement of contaminants while discharging stormwater and wastewater. The extent of

[4] The NMFS has not yet promulgated an ESA section 4(d) rule prohibiting take of threatened eulachon. Anticipating that such a rule may be issued in the future, we have included a prospective incidental take exemption for eulachon. The elements of this ITS for eulachon would become effective on the date on which any future 4(d) rule prohibiting take of eulachon becomes effective. Nevertheless, the amount and extent of eulachon incidental take, as specified in this statement, will serve as one of the criteria for reinitiation of consultation pursuant to 50 C.F.R. § 402.16(a), if exceeded.
[5] Ibid.

take is the 72.6 acres of impervious surfaces created by the development of the NEXT catchment. This surrogate indicator of take is both easily observable and causally linked to incidental take by the amount of contaminated area because a larger area would likely increase the amounts of contaminated water and sediment, and expose more listed fish to this degraded habitat condition. It functions as an effective reinitiation trigger because it is a clear, measurable limit that is easily monitored for exceedance, so reinitiation could be triggered at any time during the operation of the facility.

3. Take in the form of death and injury of ESA-listed salmonids and eulachon due to wake stranding events, turtles and large whale species due to vessel strikes, and SRKW due to vessel noise from an increase in vessel traffic of 171 OGVs. The extent of take for wake stranding and OGV strikes is the number of vessels that will access the NEXT facility. In this case take will be exceeded if more than 171 vessels dock at the NEXT facility, As explained above, the ITS does not include an exemption for any future incidental take of marine mammals by third party activities associated with OGV traffic.

2.9.2 Effect of the Take

In the biological opinion, NMFS determined that the amount or extent of anticipated take, coupled with other effects of the proposed action, is not likely to result in jeopardy to the species or destruction or adverse modification of critical habitat.

2.9.3. Reasonable and Prudent Measures

"Reasonable and prudent measures" refer to those actions the Director considers necessary or appropriate to minimize the impact of the incidental take on the species (50 CFR 402.02). The USACE shall ensure that the applicant:

1. Minimize incidental take caused by vessel noise and migration obstruction,
2. Minimize incidental take caused by contaminants released from stormwater and wastewater, and
3. Monitor and report the vessel use of the facility and NEXT- associated contaminants in discharge.

2.9.4. Terms and Conditions

In order to be exempt from the prohibitions of section 9 of the ESA, the federal action agency must comply (or must ensure that any applicant complies) with the following terms and conditions. The USACE or any applicant has a continuing duty to monitor the impacts of incidental take and must report the progress of the action and its impact on the species as specified in this ITS (50 CFR 402.14). If the entity to whom a term and condition is directed does not comply with the following terms and conditions, protective coverage for the proposed action would likely lapse.

The following terms and conditions implement reasonable and prudent measure 1:

1. Require the applicant to limit the length of time that ships and tugboats run their engines at the Port Westward dock to the minimum necessary to safely moor and disembark from the dock.
2. Require the applicant to record the number of vessels that moor and off-load feedstock and load biofuel from the NEXT facility and limit those vessels to 171 ships/barges annually.

The following terms and conditions implement reasonable and prudent measure 2:

1. Require the applicant to verify the total acreage of pollution-generating impervious surfaces (PGIS) created at the facility;
2. Report the final area of new PGIS.

The following terms and conditions implement reasonable and prudent measure 3:

1. Require the applicant to submit annual monitoring and construction reports to NMFS at the end of each calendar year, including reporting the number of vessels that accessed the NEXT facility and the acreage of impervious surfaces draining to the NEXT catchment during the calendar year. Send reports to:
   projectreports.wcr@noaa.gov
   Reference Project No.: WCRO-2023-00488
   cc: david.price@noaa.gov

2.10. Reinitiation of Consultation

This concludes formal consultation for the NEXT Renewable Fuels, Oregon, LLC Renewable Green Fuels Facility.

Under 50 CFR 402.16(a): "Reinitiation of consultation is required and shall be requested by the Federal agency or by the Service where discretionary Federal agency involvement or control over the action has been retained or is authorized by law and: (1) If the amount or extent of taking specified in the incidental take statement is exceeded; (2) If new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not previously considered; (3) If the identified action is subsequently modified in a manner that causes an effect to the listed species or critical habitat that was not considered in the biological opinion or written concurrence; or (4) If a new species is listed or critical habitat designated that may be affected by the identified action."

2.11. "Not Likely to Adversely Affect" Determinations

This assessment was prepared pursuant to section 7(a)(2) of the ESA, implementing regulations at 50 CFR 402 and agency guidance for preparation of letters of concurrence. As described in Section 2 or below, the applicant's BA had concluded that the proposed action would have no effect or is not likely to adversely affect the following species (Table 8):

Table 8. NMFS' disposition of species determined by the USACE as "may affect, not likely to adversely affect".

Species	USACE species determination	USACE critical habitat determination	NMFS species determination	NMFS critical habitat determination	Further described
sDPS Green sturgeon	NLAA	NE	LAA	LAA	Section 2, above
sDPS Eulachon	NLAA	NLAA	LAA	LAA	Section 2, above
Southern resident killer whale	NLAA	NLAA	LAA	LAA	Section 2, above
Western North Pacific gray whale	NLAA	N/A	NLAA	N/A	Section 3, below
North Pacific right whale	NLAA	NLAA	NLAA	NLAA	Section 3, below
Green sea turtles	NLAA	N/A	NLAA	N/A	Section 3, below
Loggerhead turtles	NLAA	N/A	NLAA	N/A	Section 3, below
Olive ridley sea turtles	NLAA	N/A	NLAA	N/A	Section 3, below
Guadalupe fur seals	NLAA	N/A	NLAA	N/A	Section 3, below

The applicable standard to find that a proposed action is not likely to adversely affect listed species or critical habitat is that all of the effects of the action are expected to be discountable, insignificant, or completely beneficial. Beneficial effects are contemporaneous positive effects without any adverse effects to the species or critical habitat. Insignificant effects relate to the size of the impact and should never reach the scale where take occurs. Discountable effects are those extremely unlikely to occur. The effects analysis in this section relies heavily on the descriptions of the proposed action and project site conditions discussed in Sections 1.3 and 2.4, and on the effects analysis presented in Section 2.5.

Gray whales – Western North Pacific DPS

Western North Pacific gray whales (*Eschrichtius robustus*) feed during summer and fall in the Okhotsk Sea off northeast Sakhalin Island, Russia, and in the Bering Sea off southeastern Kamchatka (2020 Stock Assessment Report). The Western North Pacific gray whales are rare, with a population estimate of only 290 individuals (2018 Stock Assessment Report). Recently, information from tagging, photo-identification, and genetic studies show that Western North Pacific gray whales have been observed migrating in the winter to the eastern North Pacific off the outer coast of North America from Vancouver, B.C to Mexico (Lang 2011, Mate *et al.* 2011, Weller *et al.* 2012). Although there is potential for Western North Pacific gray whales to occur in the action area, the available data on their migration patterns and low abundance indicate their occurrence is rare.

Due to the rare occurrence of Western North Pacific gray whales in the action area, it is extremely unlikely there would be an interaction between Western North Pacific gray whales and OGVs from the NEXT facility. Therefore, the risk of ship strikes and effects from vessel sound on Western North Pacific gray whales is discountable.

North Pacific right whales
North Pacific right whales (*Eubalaena japonica*) are rarely found off the U.S. West Coast and have primarily been documented foraging in the Bering Sea and the Gulf of Alaska, where critical habitat was designated in 2006. Due to the rare occurrence of North Pacific right whales in the action area it is extremely unlikely there would be an interaction between North Pacific right whales and OGVs from the NEXT facility. Therefore, the risk of ship strikes and effects from vessel sound on North Pacific right whales is discountable.

Green sea turtle- East Pacific DPS
Green sea turtles (*Chelonia mydas)* use open ocean convergence zones and coastal areas for benthic feeding of macroalgae and sea grasses. There are no known resting areas along the U.S. West Coast. In the eastern North Pacific, green sea turtles commonly occur south of Oregon, but have been sighted as far north as Alaska (NMFS and USFWS 1998b). Stranding reports indicate that the green sea turtle appears to be a resident in waters off San Diego Bay, California (NMFS and USFWS 1998b) and in the San Gabriel River and surrounding waters in Orange and Los Angeles counties, California. Although there is potential for green sea turtles to occur along the Washington and Oregon coasts, available data indicate that occurrence is likely to be rare in the action area. Due to the rare occurrence of green sea turtles in the action area it is extremely unlikely there would be encounters between green sea turtles and OGVs and that the risk of ship strikes is discountable. Therefore the proposed action is not likely to adversely affect green sea turtles.

Loggerhead sea turtles
Loggerhead sea turtles (*Caretta caretta)* inhabit continental shelves, bays, estuaries, and lagoons in the Atlantic, Pacific, and Indian Oceans (NMFS and USFWS 1998c). On the U.S. West Coast, most sightings of loggerhead turtles are of juveniles. Most sightings are off California; however there are also a few sighting records from Washington and Alaska (Bane 1992). There are no known resting areas along the U.S. West Coast. Although there is potential for loggerhead sea turtles to occur along the Washington and Oregon coasts, available data indicate that occurrence is likely to be rare in the action area. Therefore, the risk of ship strikes is discountable and the proposed action is not likely to adversely affect loggerhead sea turtles.

Olive Ridley sea turtles
Olive ridley sea turtles (*Lepidochelys olivacea)* have a mostly pelagic distribution, but they have been observed to inhabit coastal areas. They are the most common and widespread sea turtle in the eastern Pacific. On the U.S. West Coast, they primarily occur off California although stranding records indicate olive ridley turtles have been killed by gillnets and boat collisions in Oregon and Washington waters (NMFS and USFWS 1998d). In the eastern Pacific, nesting largely occurs off southern Mexico and northern Costa Rica (NMFS and USFWS 1998d). Although there is potential for olive ridley sea turtles to occur along the Washington and Oregon coasts, available data indicate that occurrence is likely to be rare in the action area. Therefore, the risk of ship strikes is discountable and the proposed action is not likely to adversely affect olive ridley sea turtles.

Guadalupe fur seals
Guadalupe fur seals (*Arctocephalus townsendi)* occur primarily near Guadalupe Island, Mexico, their primary breeding area. As a non-migratory species, they are only occasionally found north of the U.S.-Mexican border and therefore, their encounter rate with marine vessels in the action area can be considered discountable. In addition, according to the NMFS Northwest Marine Mammal Stranding Network records, maintained by the NMFS Northwest Region, no human-caused Guadalupe fur seal mortality or serious injuries were reported from non-fisheries sources in 1998-2004. The lack of interactions with ships through reporting or the stranding network lead us to conclude that the exposure risk of collision from OGVs is discountable. Therefore the proposed action is not likely to adversely affect Guadalupe fur seals.

3. MAGNUSON–STEVENS FISHERY CONSERVATION AND MANAGEMENT ACT ESSENTIAL FISH HABITAT RESPONSE

Section 305(b) of the MSA directs Federal agencies to consult with NMFS on all actions or proposed actions that may adversely affect EFH. Under the MSA, this consultation is intended to promote the conservation of EFH as necessary to support sustainable fisheries and the managed species' contribution to a healthy ecosystem. For the purposes of the MSA, EFH means "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity", and includes the physical, biological, and chemical properties that are used by fish (50 CFR 600.10). Adverse effect means any impact that reduces quality or quantity of EFH, and may include direct or indirect physical, chemical, or biological alteration of the waters or substrate and loss of (or injury to) benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality or quantity of EFH. Adverse effects on EFH may result from actions occurring within EFH or outside of it and may include site-specific or EFH-wide impacts, including individual, cumulative, or synergistic consequences of actions (50 CFR 600.810). Section 305(b) of the MSA also requires NMFS to recommend measures that can be taken by the action agency to conserve EFH. Such recommendations may include measures to avoid, minimize, mitigate, or otherwise offset the adverse effects of the action on EFH [CFR 600.905(b)].

This analysis is based, in part, on the EFH assessment provided by the USACE and descriptions of EFH for Pacific Coast groundfish (Pacific Fishery Management Council (PFMC 2005, 2019), and Pacific Coast salmon (PFMC 2014) contained in the fishery management plans developed by the PFMC and approved by the Secretary of Commerce.

3.1. Essential Fish Habitat Affected by the Project

The proposed action and action area for this consultation are described in the Introduction section to this document. The action area includes areas designated as EFH for various life-history stages of groundfish, and Chinook and coho salmon.

In addition, the project occurs within the Columbia River estuary, which is designated as a habitat area of particular concern (HAPC) (estuarine and seagrass) for various federally managed fish species within the Pacific Coast Salmon and Pacific Coast Groundfish FMP. HAPC are described in the regulations as subsets of EFH which are rare, particularly susceptible to human-

induced degradation, especially ecologically important, or located in an environmentally stressed area. Designated HAPC are not afforded any additional regulatory protection under the MSA; however, federal projects with potential adverse impacts on HAPC will be more carefully scrutinized during the consultation process.

Two PFMC-managed salmon species are known to occur in the Columbia River and estuary: coho and Chinook salmon. In estuarine and marine areas, salmon EFH extends from the extreme high tide line in nearshore and tidal submerged environments within state territorial waters out to the exclusive economic zone (200 nautical miles) offshore of Washington (PFMC 2022). Within these areas, EFH consists of four major components: (1) spawning and incubation; (2) juvenile rearing; (3) juvenile migration corridors; and (4) adult migration corridors and adult holding habitat.

As described in Section 2.4, the action area includes important juvenile rearing, and juvenile and adult migration habitat and for five Chinook salmon ESUs and one coho salmon ESU.

The overall extent of groundfish EFH for all FMU species is identified as all waters and substrate within the following areas:

- Depths less than or equal to 3,500 m (1,914 fm) to mean higher high water level (MHHW) or the upriver extent of saltwater intrusion, defined as upstream and landward to where ocean-derived salts measure less than 0.5 ppt during the period of average annual low flow.
- Seamounts in depths greater than 3,500 m as mapped in the EFH assessment geographic information system (GIS).
- Areas designated as HAPCs not already identified by the above criteria.

3.2. Adverse Effects on Essential Fish Habitat

Migratory Pathway Obstruction

The proposed mooring of NEXT facility-associated ships and barges at Port Westward would increase migratory pathways for outmigration of juvenile salmonids due to physical presence of new ships and barges up to 342 days per year. The presence of the ships and barges will contribute to migration delay of juvenile salmonids and increase piscine predators at the facility. Impairment of migratory pathways would persist for the duration of the facility's operation (at least 50 years).

Water Quality

The NEXT facility will produce and route wastewater and stormwater containing toxic chemicals, which are not completely removed by treatment processes. Discharge would be released continuously throughout the year. Runoff sources from the surrounding landscape would include bare soil, aggregate, asphalt, and concrete from multiple areas surrounding the main facility. Stormwater runoff will be routed by sheet flow through multiple drainage ditches, waterways, and constructed wetlands prior to release into the Columbia river. Contaminants would enter the rivers through wastewater and stormwater discharges and potential operations-related spills. Salmonids and groundfish can uptake contaminants directly through their gills and through dietary exposure. Many of the fuels, lubricants, and other fluids commonly used in

motorized vehicles and construction equipment are petroleum-based hydrocarbons that contain Polycyclic Aromatic Hydrocarbons (PAHs), which are known to be highly injurious to fish. Other contaminants can include 6ppd-Q, metals, pesticides, Polychlorinated Biphenyls (PCBs), phlalates, and other organic compounds. The LC50 (95 ng/L) for coho salmon suggests that 6PPD-Q is among the most toxic chemicals known for aquatic organisms. Depending on the pollutant, its concentration, and/or the duration of exposure, exposed fish may experience effects that can range from avoidance of an affected area, to reduced growth, altered immune function, and mortality.

The normal behaviors of juvenile Chinook and coho salmon in the freshwater out-migration phase of their life cycle include a strong tendency toward shoreline obligation, which means that they are biologically compelled to follow and stay close to streambanks and shorelines and the outfalls associated with the NEXT effluent discharge. Additionally, increased contaminant levels from discharge is likely to kill some prey organisms, reducing the number, size, and diversity of prey species that are available to foraging juvenile salmonids that pass through the affected area.

The extent to which toxic chemicals would reach the estuary from the NEXT facility and affect groundfish EFH depends on many factors that are impossible to fully characterize. However, many of these contaminants are long-lived and, over the life of the NEXT facility, it is reasonable that some contaminants would increase the level of toxins in the water and sediment, and decrease the quality of groundfish EFH, including HAPCs in the Columbia River estuary.

Based on information provided in the biological assessment, the analysis of effects presented here and in the ESA portion of this document, NMFS determined that the proposed actions would have adverse effects on EFH by creating new shoreline migration impairment and the reduction of in-water and sediment quality. Further, these effects are likely to persist for the duration of the NEXT facility operations, about 50 years.

3.3. Essential Fish Habitat Conservation Recommendations

NMFS determined that the following conservation recommendations are necessary to avoid, minimize, mitigate, or otherwise offset the impact of the proposed action on EFH.

1. Monitor water quality at the discharge ports of the NEXT facility for toxic contaminants.
    a. Report results annually to NMFS
    b. Develop and implement action plans to contain and reduce the release of contaminants in Section 2.
2. Develop shoreline restoration actions that can be implemented by the applicant (or partnering restoration entity, such as LCREP or the LCFRB) to improve shoreline habitat in the Columbia River reach that will house the NEXT facility.
    a. Restoration actions should include a minimum of 300 ft of restored access to shoreline habitat to offset the length of ships that are proposed for moorage at the NEXT facility.

3.4. Statutory Response Requirement

As required by section 305(b)(4)(B) of the MSA, the USACE must provide a detailed response in writing to NMFS within 30 days after receiving an EFH conservation recommendation. Such a response must be provided at least 10 days prior to final approval of the action if the response is inconsistent with any of NMFS' EFH conservation recommendations unless NMFS and the federal agency have agreed to use alternative time frames for the federal agency response. The response must include a description of the measures proposed by the agency for avoiding, minimizing, mitigating, or otherwise offsetting the impact of the activity on EFH. In the case of a response that is inconsistent with the conservation recommendations, the federal agency must explain its reasons for not following the recommendations, including the scientific justification for any disagreements with NMFS over the anticipated effects of the action and the measures needed to avoid, minimize, mitigate, or offset such effects (50 CFR 600.920(k)(1)).

In response to increased oversight of overall EFH program effectiveness by the Office of Management and Budget, NMFS established a quarterly reporting requirement to determine how many conservation recommendations are provided as part of each EFH consultation and how many are adopted by the action agency. Therefore, we ask that in your statutory reply to the EFH portion of this consultation, you clearly identify the number of conservation recommendations accepted.

3.5. Supplemental Consultation

The USACE must reinitiate EFH consultation with NMFS if the proposed action is substantially revised in a way that may adversely affect EFH, or if new information becomes available that affects the basis for NMFS' EFH Conservation Recommendations [50 CFR 600.920(l)].

4. DATA QUALITY ACT DOCUMENTATION AND PRE-DISSEMINATION REVIEW

The Data Quality Act (DQA) specifies three components contributing to the quality of a document. They are utility, integrity, and objectivity. This section of the opinion addresses these DQA components, documents compliance with the DQA, and certifies that this opinion has undergone pre-dissemination review.

4.1 Utility

Utility principally refers to ensuring that the information contained in this consultation is helpful, serviceable, and beneficial to the intended users. The intended user of this opinion is the USACE. Other interested users could include NEXT. Individual copies of this opinion were provided to the USACE. The document will be available at the NOAA Library Institutional Repository [https://repository.library.noaa.gov/welcome]. The format and naming adhere to conventional standards for style.

4.2 Integrity

This consultation was completed on a computer system managed by NMFS in accordance with relevant information technology security policies and standards set out in Appendix III, 'Security of Automated Information Resources,' Office of Management and Budget Circular A-130; the Computer Security Act; and the Government Information Security Reform Act.

4.3 Objectivity

Information Product Category: Natural Resource Plan

Standards: This consultation and supporting documents are clear, concise, complete, and unbiased; and were developed using commonly accepted scientific research methods. They adhere to published standards including the NMFS ESA Consultation Handbook, ESA regulations, 50 CFR 402.01 et seq., and the MSA implementing regulations regarding EFH, 50 CFR part 600.

Best Available Information: This consultation and supporting documents use the best available information, as referenced in the References section. The analyses in this opinion and EFH consultation contain more background on information sources and quality.

Referencing: All supporting materials, information, data and analyses are properly referenced, consistent with standard scientific referencing style.

Review Process: This consultation was drafted by NMFS staff with training in ESA and MSA implementation and reviewed in accordance with West Coast Region ESA quality control and assurance processes.

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News

100,000 Fish Killed After Vegetable Oil Spill in Washington State Creek

As many as 100,000 small salmon and other fish have been killed over the past week after a fire at a food wareouse in Washington's Lewis County sent vegetable oil spilling into a nearby creek.

By The Associated Press • August 26, 2015

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Remnants spill into a creek from a warehouse full of food products that was destroyed in an early-morning fire on Tuesday, Aug. 18, 2015, Winlock, Wash. The fire caused vegetable oil to leak into nearby Olequa Creek and a spokesman for the Washington Department of Ecology feared the spill might have killed thousands of small salmon and other fish. (Natalie Johnson/The Chronicle via AP)

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As many as 100,000 small salmon and other fish have been killed over the past week after a fire at a food warehouse in Washington's Lewis County sent vegetable oil spilling into a nearby creek.

The Washington Department of Ecology gave its latest count of the number of fish killed to Portland's KGW News, adding that the fire sent about 1,100 gallons of burning oil into the creek through a pipe in the warehouse.

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Spokesman Chase Gallagher said Tuesday the scene in Olequa Creek appears to be a "100 percent kill for five miles" downstream, with officials unsure how many fish died "because the number is so high." Olequa Creek is a tributary of the Cowlitz River, and its Native American name means "where salmon come to spawn."

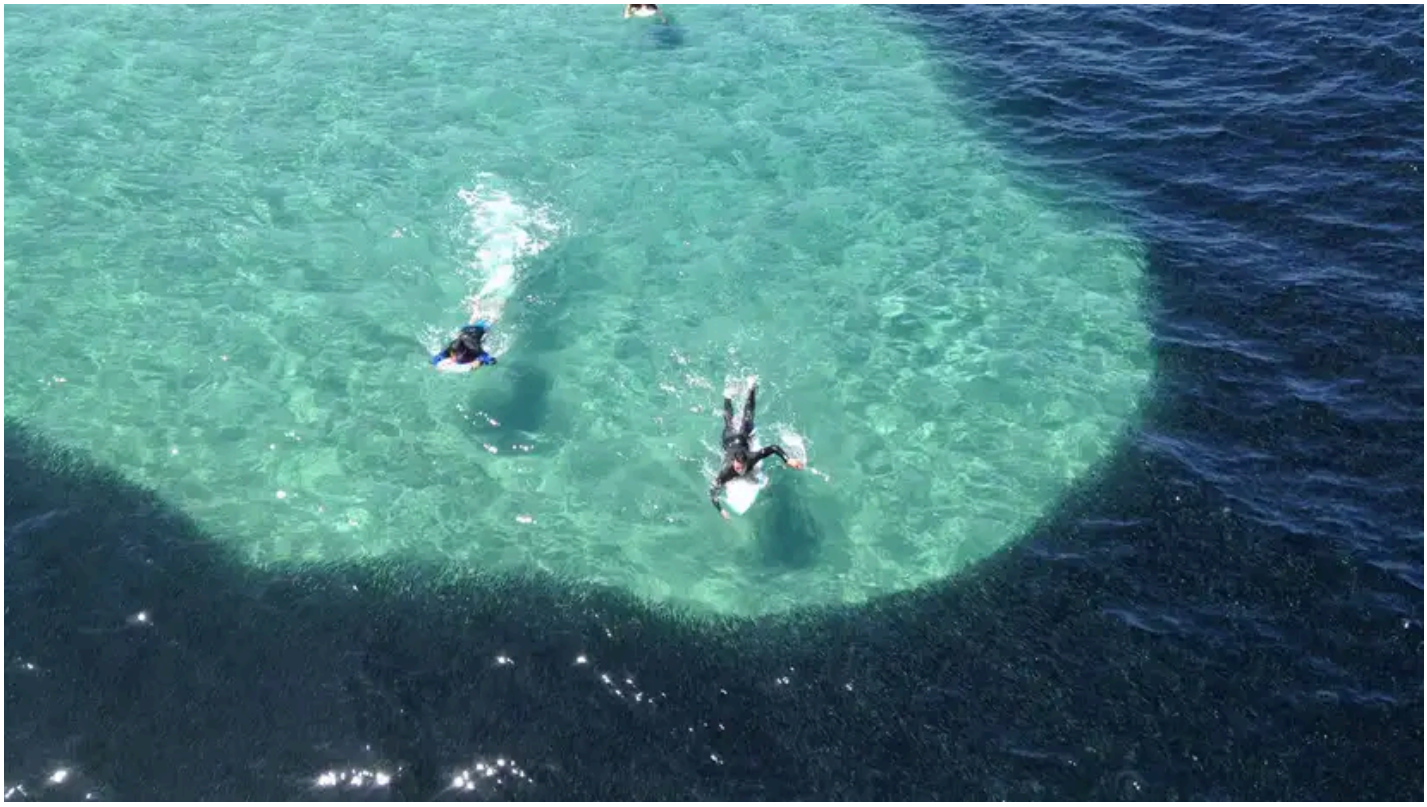
The fire was reported at Olympic Trading Company in Winlock early Tuesday morning. The company had just taken a large delivery of vegetable or other cooking oil, and Gallagher said it's extremely likely that's the oil that entered the stream.

"The combination of hot water coming off the fire with the higher temperature in the creek led to kind of an instant kill for the fish," Gallagher told KGW.

Crews were using absorbent pads and vacuum trucks to contain and clean the spill. The cause of the fire was still under investigation as of Wednesday.

MORE FROM WEATHER.COM: School of Anchovies That Looks Like an Oil Slick

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1/11

Massive School of Anchovies in La Jolla, California

Surfers paddle near a huge school of anchovies off the coast of La Jolla, California, on July 8. (Photo by Scripps Institution of Oceanography)

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TECHNOLOGY

What's Worse Than an Oil Spill? A Molasses Spill

There is no way to clean up a molasses spill.

By Svati Kirsten Narula

SEPTEMBER 13, 2013

SHARE AS GIFT SAVE



Elizabeth Miles

Thousands of fish — gasping desperately, then floating lifelessly — surfaced in Honolulu Harbor this week, suffering from oxygen deprivation caused by a massive molasses spill. This strange case of sug tion was brought on by the Matson Shipping Company, which was loading one of its vessels with 1,600 tons of molasses

Exhibit List 555

through a pipeline in the harbor early Monday morning when a leak sprung. Matson reported that up to 1,400 tons of the sludgy syrup may have escaped into the harbor and nearby Ke'ehi Lagoon.



Elizabeth Miles

There is no way to clean up a molasses spill. "It's sunk to the bottom of the harbor," Matson spokesman Jeff Hull told the *L.A. Times* on Wednesday. There, the molasses has displaced the oxygen-containing seawater that thousands of marine organisms rely on to breathe.

Hawaii News Now reported the devastating ecological impact of the spill with an underwater video recording this afternoon. In the words of Roger White, the scuba diver who shot the video, "It was shocking because the entire bottom is covered with dead fish."

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The Hawaii Department of Health, rather than the U.S. Coast Guard or Environmental Protection Agency, is responding to the accident because it is not an oil or "hazardous material" spill, according to NOAA's Office of Response and Restoration. It doesn't really matter who gets involved, because there isn't much mitigating to be done. Officials are currently monitoring water quality in the harbor, collecting dead fish (lest they attract hungry sharks and eels), and urging residents to stay out of the water.

When an oil spill occurs, a large oil slick forms on the water's surface, and emergency response efforts often focus on dispersing that oil away from the surface and down through the water column, where the oil becomes less concentrated and, consequently, less threatening to marine life. This only works if the water is sufficiently deep, though; the NOAA OR&R website says, "To avoid contaminating the sea floor, most dispersant use to date has been restricted to waters deeper than 10 meters (about 30 feet)." The waters of Honolulu Harbor are just about that deep, but no matter, because molasses behaves very differently from oil. Unlike oil, molasses sinks, and now 1,400 tons of it, highly concentrated, are bearing down on the sea floor off the coast of Oahu.

Estimates on how long it will take the molasses to disperse on its own and eventually "flush out" of the harbor vary. Gary Gill, from the Hawaii Department of Health, said he hoped that the tides would clean out the harbor "over the next couple days." NOAA said "a week or longer," and Hawaii News Now quoted a local marine science expert who simply said it would take "a long time." Tidal currents in the area are generally weak.

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Elizabeth Miles, who has lived on a sailboat at Honolulu's La Mariana marina for the past six years, told me "these fish are like part of the family" for all the residents of the 90 boats there, "and [Ke'ehi] lagoon is our backyard."

The Hawaii health department said in a statement that the molasses could also cause "an unusual growth in marine algae... an increase in harmful bacteria… and other environmental impacts." On Thursday morning, Miles noticed a change in the water around her home: "There's some sort of new slimy algae stringy filmy growth that's starting to cover the surface. I suppose that has something to do with the nutrients in the molasses."

Another Matson molasses spill occurred ten years ago in Maui, but that was in December, when winter storm conditions contributed to flushing the water, and the contributing pipeline leak was identified and stopped relatively quickly, so only about 50,000 gallons of molasses escaped into [illegible]ter. The 1,400 ton estimate of the Honolulu spill equates to over 200,00

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"We're all devastated," Miles said. "I mean, it's not a clean area, because it's a lagoon, but we can usually see the bottoms of our keels and the water is turquoise… and now it's black. It's going to be black for a long time, I think."

ABOUT THE AUTHOR



Svati Kirsten Narula

Svati Kirsten Narula is a reporter for Quartz.

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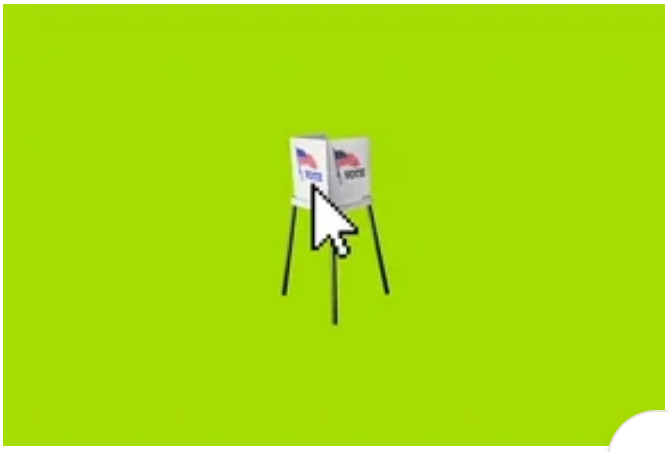


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Silicon Valley's Very Bad Night

America has made its feelings about data centers crystal clear.

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$500 Million Bought Elon Nothing

Musk's unprecedented spending may even have hurt Republicans.

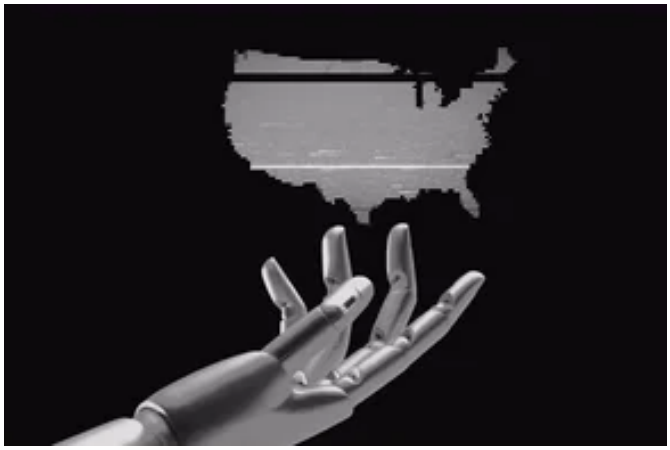


Illustration by The Atlantic. Source: Getty.

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AI investments are driving the economy. That's a dangerous tightrope.

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Illustration by Adam Maida / The Atlantic

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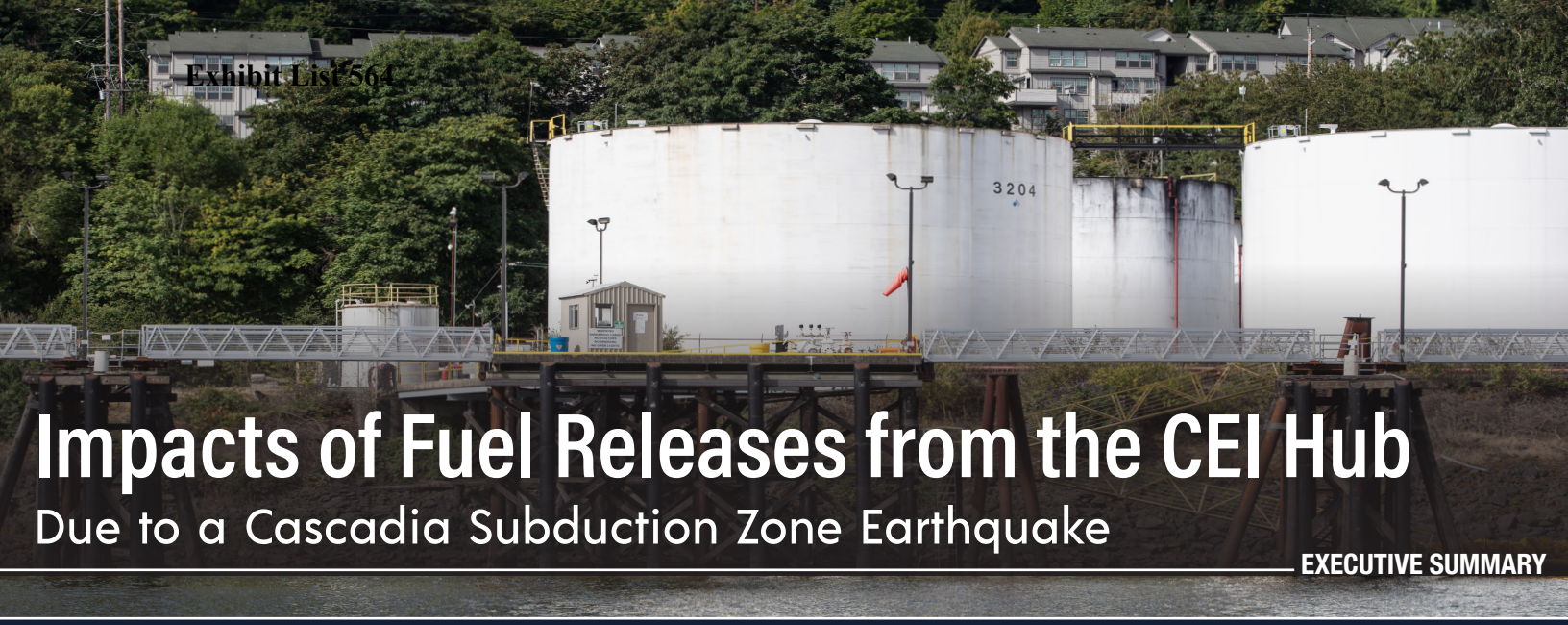
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Impacts of Fuel Releases from the CEI Hub

Due to a Cascadia Subduction Zone Earthquake

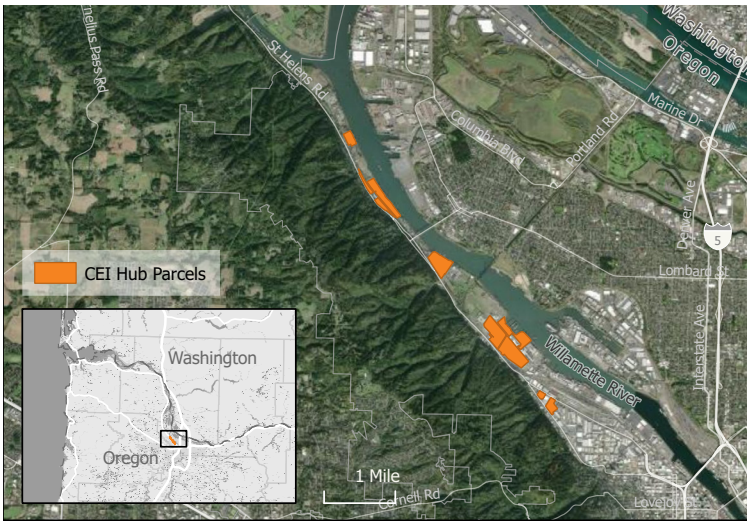
EXECUTIVE SUMMARY

The purpose of this study is to identify the magnitude and extent of potential fossil fuel releases at the CEI Hub from a CSZ earthquake and to evaluate the resulting damages. ECONorthwest, Salus Resilience, and Enduring Econometrics prepared this report for the City of Portland and Multnomah County. For more information about this report, contact: Laura Marshall, Project Manager at marshall@econw.com.

WHAT IS THE CEI HUB?

The Critical Energy Infrastructure Hub (CEI Hub) is a six-mile area in Northwest Portland along the Willamette River (Figure ES-1). There are 10 companies on 31 properties located at the CEI Hub that vary in size from 0.1 to 31.27 acres for a total of 219.85 acres. The CEI Hub facilities are critical to Oregon's fossil fuel infrastructure — over 90 percent of the state's liquid fuel supply is transported through CEI Hub facilities, including gasoline and diesel. The CEI Hub supplies all the jet fuel to Portland International Airport. There are over **150 different types of materials** stored at the CEI Hub, most of which are petroleum-based. There are **630 tanks** of varying sizes throughout the CEI Hub holding a combined active storage tank capacity of at least **350.6 million gallons**.

FIGURE ES-1. Location of CEI Hub Properties



Source: Created by ECONorthwest.



WHAT IS THE RISK?

The CEI hub is located on unstable soils that are subject to liquefaction and lateral spreading in an earthquake, and the tanks are vulnerable to seismic activity because many were built prior to modern knowledge about earthquake risk. The proximity of the CEI hub to natural assets, like the Willamette River and Columbia River, and the dense urban core in the City of Portland, make the risk of accident, spill, or major failures due to a seismic event particularly concerning.

A magnitude 8 or 9 Cascadia Subduction Zone (CSZ) earthquake would impact the CEI Hub with ground shaking, liquefaction (soil softening and movement), lateral spread (horizontal soil movement), and landslides. The earthquake would disturb tanks and their contents and tanks that were not build to modern seismic design standards pose risk of failure. Additional fuel releases could occur due to connection failures and other incidental damages. There are containment walls in place on many CEI Hub properties,

Exhibit List 565

however, in many cases, these containment structures will be insufficient to contain the potential cumulative volume of releases from multiple tank failures that would occur in a CSZ earthquake.

In total, 397 tanks could release stored materials as a result of the CSZ earthquake.[1] **The total potential releases from the materials stored in tanks at the CEI Hub range from 94.6 million to 193.7 million gallons** (Table ES-1). Approximately 57 percent of the total potential releases would be released onto ground and 43 percent have the potential to flow into the Willamette River. The estimates of fuel releases from the CEI Hub are the same magnitude as what was released in the Deepwater Horizon spill of 2010 — the largest oil spill in U.S. waters to date.

WHAT WILL HAPPEN IF FUELS ARE RELEASED?

Releases of fuel from the CEI Hub into the air, ground, and water would pose threats to the resources near, downstream, and downwind of the facilities. The fuel releases are likely to cause explosions and fires which pose immediate threats to people on-site at CEI Hub facilities and on adjacent properties. A petrochemical fire poses significant risk to the surrounding areas because containment and suppression may not be possible in the aftermath of the earthquake. If the fire spreads to other properties there are very large threats to human life, safety, physical structures, and natural resources. The fumes from fires and chemical materials will also create health hazards for those who are exposed. People who are in the immediate area as well as emergency responders and clean-up personnel are most at risk from high exposure levels.

The fuel that is released into the Willamette River will behave differently depending on the type of material released. Light and medium oils, such as gasoline and diesel, float in water and will travel downstream until they are contained or evaporate. Heavier fuels will sink and travel as sediment in the river. The further the fuels travel in water, the more environmental resources they will degrade, and more properties will be impacted by oiling. The Lower Willamette River and Lower Columbia River provide habitat to an abundance of species that could be affected by fuel releases. The rivers are also transportation channels, and fuel releases would cause closures for clean-up, which would result in economic losses for the navigation industry as well as cut off supply chains from the river when they are critically needed after the earthquake. Harms to natural resources would also result in a loss of cultural resources that are of particular importance to Tribal populations for subsistence, transportation, commerce, and ceremonial purposes.



"The total potential releases from the materials stored in tanks at the CEI Hub range from 94.6 million to 193.7 million gallons."

WHAT WILL BE THE DAMAGES AND COSTS OF FUEL RELEASES?

The minimum costs to society of potential fuel releases at the CEI Hub range from **$359 million to $2.6 billion** (Table ES-2). Because not all costs were monetized, this range of costs represents only a portion of the total costs likely to be imposed on society from fuel releases from the CEI Hub.

These costs do not include any costs caused by an inability to perform earthquake recovery efforts due to fuel shortages. To the extent that fuel scarcity impedes emergency response activities, there will be financial and non-financial costs, including injury

TABLE ES-1. Summary of Total Potential Releases by Location

Spill Location	Number of Tanks with 50–100 percent failure	Number of Tanks with up to 10 percent failure	Volume Released Min (gal)	Volume Released Max (gal)
Ground	269	21	53,882,252	111,183,900
Water (Including potentially in water)	96	11	40,751,753	82,503,352
Total	**365**	**32**	**94,634,005**	**193,687,251**

Source: Created by Salus Resilience (see Appendix B).

[1] This value excludes empty tanks from the active tanks that could release materials.

Exhibit List 566

Category of Cost	Summary of Costs	Range of Monetized Costs for the Modeled Scenario
Direct Impacts to People	Assuming an explosion occurs, between 0 to 7 people could be killed and 2 to 80 people could be injured. The range of costs for mortality and morbidity are between $49,000 to $74.1 million, with an average cost of $37.1 million.	$49,000 to $74.1 million
Impacts to Property	Assuming fuels in the water travel downstream to the Longview Bridge, the potential impact on residential property values is up to $35.4 million. There is $2.5 billion in total riverfront property value in the downstream area.	$11.8 million to $35.4 million
Impacts to Navigation	A one-week closure of the shipping channel between the I-405 bridge and Longview Bridge would result in additional operating costs for commercial vessels of between $11.8 million and $17.8 million.	$11.8 million and $17.8 million
Impacts to Fisheries	To the extent that fuel releases reduce reproduction or cause direct mortality to aquatic species there will be a reduction in income to the fishing industry, impacting owners, employees, and suppliers who rely on these funds. Increases in hatchery production would likely be needed, which would result in additional costs.	Not Monetized — Potential for significant mortality to commercial fisheries species and loss to commercial fishing entities
Impacts to Recreation	Average per-trip values of recreation for participants (i.e., consumer surplus) are between $68 to $130 per person per day. Recreationalists contribute spending to local economies at an average value of between $98 to $478 per trip. Canceled recreational trips due to fuel releases would reduce both value for the participant and economic activity for the businesses that rely on the recreational spending. A one-month closure of the Lower Columbia River and Lower Willamette River for salmonid fishing would result in a loss of consumer surplus of $3.4 million and a loss of $3.2 million in direct trip spending.	Not Monetized — Damage to recreational resources that cannot be easily rebuilt, such as fire damage to Forest Park, will result in long-term losses to recreation.
Impacts to Human Health	The health costs of exposure to toxins for nearby people and response workers is $121 million to $249 million for both acute and chronic conditions. The primary health costs are increased risk of heart attack, decreases in productivity, and lost workdays. Additional costs would be borne from evacuations and strains on emergency response services.	$121 million to $249 million — with potential for additional costs to mental health and non-documented physical health costs.
Impacts to Habitats and Species	Habitats and species would be harmed from fuel releases. The costs of habitat restoration as compensation for habitat injury would require between 175 and 418 acres of wetland to be restored. An additional 39 to 1,219 acres of constructed wetland could be needed to compensate for injuries to bird populations. There is also the potential for compensation needed for aquatic and mammal species that are injured by the event. The expected total costs for habitat restoration are between $39.7 million and $304.3 million, depending on whether the spill occurs in the summer or in the winter. Total damages from injury to habitats and natural resources and required compensation are expected to range between $87 million to $669 million, depending on whether the spill occurs in the summer or in the winter.	$87 million to $669 million
Cleanup Costs	Cleanup costs are projected to be between $109 million to $1.4 billion.	$109 million to $1.4 billion
Impacts to Cultural Values	Fuel releases in the Willamette River and Columbia River would harm cultural resources that are of particular importance to Tribal populations for subsistence, transportation, commerce, and ceremonial purposes. Impacts to this area would perpetuate historical inequities to a water resource already contaminated as part of the Portland Harbor Superfund.	Not Monetized — Impacts to waterways and aquatic species like salmon would result in large cultural losses.
Impacts to Fuel Prices	Releases of fuel from the CEI Hub would reduce the supply of fuels needed for transportation and commercial activity in Oregon. The effects of the earthquake on transportation infrastructure will alter the demand for fuels. A lack of fuel could constrain emergency response activities. The total economic cost to consumers of the higher fuel prices and reduction is between $18.8 million and $120.8 million. The lost value of consumption from fuel scarcity would be $11.7 million for a three-day period.	$18.8 million to $120.8 million — with additional costs from loss of consumption and delays in recovery efforts
Total Monetized Costs		**$359 million to $2.6 billion**

Source: Created by ECONorthwest.

Exhibit List 567

and loss of life. The costs to society also do not include fines, penalties, lost revenue, or equipment replacement costs borne by the CEI Hub operators. Not all costs are able to be monetized due to lack of data, uncertainty, confounding variables caused by the earthquake, and/or difficulty valuing the resource. The costs are based upon a multitude of assumptions and scenarios about the type and magnitude of fuel releases, emergency response actions and timelines, and natural phenomenon like air, water, and fire dispersion — these assumptions are detailed in the full report.

WHO WILL BE LIABLE AND HOW WILL COSTS BE PAID FOR?

The Oil Pollution Act of 1990 (OPA), passed by Congress and signed into law in the wake of the Exxon Valdez oil spill, is the established liability structure to recover damages from oil spills. Under OPA, "Responsible Parties" are liable for removal costs and damages that are attributable to their release of oil. Fuel releases from the CEI Hub could exceed the statutory liability limits established under OPA or deemed an "Act of God" (making the responsible party not liable). For these situations, OPA established the Oil Spill Liability Trust Fund to pay for any excessive or unfunded liabilities.





"Under OPA, onshore facilities like the CEI Hub have liability limits of $672,514,900 PER SPILL for each responsible party. "



All damages and costs of fuel releases from the CEI Hub report are potentially recoverable under OPA, with the exception of personal injury/wrongful death, which would be potentially recoverable under separate civil action. However, what will actually be paid out to people who are harmed by fuel releases could be less than the full amount that would be required to compensate them for the damage due to transaction costs and inefficiencies. Uncompensated damages may be distributed inequitably across injured parties due to existing structural inequities in the legal system. Uncompensated damages are most likely to occur for claimants with damages that are more difficult to prove.

Impacts of Fuel Releases from the CEI Hub

due to a Cascadia Subduction Zone Earthquake

FEBRUARY 2022

PREPARED FOR

Multnomah County
Office of Sustainability

PBEM

PREPARED BY

ECONorthwest
ECONOMICS · FINANCE · PLANNING

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SALUS RESILIENCE

Enduring Econometrics

Chapter 1: Impacts of a Cascadia Subduction Zone Earthquake on the CEI Hub

January 2022

Prepared for:

Multnomah County Office of Sustainability

and City of Portland Bureau of Emergency Management

Prepared by:

ECONorthwest
ECONOMICS · FINANCE · PLANNING

SALUS RESILIENCE

Enduring Econometrics

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1-1 Introduction

1-1.1 Background on CEI Hub

The Critical Energy Infrastructure Hub (CEI Hub) is a six-mile area in Northwest Portland along the Willamette River (Figure 1). The CEI Hub facilities are critical to Oregon's fossil fuel infrastructure - over 90 percent of the state's liquid fuel supply is transported through CEI Hub facilities, including gasoline and diesel. Roughly 70 percent of the fuel arrives by pipe and another 30 percent arrives by tanker barge. [1] The CEI Hub supplies all of the jet fuel to Portland International Airport. The natural gas stored at CEI Hub facilities is used to supplement the natural gas deliveries during peak winter demand. In addition to the fuel storage facilities, the CEI Hub also contains liquid fuel and natural gas pipelines and transfer stations, a liquefied natural gas storage tank, storage of other non-fuel materials, a high-voltage electrical substation, and transmission lines.

[1] Oregon Seismic Safety Policy Advisory Committee. (2013). *The Oregon Resilience Plan: Reducing Risk and Improving Recover for the Next Cascadia Earthquake and Tsunami, Chapter 6: Energy*.

Figure 1. CEI Hub Location



Source: Created by ECONorthwest

A magnitude 8 or 9 Cascadia Subduction Zone (CSZ) earthquake would impact the CEI Hub with ground shaking, liquefaction (soil softening and movement), lateral spread (horizontal soil movement), and landslides.[2] The significant ground disturbance and resulting impacts to the tanks could result in releases of the materials stored at the CEI Hub into land, water, and air. A fire is also possible at the site due to the combination of flammable fuels and earthquake disturbances. Releases from fuel tanks at the CEI Hub would pose a major hazard to people, marine life, and property, as well as contaminate the environment and require significant clean-up. The purpose of this analysis is to model the likely scenarios of releases and describe the potential resulting physical impacts.

1-1.2 Study Purpose

On October 31st, 2019, the Multnomah County Board of Commissioners adopted resolution 2019-091 which opposes the expansion of infrastructure for transporting or storing fossil fuels in Multnomah County, and supports efforts to require fossil fuel industry to bear the full cost of damages caused by transporting, storing, or using fossil fuels. On December 18, 2019 the Portland City Council adopted ordinance 189807 that restricts large new oil train terminals and

[2] Yumei Wang, Steven F. Bartlett, and Scott B. Miles. (2012). *Earthquake Risk Study for Oregon's Critical Energy Infrastructure Hub: Final Report to Oregon Department of Energy and Oregon Public Utility Commission.* Oregon Department of Geology and Mineral Industries. August.

other fossil fuel projects in the City of Portland, prohibits the establishment of new major oil storage facilities in Portland, and limits expansion at existing facilities. The language in the Multnomah County Ordinance states that:

> "The impacts of an earthquake or another catastrophic event involving the Critical Energy Infrastructure Hub would be significant and could include immediate threats to life and safety, longer term pollution and health effects, and economic disruption. The burden of these impacts would fall disproportionately on communities of color and low income populations, and in the absence of strong policy protections the cost of response and cleanup would be borne by taxpayers.
>
> Multnomah County seeks to protect itself and the community from the cost of damage to fossil fuel infrastructure by exploring strategies to shift financial responsibility for costs of risks associated with fossil fuel infrastructure to the companies that own and earn revenues from the infrastructure."

As part of the 2019 resolutions, the Board of County Commissioners approved the allocation of funds to inventory costs associated with risks to the fossil fuel infrastructure located in the CEI Hub, as well as the existence and adequacy of insurance and other financial assurance mechanisms held by the fossil fuel companies that have infrastructure in the Hub.

The purpose of this study is to identify the magnitude and extent of potential fossil fuel releases at the CEI Hub from a CSZ earthquake and to evaluate the resulting damages. Specifically, this research performs the following:

- Summarizes available information about conditions at the CEI Hub.
- Describes the likely effects of a major earthquake on CEI Hub facilities.
- Develops qualitative descriptions and quantitative estimates of the earthquake's effects at the CEI Hub, including potential releases of fossil fuels.
- Estimates the economic impacts of fossil fuel releases and infrastructure failures.
- Identifies and describes what costs might be covered by existing insurance or federal programs and what costs are not clearly the responsibility of either owner-operators or another party.

This evaluation is limited to only the effects of a CSZ earthquake at the CEI Hub. It is beyond the scope of this analysis to consider short-term or long-term potential damages to the environment or human health caused by accidents, volatilizing toxins, and/or chemical spills not caused by a CSZ earthquake – including any potential damages not directly related to the earthquake posed by the storage tanks, railroad cars, ships, trucks, and/or pipelines carrying products to and from the CEI Hub.

A CSZ earthquake would also affect other nearby infrastructure for fuels and materials. The industrial areas of Portland, Oregon and Vancouver, Washington along the Willamette River and Columbia River store, use, and transport other fossil fuels and chemicals, including toxic

inhalation hazard materials that also have the potential to be released due to earthquake damages and would complicate response efforts and strain response resources.[3]

[3] As defined in the Federal Register (69 FR 50987): "Toxic inhalation hazard materials (TIH materials) are gases or liquids that are known or presumed on the basis of tests to be so toxic to humans as to pose a hazard to health in the event of a release during transportation".

1-2 Prior Studies Related to the CEI Hub

Several prior studies have evaluated the impacts of a CSZ earthquake on the CEI Hub, documented hazardous materials releases, and described impacts to the surrounding environment and economy. However, these studies have not performed the analysis needed to identify the magnitude, location, and extent of releases and the specific costs on the surrounding environment. This report builds upon these prior studies to supply that needed information. As background information on the history of research of the risks at the CEI Hub, a summary of relevant prior literature is detailed below.

1-2.1.1 Dusicka and Norton – Liquid Storage Tanks at the Critical Energy Infrastructure (CEI) Hub Seismic Assessment of Tank Inventory (2019)

The Dusicka and Norton study from 2019 is directly related to the work being performed for this report.[4] In this publication, the authors evaluate the seismic integrity of the tanks at the CEI Hub and provide a conceptual estimate of $300 million as the cost for seismic mitigation for the large capacity tanks. As part of this work the researchers also estimated the quantity and characteristics of the tanks and the supporting soil.

Through a public records request and information from the City of Portland, the authors identified nine companies with a total of total of 514 known tanks, of which 146 were identified as out of service. The majority of the tanks were built before 1960. Based on secondary information, this report concludes that there is a risk of both liquefaction and landslides at the CEI Hub from a CSZ earthquake. Structural mitigation (i.e., retrofitting the tanks so that they are more seismically resilient) could occur through tank anchoring or soil mitigation.

1-2.1.2 DOGAMI – Earthquake Risk Study for Oregon's CEI Hub (2012)

Prepared for the Oregon Department of Geology and Mineral Industries (DOGAMI), this 2012 study evaluated the geomorphic earthquake risks at the CEI Hub.[5] The seismic hazards of a CSZ earthquake on the CEI Hub include ground shaking, liquefaction, lateral spread, landslides, co-seismic settlement, and bearing capacity failures. Secondary hazards resulting from the initial seismic impacts include fire and hazardous materials releases. In addition to the tanks at the CEI Hub, this study also evaluated the pipeline that runs under the Willamette River. The pipeline was built in the 1960s and could be damaged or broken by the seismic hazards from the earthquake, particularly liquefaction and lateral spread.

[4] Dusicka, P. and Norton, G. (2019). *Liquid Storage Tanks at the Critical Energy Infrastructure (CEI) Hub Seismic Assessment of Tank Inventory*. Mapleaf LLC and Portland State University. Prepared for Portland's Bureau of Emergency Management. May.

[5] Wang, Y., Bartlett, S.F., Miles, S.B. (2012). *Earthquake Risk Study for Oregon's CEI Hub. Prepared for Oregon Department of Geology and Mineral Industries (DOGAMI).*

The findings from this report indicate that western Oregon will likely face an electrical blackout, extended natural gas service outages, liquid fuel shortages, and damage and losses in the tens of billions of dollars in a future major Cascadia earthquake. The report recommends immediate proactive seismic mitigation actions.

1-2.1.3 Other Relevant Studies

1-2.1.3.1 OSSPAC - CEI Hub Mitigation Strategies: Increasing Fuel Resilience to Survive Cascadia (2019)

A study completed by the Oregon Seismic Policy Advisory Safety Commission (OSSPAC) at the request of the Oregon Governor and the State Resilience Officer focused on fuel resilience following the CSZ event.[6] Through meetings and testimony with experts, agencies, and interested stakeholders, OSSPAC presented findings and recommendations on the regulatory authority for: seismic upgrades, statutory authority to develop long-term mitigation efforts, public-private partnerships and incentives to harden current infrastructure, and encouraging seismic awareness in the private sector. The major finding from this work is as follows:

> "The Critical Energy Infrastructure Hub is a major threat to safety, environment, and recovery after a Cascadia Subduction Zone earthquake on par with the 2011 Fukushima nuclear meltdown in Japan. Owners of privately-owned liquid fuel tanks at the Hub need to be compelled to seismically strengthen their infrastructure. No state agency is a perfect fit to be designated as the regulatory authority over these facilities."

1-2.1.3.2 Oregon Solutions – Critical Energy Infrastructure Hub Assessment Findings (2019)

A 2019 study by Oregon Solutions identified potential avenues for collaborative action that might increase resiliency of the CEI Hub.[7] Oregon Solutions was established at the state level through the passage of the 2001 Sustainability Act and provides collaborative governance assistance through partnerships. The report is the product of interviews conducted by Oregon Solutions with parties and stakeholders representing key interests related to the CEI Hub between July 2018 and January 2019.

[6] Oregon Seismic Safety Policy Advisory Commission of the State of Oregon (OSSPAC). (2019). *CEI Hub Mitigation Strategies: Increasing Fuel Resilience to Survive Cascadia*. December 31. OSSPAC Publication 19-01.

[7] Oregon Solutions. (2019). *Critical Energy Infrastructure Hub Assessment Findings.* Prepared for the Portland City Club's Earthquake Resiliency Advocacy Committee (CCERAC) and the city of Portland's Bureau of Emergency Management (PBEM).

1-2.1.3.3 Other Reports

In addition to these reports that are specific to the CEI Hub, other relevant information sources include the Oregon Resilience Plan, particularly *Chapter 5: Transportation*, as well as the studies associated with the Portland Harbor Superfund site. [8, 9]

[8] More information and a copy of the Oregon Resilience Plan is available at: https://www.oregon.gov/gov/policy/orr/pages/index.aspx

[9] More information about the Portland Harbor Superfund is available at: https://cumulis.epa.gov/supercpad/SiteProfiles/index.cfm?fuseaction=second.Cleanup&id=1002155#bkground

1-3 CEI Hub Fuel Releases

1-3.1 Methodology

Estimating the potential failures and releases associated at the CEI Hub due to a CSZ earthquake requires combining data about the location, contents, and integrity of critical infrastructure with information about the stability and risks of the soils that they are located on. Tank data is based upon information from the Office of Oregon State Fire Marshal (OSFM) and the City of Portland (COP), the latter of which was developed from the Portland State University (2019) study of the CEI Hub.[10, 11] Under the Oregon Community Right to Know and Protection Act (ORS 453.307-414) that requires Oregon employers to report their hazardous substances to OSFM, including where they are stored, and the hazards associated with them.[12] The geological risks and susceptibility of the location to earthquake impacts is based upon a geologic analysis, detailed in Appendix A.

An onsite engineering analysis to determine tank risk and susceptibility to failure from a CSZ earthquake was not conducted for this analysis. Such a review would provide more precise estimates about the potential tank failures and releases, as well as be able to identify if individual tanks meet current seismic design standards. The estimates and characterizations of tank conditions and susceptibility to failure are based on available information from the sources identified above. It is possible that tanks are retrofitted or otherwise have lower risks of failure than identified herein. However, because that information was not publicly available or offered by the facility owners that information is not reflected in the estimates of tank contents or probability of tank failure from the CSZ earthquake.

As tanks deform and fail during an earthquake, a portion of the materials contained inside them will be released. The specific volume that is released will depend on the ground displacement, nature of the failure, capacity of the tank, and the amount of material in the tank at that time. Most tanks in the CEI Hub have floating lids, meaning that in the event of an earthquake materials could slosh outside of the tank's containment. Connection failures and other incidental damages could also result in releases even if the tank itself does not fail. Throughout the CEI Hub there is a high likelihood of liquefaction and lateral spread from a CSZ earthquake that would disturb tanks and their contents.

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[10] A full description of the methodologies used for the information in this section are detailed in Appendix A, which contains an evaluation of the geotechnical risks at the CEI Hub, and Appendix B, which contains an evaluation of tank contents, likelihood of failure, and location of releases.

[11] Dusicka, P. and Norton, G. (2019). *Liquid Storage Tanks at the Critical Energy Infrastructure (CEI) Hub Seismic Assessment of Tank Inventory*. Mapleaf LLC and Portland State University. Prepared for Portland's Bureau of Emergency Management. May.

[12] More information about Oregon Community Right to Know and Protection Act (ORS 453.307-414) is available at: https://www.oregon.gov/osp/programs/sfm/pages/community-right-to-know.aspx

Because soils are unstable throughout the CEI Hub, the likelihood of tank failure varies based upon the age of the tank to reflect engineering design considerations for if and how much of the contents could be released. Engineering design standards have changed over time. American Society of Civil Engineers design standards and state and city building codes prior to 1993 do not meet current seismic design standards. Liquefaction of soft soils was incorporated into City of Portland requirements for seismic design after 2004. Accordingly, these dates are used as thresholds for estimating the likelihood of tank failure and percent of contents that could be released, as follows:

- **Prior to 1993:** Tanks will likely fail during the CSZ event and release 50 to 100 percent of contained materials.
- **Between 1993 and 2004:** Tanks are assumed to be designed for shaking but are susceptible to failure due to liquefaction settlement and lateral spread.[13] Up to 10 percent of contained materials could be released due to connection failures and other incidental damages.
- **After 2004:** Tanks have been designed to withstand appropriate shaking and deformation and thus are not likely to fail during the CSZ event. However, up to 10 percent of contained materials could be released.

Released materials will flow out onto the ground and properties of the various operators. While on-site containment structures are designed to capture a potential release, it is possible that the CSZ earthquake could damage these masonry containment walls. In many cases, these containment structures are insufficient to contain the potential cumulative volume of releases from multiple tank failures. As a result, depending on tank location, damage zone, distance from the water, and topography, substantial portions may flow into the Willamette River. Damage zones vary throughout the CEI Hub properties, with different volumes staying on land or entering the water, as described in Table 1. Appendix B provides additional information about releases by area type.

Table 1. Damage Zones by Area

	Damage Zone (distance from water in feet)		
Location	**In Water**	**Potentially in Water**	**On Land**
Area 1 - Kinder Morgan N	0-500	500-750	750+
Area 2 - Linnton N	0-500	500-750	750+
Area 2 - Linnton S	0-500	500-750	750+
Area 3 - NW Natural	0-250	250-500	500+
Area 4 - Willbridge	0-250	250-500	500+
Area 5 - Equilon	N/A	N/A	All

Source: Created by Salus Resilience, see *Appendix B*.

[13] Liquefaction is the phenomenon after an earthquake when soils lose holding strength, causing them to behave like a liquid rather than a solid and contents above or below the soil to be displaced. Lateral spread refers to the lateral movement of soils which can result in ground tears, open surface cracks, and fissures.

1-3.2 Fuel and Hazardous Material Types

There are over 150 different types of materials stored at the CEI Hub, each with a unique chemical composition. Most of the fuels stored at the CEI Hub are petroleum-based but react in the environment in different ways. The American Petroleum Institute (API) gravity is a measure of how heavy or light a petroleum liquid is compared to water. If a product has an API gravity of less than 10, it sinks in water. If the product has an API gravity greater than 10, it floats in water. Based on API ranking, the materials at CEI Hub can be assigned to the following categories.

- **Heavy Oil (API: Between 10 and 22.3)**: Heavy oils are dense and have a high resistance to flow. They generally float in water and do not disperse readily.
    - **Asphalt (API**: **11):** Also known at bitumen, asphalt is a highly viscous petroleum product primarily used in road construction.
    - **Bunker (API: 12 to 14)**: Bunker crude oil is heavy oil typically used as a vessel fuel.
- **Medium Oil (API: Between 22.3 and 31.1)**: Medium oils include motor oils, which are derived from both petroleum and non-petroleum chemicals. Most motor oils are derived from crude oil, with additives to improve certain properties. Motor oils are generally used for lubricating internal combustion engines.
- **Biodiesel (API: 25.7 to 33.0):** Biodiesel is a fuel made from natural, renewable sources, such as new and used vegetable oils and animal fats, for use in a diesel engine.
- **Light Oils (API: Greater than 31.1)**
    - **Diesel (API: 35)**: Diesel oil is produced from crude oil. It is used as a fuel for diesel vehicles and burning.
    - **Jet fuel (API: 45):** Jet fuel is an aviation fuel. The most commonly used fuels for commercial aviation are Jet A and Jet A-1. Jet fuel is a mixture of a large number of different hydrocarbons.
    - **Ethanol (API: 48)**: Ethanol is an alcohol product produced from corn, wheat, sugar cane, and biomass and is primarily used as an additive in gasoline to increase its octane level or as a stand-alone fuel.
    - **Gasoline (API: 60)**: Gasoline or petrol is a petroleum-derived liquid flammable mixture consisting mostly of hydrocarbons and enhanced with isooctane or aromatics hydrocarbons toluene and benzene to increase octane ratings.[14] It is used as fuel for gasoline vehicles and burning.
- **Liquified Natural Gas (API: N/A):** Natural gas is lighter than air and will dissipate into the air if released.
- **Additives (API: N/A)**: Nearly all commercial motor oils contain additives. Additives are used for viscosity and lubricity, contaminant control, for the control of chemical breakdown, and for seal conditioning of oil.

[14] ALS Life Sciences. (No Date). *Library of Petroleum Products and Other Organic Compounds*. Retrieved from https://www.alsglobal.es/media-general/pdf/library-of-petroleum-products-and-other-organic-compounds.pdf

- **Slop Oil (API: Varies):** Slop Oil is defined as oil that is emulsified with water and solids. It is not usable as a fuel and contains similar contamination properties as the original oil source it contains.
- **Other:** Other products that do not fall into one of the prior categories includes unknown/unavailable contents, cutter, hydraulic fluids, storm water, and water.
- **Empty:** Tanks without any materials are categorized as "Empty".
- **Out of Service:** Tanks listed as out of service, rather than empty or with materials.
- **Extra Heavy Oil (API: Less than 10):** There is no evidence of extra heavy oils at the CEI Hub.

1-3.2.1.1 Flammability

Different fuel types have different risks of ignition. Whether materials burn following a release determines the range of air-quality and in-water environmental impacts. The assigned flammability of the materials is based upon Occupational Safety and Health Administration (OSHA) categories, as follows:[15]

- **Category 1:** Liquids with flashpoints below 73.4°F (23°C) and boiling point at or below 95°F (35°C). Examples: gasoline, some medium oils, and natural gas.
- **Category 2:** Liquids with flashpoints below 73.4°F (23°C) and boiling points at or above 95°F (35°C). Examples: Unleaded gasoline, ethanol, and bunker.
- **Category 3:** Liquids with flashpoints at or above 73.4°F (23°C) and at or below 140°F (60°C). Examples: Diesel, biodiesel, and jet fuel.
- **Category 4:** Includes liquids having flashpoints above 140°F (60°C) and at or below 199.4°F (93°C). When a Category 4 flammable liquid is heated for use to within 30°F (16.7°C) of its flashpoint, it must be handled as a Category 3 liquid with a flashpoint at or above 100°F (37.8°C). Examples: Marine diesel.

1-3.2.1.2 Hazardous Materials

Materials are deemed hazardous based on a combination of flammability, environmental harm, and risk from direct exposure to humans. Materials have their own Material Safety Data Sheets (MSDSs) that define the risk of harm. The categories used for this analysis are based on the MSDSs, as follows:

- **Category H – Hazardous**
  - All flammable materials are considered hazardous except for biodiesel.
  - Examples include gasoline, diesel, ethanol, jet fuel, and others.
- **Category NH – Non-Hazardous**
  - Examples include contact water and stormwater.
- **Not Available**

[15] OSHA's Directorate of Training and Education. (No Date). *Flammable Liquids: 29 CFR 1910.106*. Retrieved from https://www.osha.gov/sites/default/files/training-library_TrngandMatlsLib_FlammableLiquids.pdf

- Information was not available for these materials.
- Examples include motor oil, transmission fluid, additives, and others.

1-3.3 Quantities of Materials at CEI Hub

There are **630 tanks** of varying sizes throughout the CEI Hub holding a combined active storage tank capacity of at least **350.6 million gallons**.[16, 17] There is varying information available about the 630 tanks, as follows:

- **558 tanks** have available location data from either OSFM data, COP data, or City of Portland permitting information.[18] Of these tanks:
  - 143 are listed as "Out of Service" and thus not evaluated in the analysis.
  - 18 are listed as "Empty".
  - 4 tanks have unknown contents. These tanks are located at Chevron (1 tank), and Shore Terminals (3 tanks). These tanks are evaluated in the analysis as "Unknown" material types.
  - 393 tanks are in service and have known contents information. Of these tanks:
    - 365 tanks have tank capacity information, measured in gallons.
    - 28 tanks are missing capacity information. These tanks are located at BP (2 tanks), Shore Terminals (1 tank) and Zenith Energy (25 tanks).
- **72 tanks** were identified via aerial photographs but are not identified in the OSFM or COP datasets; these tanks are all in Area 4 (Zenith Energy) and are all relatively small tanks. These tanks are missing specific location details, tank age, tank contents, and tank capacity information. Because of the missing information these tanks were excluded from the analysis. Due to the location of the property, it is likely that any releases from these tanks would be onto the ground.

The are 415 active tanks, defined as tanks that are not out of service and excluding the 72 tanks in Area 4 of unknown status that were identified in aerial photos alone. Empty tanks are included in the active tank definition, as they could be filled. The majority of the active tank total capacity at the CEI Hub, approximately 65 percent or 215 million gallons, are light oils (e.g., gasoline and diesel) (Table 2).

Table 2. Total Maximum Capacity of Materials at CEI Hub in Active Tanks

Material Type	Maximum Tank Capacity (gallons)	Percent of Total Maximum Capacity	Number of Tanks	Percent of Tanks
Light Oil	215,337,397	65%	130	31%
Medium Oil	43,829,634	13%	144	35%

[16] For comparison to prior research estimates, Dusicka and Norton (2019) estimated that there are at least 362 tanks with a total capacity of 362.9 million gallons (8.64 million barrels) across all tanks (including out of service tanks).

[17] The 350.6 million gallons value does not account for out of service tanks or the 102 tanks that have unknown capacity. Accordingly, the true value of total capacity is likely higher than this value. However, tanks are rarely filled to full capacity, so this total capacity value does not reflect the amount of total materials on site.

[18] City of Portland, *Portland Maps*, available at: portlandmaps.com

Heavy Oil	34,928,796	10%	29	7%
Other	24,587,064	7%	50	12%
Natural Gas	7,100,000	2%	1	0%
Biodiesel	4,082,877	1%	10	2%
Slop Oil	1,826,017	1%	16	4%
Additive	702,924	0%	13	3%
Empty	344,469	0%	18	4%
Unknown	0	0%	4	1%
Total	**332,739,178**	**100%**	**415**	**100%**

Source: Salus Resilience, Appendix B
Note: Out of service tanks and the tanks of unknown status in Area 4 are not included in the total.

Although total maximum tank capacity represents the maximum amount of materials that could be located at the CEI Hub, tanks are not usually filled to full capacity. Average fill levels are available for 314 tanks from the COP data. On average for the tanks with information, tanks are filled to 67 percent capacity. Tank capacity is variable, since active tanks have their contents filled and distributed regularly. The utilization of the tanks varies by day, tank, owner, material, shipments, and other factors. An assumption in this analysis is that all active tanks are filled to 67 percent capacity. Using the 67 percent fill assumption, the total contents in active tanks at is 233.5 million gallons, on average (Table 3).

Table 3. Estimated Filled Capacity of Materials at CEI Hub in Active Tanks

Material Type	Average Expected Fill (gallons)
Light Oil	144,738,841
Medium Oil	39,585,777
Heavy Oil	23,402,293
Other	16,473,333
Natural Gas	4,757,000
Biodiesel	2,808,788
Slop Oil	1,223,431
Additive	470,959
Empty	0
Unknown	0
Total	**233,460,422**

Source: Salus Resilience, Appendix B
Note: Out of service tanks and the tanks of unknown status in Area 4 are not included in the total.

1-3.4 Tank Age

Of the 415 active tanks, 91 percent were built prior to 1993 or are missing information on year built, in which case they are assumed to have been built prior to 1993 (Table 4).[19] Tank age drives the assumptions for which tanks will fail, as described in Section 3.1.

[19] There were 72 tanks without a known year built and assumed to have been built prior to 1993.

Table 4. Number of Active Tanks and Year Built by Material Type

Material Type or Status	Built before 1993 or Unknown	Built between 1993-2004	Built after 2004	Total
Medium Oil	142	2		144
Light Oil	110	14	6	130
Other	47		3	50
Heavy Oil	25	4		29
Empty	16	2		18
Slop Oil	15	1		16
Additive	11		2	13
Biodiesel	10			10
Unknown	4			4
Natural Gas			1	1
Total	**380**	**23**	**12**	**415**

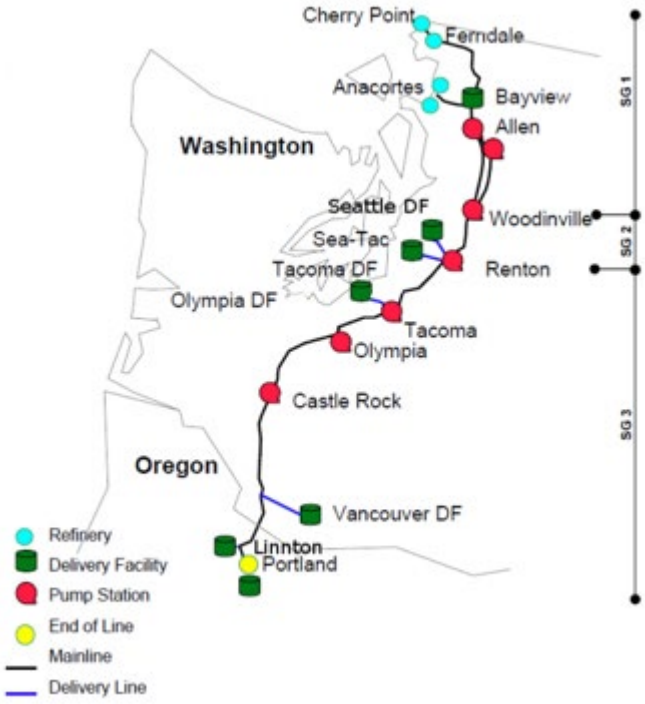
Source: Salus Resilience, Appendix B

1-3.5 Pipelines and Rail Tankers

The CEI Hub is supplied by the Olympic Pipeline which connects as far north as Bellingham, Washington and transports gasoline, diesel, and jet fuel in pipes between 12 to 20 inches in diameter (Figure 2).[20] There are also other pipelines connecting to the CEI Hub for fuels, including the Kinder Morgan pipeline that links petroleum terminals in the Portland region, including to the Portland International Airport. Like tanks, pipelines are also subject to potential failure due to seismic risks. For the Olympic Pipeline, breaks could occur north of the CEI Hub. Pipeline contents and the resulting risk of release vary by day. Since the material is ultimately stored in tanks at the CEI Hub, the effect of pipeline releases is partially accounted for in the tank capacity. Given these uncertainties, this analysis does consider the effects of a pipeline rupture at the CEI Hub, but focuses solely on tank capacity.

[20] For more information see BP Olympia Pipeline website: https://www.bp.com/en_us/united-states/home/products-and-services/pipelines/our-pipelines.html#accordion_olympic

Figure 2. Olympic Pipeline Map



Source: BP, Olympic Overview website, available at: https://www.bp.com/content/dam/bp/country-sites/en_us/united-states/home/documents/products-and-services/pipelines/olympic-overview.pdf

There are also railroad tankers that travel to CEI Hub properties for storage and shipment. For example, rail cars filled with Canadian tar sands crude oil are transported through the Columbia River Gorge to the CEI Hub. The crude oil is then stored in tanks before being transported to other locations, such as China, South Korea, and West Coast refineries.[21] Like the pipelines, the stored material from railroad tankers is accounted for in the tanks. It is beyond the scope of this analysis to also consider potential risks and economic damages associated with railroad tanker derailment due to a CSZ earthquake outside of the CEI Hub. However, the 2016 oil tanker derailment in Moiser, Oregon discussed in Section 5.1.1 provides a case study of the effects of releases of Bakken crude oil along the Columbia River.

1-3.6 Ground Releases

Of the 415 total active tanks, 308 are in active use and have the potential to release contents onto to the ground.[22] Based on location and tank age, 285 tanks have the potential to release 50 to 100 percent of their tank contents onto the ground and 23 tanks have the potential to release up to

[21] Friedman, G.R. (2019). Crude oil trains increasingly travel through Portland, alarming regulators. *The Oregonian*. August 29. Available at: https://www.oregonlive.com/news/g66l-2019/04/877e9ecf591571/crude-oil-trains-increasingly-travel-through-portland-alarming-regulators.html

[22] A detailed table is provided in Appendix B.

10 percent of their contents onto the ground. In total, a range of 53.9 million gallons to 111.2 million gallons would be released to ground surfaces (Table 5).

Table 5. Materials with Potential to Release to the Ground Surface

Substance Type	Number of Tanks	Volume Released Min (gal)	Volume Released Max (gal)
Medium Oil	144	19,506,218	39,069,770
Light Oil	73	30,811,094	63,657,094
Other	36	2,195,027	5,241,511
Empty	18	0	0
Heavy Oil	17	323,948	647,895
Slop Oil	8	462,794	925,588
Additive	7	146,803	293,605
Biodiesel	3	436,369	872,738
Natural Gas	1	0	475,700
Unknown	1	0	0
Total	**308**	**53,882,252**	**111,183,900**

Source: Created by Salus Resilience, Appendix B

1-3.7 Water Releases

Based on location and tank age, 107 active tanks have the potential to release materials that could flow into the Willamette River.[23] Of those, 96 of these tanks have the potential to release between 50 to 100 percent of their contents to the Willamette River and 11 tanks have the potential to release up to 10 percent of their contents into the water. In total, a range of 40.8 million to 82.5 million gallons could potentially reach the water (Table 6).

Table 6. Materials with Potential to Release to the Water Surface

Substance Type	Number of Tanks	Volume Released Min (gal)	Volume Released Max (gal)
Light Oil	57	26,474,505	53,930,869
Other	14	1,782,545	3,565,452
Heavy Oil	12	11,290,612	22,598,542
Slop Oil	8	148,763	297,557
Biodiesel	7	968,025	1,936,050
Additive	6	87,303	174,881
Unknown	3	0	0
Total	**107**	**40,751,753**	**82,503,352**

Source: Created by Salus Resilience, Appendix B

1-3.8 Total Potential Releases

In total, 397 tanks could release stored materials as a result of the CSZ earthquake.[24] Based on tank age and location, approximately 365 tanks could release 50 to 100 percent of their materials and 32 tanks could release up to 10 percent of stored materials. Together, the total potential

[23] A detailed table is provided in Appendix B.

[24] This value excludes empty tanks from the active tanks that could release materials.

releases from the materials stored in tanks at the CEI Hub range from 94.6 million to 193.7 million gallons (Table 7). Approximately 57 percent of the total potential releases would be released onto ground and 43 percent have the potential to flow into the Willamette River.

Table 7. Summary of Total Potential Releases by Location

Spill Location	Number of Tanks with 50–100 percent failure	Number of Tanks with up to 10 percent failure	Volume Released Min (gal)	Volume Released Max (gal)
Ground	269	21	53,882,252	111,183,900
Water (Including potentially in water)	96	11	40,751,753	82,503,352
Total	**365**	**32**	**94,634,005**	**193,687,251**

Source: Created by Salus Resilience, Appendix B

1-3.9 Burning Materials and Fire Potential

A fire at the CEI Hub involving the fuels stored on-site is a likely scenario following a CSZ earthquake. Many fuel storage tanks have a metal floating lid which in an earthquake could scrape against the metal perimeter, creating a spark and potentially a fire. Fires within tanks could result in large explosions, further threatening people, property, and environmental resources. There are also power lines throughout the CEI Hub which could fall due to the earthquake and serve as a potential ignition source.

Of the 393 active tanks that are not empty and have known contents at the CEI Hub, 200 tanks (approximately 51 percent), have materials that have are known to be flammable (Table 8). Based on the total estimate of releases, approximately 93 percent of releases will be of flammable materials (i.e., in Category 1 through 4). The total capacity of tanks with flammable materials is 298.7 million gallons. Therefore, the contents of these tanks all have the potential to burn, either on land or in the water. Because burning requires both a fuel and an ignition source, the specific amount of materials that would burn are a function of location and event-specific factors.

Table 8. Tanks and Capacity by Flammability Category

Flammability Category	Number of Tanks	Volume Released Min (gal)	Volume Released Max (gal)
Category 1 (Most Flammable)	106	37,987,895	78,549,612
Category 2	28	22,455,581	45,248,842
Category 3	66	27,474,245	55,541,111
Category 4	0	0	0
Not Flammable	14	864,764	1,729,889
Unknown	183	5,851,521	12,617,797
Empty	18	0	0
Total	**415**	**94,634,005**	**193,687,251**

Source: Created by Salus Resilience, Appendix B

1-4 Substance Information

1-4.1 Substance Toxicities

The fuels stored at the CEI Hub are toxic, meaning that they can harm living things. Accordingly, release of these materials will be harmful to organisms that they come in to contact with through the ground, water, and/or air. The level of harm depends on the substance, the level of exposure, and the pathway of exposure. Harm to living organisms can be caused by direct physical contact – such as oil smothering plant and animals – or biochemical, which refers to the poisonous nature of the chemicals.[25] The chemical characteristics of petroleum substances also interact with the physical and biochemical features of the habitat where a spill occurs – meaning that the total effect is a combination of both the substance that is released as well as the environment that it is released into.

The biochemical response varies based on the specific chemical composition of the compound. Because fuels, additives, oils, and the other substances stored at the CEI Hub have different chemical compositions depending on the specific blend, they can vary in toxicity even within certain categories of substances.[26]

Two of the primary toxic biochemical substances associated with petroleum products are **volatile organic compounds (VOCs)** and **polycyclic aromatic hydrocarbons (PAHs)**. VOCs disperse into the air and can be toxic when inhaled. Because VOCs evaporate into the air, they are generally a concern only right after oil is spilled – oil floating on water surfaces quickly volatize and lose their VOCs. At the site of a fresh oil spill, these VOCs can threaten nearby residents, responders working on the spill, and air-breathing marine mammals.[27] In contrast, PAHs can persist in the environment for many years, in some cases continuing to harm organisms long after the oil first spills. Studies in Alaska and Washington suggest that PAHs are particularly harmful to fish eggs and embryos.[28]

[25] NOAA, Office of Response and Restoration, *The Toxicity of Oil: What's the Big Deal?*. Available at: https://response.restoration.noaa.gov/about/media/toxicity-oil-whats-big-deal.html

[26] NOAA, Office of Response and Restoration, *How Toxic is Oil*?. Available at: https://response.restoration.noaa.gov/oil-and-chemical-spills/significant-incidents/exxon-valdez-oil-spill/how-toxic-oil.html

[27] NOAA, Office of Response and Restoration, *The Toxicity of Oil: What's the Big Deal?*. Available at: https://response.restoration.noaa.gov/about/media/toxicity-oil-whats-big-deal.html

[28] NOAA, Office of Response and Restoration, *How Toxic is Oil*?. Available at: https://response.restoration.noaa.gov/oil-and-chemical-spills/significant-incidents/exxon-valdez-oil-spill/how-toxic-oil.html

1-4.1.1 Toxicity by Substance

Oil is grouped into five basic groups in the Code of Federal Regulations (Table 9).[29] The two most common substances at the CEI Hub, gasoline and diesel, are in Group 1 and Group 2, respectively. Diesel is one of the most acutely toxic oil types and can cause high mortality rates in fish and invertebrates when released into water resources.[30]

Table 9. Five Basic Groups of Oil

Group 1: Non-Persistent Light Oils (Gasoline, Condensate)	Highly volatile (should evaporate within 1-2 days). Do not leave a residue behind after evaporation. High concentrations of toxic (soluble) compounds. Localized, severe impacts to water column and intertidal resources. Cleanup can be dangerous due to high flammability and toxic air hazard.
Group 2: Persistent Light Oils (Diesel, No. 2 Fuel Oil, Light Crudes)	Moderately volatile; will leave residue (up to one-third of spill amount) after a few days. Moderate concentrations of toxic (soluble) compounds. Will "oil" intertidal resources with long-term contamination potential. Cleanup can be very effective.
Group 3: Medium Oils (Most Crude Oils, IFO 180)	About one-third will evaporate within 24 hours. Oil contamination of intertidal areas can be severe and long-term. Oil impacts to waterfowl and fur-bearing mammals can be severe. Cleanup most effective if conducted quickly.
Group 4: Heavy Oils (Heavy Crude Oils, No. 6 Fuel Oil, Bunker C)	Little or no evaporation or dissolution. Heavy contamination of intertidal areas likely. Severe impacts to waterfowl and fur-bearing mammals (coating and ingestion). Long-term contamination of sediments possible. Weathers very slowly. Shoreline cleanup difficult under all conditions.
Group 5: Sinking Oils (Slurry Oils, Residual Oils)	Will sink in water. If spilled on shoreline, oil will behave similarly to a Group 4 oil. If spilled on water, oil usually sinks quickly enough that no shoreline contamination occurs. No evaporation or dissolution when submerged. Severe impacts to animals living in bottom sediments, such as mussels. Long-term contamination of sediments possible. Can be removed from the bottom of a water body by dredging.

Source: NOAA, Office of Response and Restoration, *Oil Types*, Available at: https://response.restoration.noaa.gov/oil-and-chemical-spills/oil-spills/oil-types.html

Jet fuel is not included in the five basic groupings, but is also stored at the CEI Hub. Jet fuel is composed of light hydrocarbons with low viscosities. When spilled on open water, most of the

[29] Title 33, Chapter I, Subchapter O, Part 155, Subpart D. §155.1020.

[30] NOAA, Office of Response and Restoration, *Small Diesel Spills*. Available at: https://response.restoration.noaa.gov/sites/default/files/Small-Diesel-Spills.pdf

jet fuel will evaporate or naturally disperse within a day or less, leading predominantly to air quality impacts rather than aquatic impacts.[31] However, jet fuel can attach to fine-grained suspended sediments in the water, which then settle out and get deposited on the bottom of a waterbody. Although jet fuels are relatively less acutely toxic than diesel, high levels of mortality in animals and plants are expected where larger amounts of this type of petrochemical soak into wetland soils.

Biodiesel and non-petroleum oils, which are also stored at the CEI Hub in lower quantities, generally have low fire risk and a lower risk of biochemical toxicity, but pose a high risk of smothering to wildlife. The physical effects of coating animals and plants with oil include hypothermia, dehydration, diarrhea, starvation, or suffocation from the clogging of nostrils, throat, or gills, as well as from the reduction in water oxygen content.[32]

Ethanol, another substance present at the CEI Hub, is also toxic to animals through primarily physical effects. However, instead of smothering, the main risk from ethanol is lower dissolved oxygen levels which can kill fish and other aquatic species.[33]

1-4.2 Fate and Transport of Contaminants

Fate and transport refer to the outcomes of released materials – how far they go and where they end up. Because of their different chemical compositions, oils vary in terms of how they react with the environment. Depending on their density, oils that are heavier than water will sink while oils that are lighter than water will float on the surface (absent heavy disturbances). Light oils like gasoline have a density of 0.85 gram per cubic centimeter (g/cc) – most types of oils have densities between about 0.90 and 0.98 g/cc.[34] The density of river water is usually about 1.0 g/cc.

Heavy oils can have a density as high as 1.01 g/cc, meaning they would sink in a river. Clean up can be very difficult and disruptive to the environment for this type of spill. Methods for cleaning up heavy oil spills can include vacuuming, dredging, scraping, and other invasive methods. Because these methods directly affect the environment, they can result in relatively greater injury to habitats, species, and other natural resources.

Medium and light oils are lighter than water and, due to their volatility, will disperse into the air through evaporation. Within a few days following a spill, light crude oils can lose up to 75 percent of their initial volume and medium crudes up to 40 percent through evaporation, but

[31] NOAA, Office of Response and Restoration, *Kerosene and Jet Fuel Spills*. Available at: https://response.restoration.noaa.gov/sites/default/files/Kerosene-Jet-Fuel.pdf

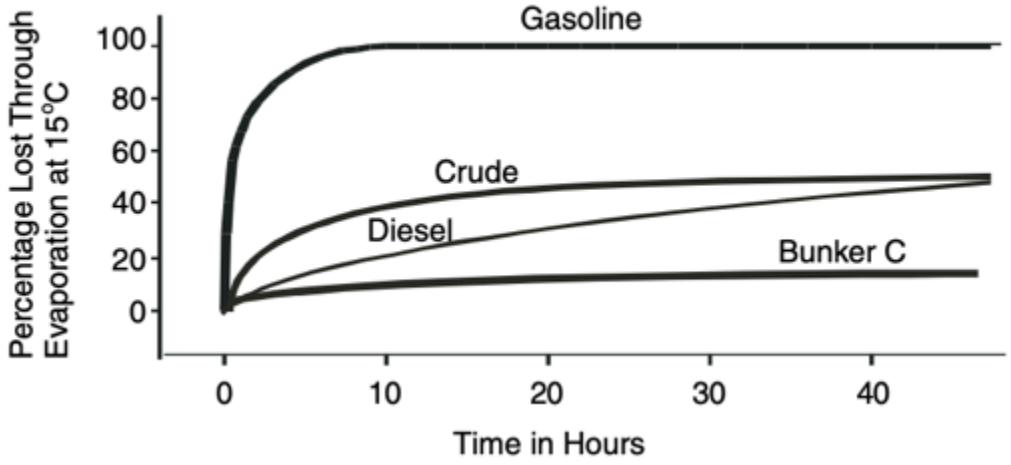
[32] NOAA, Office of Response and Restoration, *Non-Petroleum Oil Spills*. Available at: https://response.restoration.noaa.gov/sites/default/files/Non-Petroleum-Oil.pdf

[33] NOAA, Office of Response and Restoration, *Denatured Ethanol Spills*. Available at: https://response.restoration.noaa.gov/sites/default/files/Denatured-Ethanol.pdf

[34] NOAA, Office of Response and Restoration, *Oil Spills in Rivers*. Available at: https://response.restoration.noaa.gov/oil-and-chemical-spills/oil-spills/resources/oil-spills-rivers.html

heavy oils will lose only 10 percent of their volume in the first few days following a spill (Figure 3).[35]

Figure 3. Evaporation Rates of Different Types of Oils



Source: National Research Council. (2003). *Oil in the Sea III: Inputs, Fates, and Effects*. Washington, DC: The National Academies Press. https://doi.org/10.17226/10388.

After a spill occurs, how the physical and chemical characteristics of oil interact with the physical and biochemical features of the habitat is known as "weathering". Weathering is influenced by the characteristics of the substance, including:

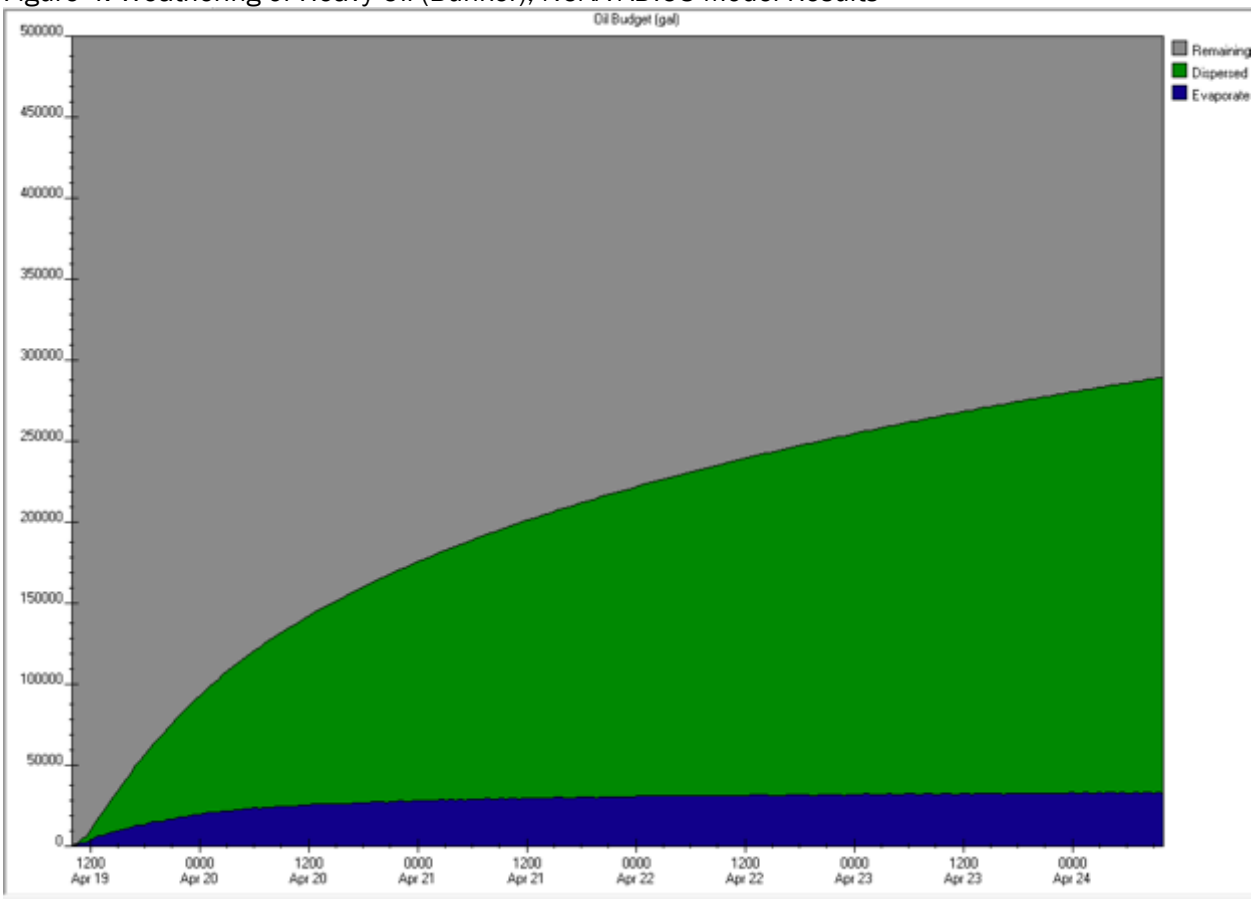
- How rapidly the substance evaporates;
- How easily the substance is broken down by microbes in the environment; and
- How rapidly sunlight degrades the substance.

Weathering can be modeled using NOAA's Automated Data Inquiry for Oil Spills (ADOIS) that uses location- and material-specific parameters to model the results of oil releases into water environments.[36] For a heavy oil, like bunker, a large percentage of the oil will remain even weeks later (Figure 4). In contrast, a light oil, like gasoline, will fully disperse or evaporate within 1 or 2 days (Figure 5).

[35] National Research Council. (2003). *Oil in the Sea III: Inputs, Fates, and Effects*. Washington, DC: The National Academies Press.

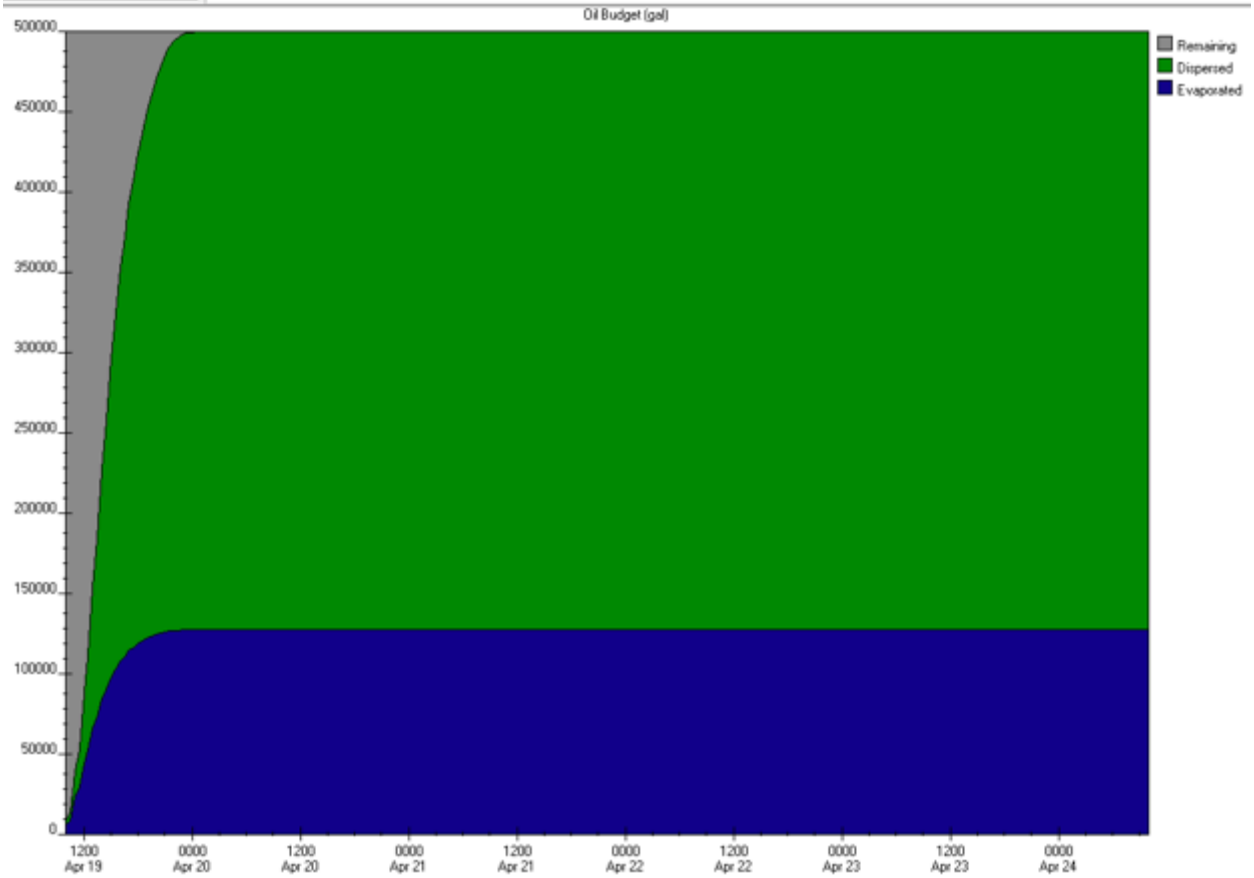
[36] More information about the ADIOS model can be found at: https://response.restoration.noaa.gov/oil-and-chemical-spills/oil-spills/response-tools/adios.html

Figure 4. Weathering of Heavy Oil (Bunker), NOAA ADIOS Model Results



Source: NOAA ADIOS® (Automated Data Inquiry for Oil Spills) Model

Figure 5. Weathering of Light Oil (Diesel), NOAA ADIOS Model Results



Source: NOAA ADIOS® (Automated Data Inquiry for Oil Spills) Model

Materials that are dispersed through the water column are not easily recoverable via clean-up. Dispersed and remaining materials will continue to interact with the environment in which they reside through oxidation, biodegradation, and emulsification, defined as follows:[37]

- **Oxidation** is when water and oxygen combine with oil to produce water-soluble compounds. This process affects oil slicks mostly around their edges. Thick slicks may only partially oxidize, forming *tar balls*. These dense, sticky, black spheres may linger in the environment, and can collect in the sediments of slow-moving streams or lakes or wash up on shorelines long after a spill.

- **Biodegradation** occurs when micro-organisms such as bacteria feed on oil. A wide range of micro-organisms is required for a significant reduction of the oil. As a clean-up method to support biodegradation, nutrients such as nitrogen and phosphorus are

[37] Environmental Protection Agency. (No Date). *The Fate of Spilled Oil*. Retrieved from https://archive.epa.gov/emergencies/content/learning/web/html/oilfate.html#:~:text=Evaporation%20occurs%20when%20the%20lighter,sink%20to%20the%20ocean%20floor.

sometimes added to the water to encourage the micro-organisms to grow and reproduce. Biodegradation tends to work best in warm water environments.

- **Emulsification** is a process that forms *emulsions*, a mixture of small droplets of oil and water. Emulsions are formed by wave action, and greatly hamper weathering and cleanup processes. Two types of emulsions exist: water-in-oil and oil-in-water. Water-in-oil emulsions formed when strong currents or wave action causes water to become trapped inside viscous oil. These emulsions may linger in the environment for months or even years. Emulsions cause oil to sink and disappear from the surface, which give the false impression that it is gone and the threat to the environment has ended.

1-4.3 Oil Spill Clean-Up

Clean-up actions following oil spills in water resources fall generally into three categories depending on the weathering characteristics of the released substance(s):

- **Containment without removal**: Generally performed for volatile substances like light fuels that will naturally quickly evaporate or disperse and often is done using booms. Because the oil remains on the surface, this is an effective method.
- **Containment with removal**: Generally used with heavier fuels, such as through accelerated biodegradation, use of skimmers, use of sorbents (materials to soak up liquids), use of dispersants, and in situ burning.[38]
- **Intensive removal**: Intensive removal includes dredging and scraping vegetation and soils, as well as direct removal of oil residues from animals.

Clean-up on shorelines or other land depends on the habitat characteristics. Clean-up responses are time-sensitive to prevent the runoff of substance into water resources. Containment methods can be used to minimize this risk. Natural processes of evaporation, oxidation, and biodegradation also occur for spills on land. Physical clean-up methods can include wiping with sorbent materials, pressure washing, raking, and bulldozing, as well as burning – with proper disposal after materials have been removed from the site.[39]

[38] EPA Office of Emergency and Remedial Response. (1999). *Understanding Oil Spills and Oil Spill Responses*.

[39] EPA Office of Emergency and Remedial Response. (1999). *Understanding Oil Spills and Oil Spill Responses*.

1-5 Case Studies of Other Fossil Fuel Infrastructure Failures

Other fossil fuel releases provide examples of the effects of releases in different environments and for different substances. This section describes other fossil fuel infrastructure failures, their effects, and their associated damages. These case studies are not meant to be comprehensive of all instances of fossil fuel failures and oil spills. Rather, it provides examples that can be used to understand the potential effects of fuel releases at the CEI Hub. Failures at the CEI Hub due to a CSZ earthquake have the potential to result in the largest oil spill in U.S. history. Estimates of releases are the same magnitude as what was released in the Deepwater Horizon spill – the largest oil spill in U.S. waters to date.

1-5.1 Case Study Details

The case studies are organized into four categories:

- Case studies of fuel releases in Oregon;
- Case studies of fuel releases in river shipping channels and water resources;
- Case studies of other fuel releases at tank farms, near sensitive habitat, or due to earthquakes.

1-5.1.1 Fuel Releases in Oregon

There have been spills of other fossil fuels in Oregon, particularly related to road and rail incidences. A failure at the CEI Hub would be more than ten times larger than the previous largest oil spill that occurred in 1984. An oil spill on the scale of the potential releases at the CEI Hub is unprecedented. In terms of the environmental effects of the spill, the guidance from the Clean Water Act and the Oregon Department of Environmental Quality highlights how even minimal oil releases require a response to minimize damages. Any amount of oil spilled into water and spills over 42 gallons on land must be reported to emergency services in Oregon.[40]

1-5.1.1.1 Lindsey Lake Tanker Spill near Hood River, OR (2019)

On February 11, 2019, a tanker truck carrying winter-grade diesel fuel overturned on Interstate 84 near Hood River, Oregon. An estimated 4,400 gallons of winter blend diesel were spilled onto the roadway, approximately half of which flowed into the partially frozen Lindsey Lake

[40] Oregon Department of Environmental Quality, *How To Report A Spill*. Available at: https://www.oregon.gov/deq/Hazards-and-Cleanup/env-cleanup/Pages/How-To-Report-A-Spill.aspx#:~:text=The%20National%20Response%20Center%3A%201%2D800%2D424%2D8802&text=Where%20is%20the%20spill%3F,What%20spilled%3F

nearby.[41] Lindsey Lake is hydraulically connected to the Columbia River as well as a known salmon spawning lake habitat, making the spill a threat to the greater regional ecosystem. As part of containment, responders placed a boom on the lake to protect spawning locations and sensitive vegetation.[42] In addition, impacted snow was collected and monitoring wells were installed to further determine environmental damage. Oregon Department of Environmental Quality (DEQ) issued the operating party Space Age Fuel a civil penalty of $66,000 for environmental damages.[43] As of October 22, 2019, the cleanup cost to date was $3.4 million.[44]

1-5.1.1.2 Columbia River Oil Train Derailment near Mosier, OR (2016)

On June 3, 2016 an oil train derailed near Mosier, Oregon, resulting in the discharge of 47,000 gallons of Bakken crude oil approximately 600 feet from the Columbia River.[45] Four train cars caught fire and the fire was extinguished the next day. The incident resulted in the closure of I-84 (10 hours) and the rail line, as well as a nearby park. People were evacuated from their homes ,and damage to the city's wastewater system prevented residents from using water for three days.

The day after the incident, an oil sheen on the Columbia River prompted the use of booms for containment. Within a few days, the sheen dissipated with no further cleanup beyond the containment booms. There were no observed effects on wildlife from the incident.[46] Air quality monitoring began the day of the incident. In the immediate area of the derailment, there were detected levels of Benzene, Hexane, O_2, $PM_{2.5,}$ and VOC.[47] More broadly, PM_{10}, O_2, $PM_{2.5}$, and VOCs were detected as far as 3 miles away.[48]

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[41] U.S. Environmental Protection Agency. (No Date). *Lindsey Lake Tanker Truck Spill*. Available at: https://response.epa.gov/site/site_profile.aspx?site_id=14106

[42] Oregon Department of Environmental Quality. (2019). *Presentation to the Environmental Quality Commission*. November 15. Available at: https://www.oregon.gov/deq/EQCdocs/11152019_EmergencyResponse_Slides.pdf

[43] Oregon Department of Environmental Quality. (2020). *Notice of Civil Penalty Assessment and Order Case No. LQ/SP-ER-2019-296*. April 24. Available at: https://www.oregon.gov/deq/nr/0420SpaceAgeFuel.pdf

[44] Oregon Department of Environmental Quality. (2019). *Presentation to the Environmental Quality Commission*. November 15. Available at: https://www.oregon.gov/deq/EQCdocs/11152019_EmergencyResponse_Slides.pdf

[45] U.S. Environmental Protection Agency, Region 10. (2016). *Mosier Oil Train Derailment*. Available at: https://response.epa.gov/site/site_profile.aspx?site_id=11637

[46] U.S. National Response Team. (2016). *Mosier Oil Train Derailment.* Available at: https://nrt.org/site/download.ashx?counter=4472

[47] Center for Toxicology and Environmental Health. (2016). *Mosier Unit Train Derailment Mosier, OR Preliminary Summary of Air Monitoring Results June 5, 2016*. Available at: https://www.deq.state.or.us/Webdocs/Forms/Output/FPController.ashx?SourceIdType=11&SourceId=6115&Screen=Load

[48] Center for Toxicology and Environmental Health. (2016). *Mosier Unit Train Derailment Mosier, OR Preliminary Summary of Air Monitoring Results June 5, 2016*.

1-5.1.1.3 Tanker SS MobilOil, Columbia River, OR (1984)

On March 19, 1984, the oil tanker SS MobilOil grounded on the Columbia River near St. Helens. The National Transportation Safety Board determined the cause to be a steering gear failure which forced the ship to run aground on a rocky reef.[49] The reef ripped open four holding tanks and released an estimated 170,000 gallons of heavy residual oil, number six fuel oil, and industrial fuel oil into the river.[50] Oil was spread along the Washington and Oregon coastal shoreline as far south as Cannon Beach and as far north as the entrance to the Strait of Juan de Fuca.

The containment and cleanup effort involved 60 people who used booms to block moorings and marinas. The total cleanup cost was estimated at $3 million, and the cost to repair the tanker was estimated at $5 million.[51] After the spill, there were many dead waterbirds in the area.

1-5.1.2 Fuel Releases into Shipping Channels and Water Resources

The CEI Hub is along the Willamette River, a shipping channel for accessing the Port of Portland and other port facilities. Previous incidents of oil spills in river shipping channels demonstrate not only the environmental effects of discharge into water and riparian habitats but also the economic impact that results from the closure of shipping lanes.

1-5.1.2.1 Refugio Incident near Gaviota, CA (2015)

The Refugio Incident near Gaviota, California was a pipeline oil spill located north of Refugio State Beach in Santa Barbara County, California. On May 19, 2015, Line 901, a 10.6-mile pipeline owned by Plains All American Pipeline, ruptured and spilled over 123,000 gallons of crude oil.[52] Over 53,000 gallons of the spilled oil ended up in the Pacific Ocean, where it caused death and disruption to wildlife and vegetation, as well as other environmental damages.[53] The oil reached

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[49] Speich, S.M., and Thompson, S.P. (1987). *Impacts on Waterbirds from the 1984 Columbia River and Whidbey Island, Washington, Oil Spills.* Available at: https://sora.unm.edu/sites/default/files/journals/wb/v18n02/p0109-p0116.pdf

[50] U.S. Department of Energy Office of Scientific and Technical Information (1984). *Marine accident report - grounding of United States Tankship SS MOBILOIL, in the Columbia River near Saint Helens, Oregon, March 19, 1984.* Available at: https://www.osti.gov/biblio/5742109-marine-accident-report-grounding-united-states-tankship-ss-mobiloil-columbia-river-near-saint-helens-oregon-march

[51] U.S. Department of Energy Office of Scientific and Technical Information. (1984). *Marine accident report - grounding of United States Tankship SS MOBILOIL, in the Columbia River near Saint Helens, Oregon, March 19, 1984.*

[52] Anderson, M. (2020). *Refugio Beach Oil Spill Draft Damage Assessment and Restoration Plan/ Environmental Assessment Presentation.* May 13. Available at https://pub-data.diver.orr.noaa.gov/admin-record/6104/DARPPublicMeetingMAndersonIntroOverviewSlides_5-13-20_forwebposting.pdf

[53] NOAA. (2015). *Refugio Beach Oil Spill*. Available at https://darrp.noaa.gov/oil-spills/refugio-beach-oil-spill; National Oceanic and Atmospheric Administration (NOAA). (2020). *Draft Restoration Plan to Support Recovery of Natural Resources Following Refugio Beach Oil Spill.* April 22. Available at: https://pub-data.diver.orr.noaa.gov/admin-record/6104/20200422_FINAL%20DARP%20Press%20Release.mediaready.pdf

other beaches as far south as Los Angeles County.[54] In March of 2020, nearly five years after the incident, a $22.3 million settlement was authorized through the Damage Assessment and Restoration Plan and Environmental Assessment.

The spill impacted recreation, commercial fisheries, and closed beaches. Recreation closures occurred at Refugio State Beach (1 month)[55] and El Capitán State Beach (2 months).[56] The Draft Restoration Plan estimates over 140,000 lost recreational user-days valued at $3.9 million.

Air quality monitoring began the day after the spill for approximately one month for VOCs, benzene, hexane, toluene, atmospheric flammability as a percent of the lower explosive limit, and hydrogen sulfide (H2S).[57] The air monitoring did not detect crude oil-associated compounds that exceeded U.S. Environmental Protection Agency standards for VOCs. As such, the assessment determined no human health risks from these airborne compounds. Of note is that there was no fire or ignition of VOCs from the event.

1-5.1.2.2 TX City Y Spill in Houston Channel, TX (2014)

On March 22, 2014, the bulk carrier M/V Summer Wind collided with the oil tank-barge Kirby 27706 in Galveston Bay near Texas City, Texas. As a result, the barge spilled approximately 168,000 gallons of intermediate fuel oil into lower Galveston Bay, the majority of which then flowed into the Gulf of Mexico.[58] Most of the discharged oil was on shorelines between Galveston and Matagorda Islands.[59] Damages and impacts for this incident are still being evaluated, but the release caused the closure of the heavily trafficked Port of Houston for 3 days.[60] As of 2015, PAHs from the oil spill continue to pose environmental risks in the marine environment.[61] In 2016, Kirby Island Marine L.P. agreed to pay $4.9 million in Clean Water Act civil penalties due to the incident.[62]

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[54] NOAA. (2020). *Draft Restoration Plan to Support Recovery of Natural Resources Following Refugio Beach Oil Spill.* April 22.

[55] Rocha, Veronica (2015). "El Capitan beach to reopen a month after Santa Barbara County oil spill". *Los Angeles Times*. June 19.

[56] Moore, J.C. (2015). "Refugio State Beach to reopen today after oil-spill closure". *Ventura County Star*. July 17.

[57] Center for Toxicology and Environmental Health, LLC. (2015*). Community Air Monitoring and Sampling Summary: Refugio Incident.* June 15.

[58] NOAA, Office of Response and Restoration. (2014). *Texas City Y Oil Spill*. Available at: https://darrp.noaa.gov/oil-spills/texas-city-y

[59] Yin, F., Hayworth, J. S., & Clement, T. P. (2015). A tale of two recent spills—comparison of 2014 Galveston Bay and 2010 Deepwater Horizon oil spill residues. *PloS one*, 10(2), e0118098.

[60] NOAA, Office of Response and Restoration. (2014). *Update on the Texas City "Y" Response in Galveston Bay*. Available at: https://response.restoration.noaa.gov/about/media/update-texas-city-y-response-galveston-bay.html

[61] Yin, F., Hayworth, J. S., & Clement, T. P. (2015). A tale of two recent spills—comparison of 2014 Galveston Bay and 2010 Deepwater Horizon oil spill residues. *PloS one*, 10(2), e0118098.

[62] U.S. Department of Justice. (2016). *Kirby Inland Marine to Pay $4.9 Million in Civil Penalties and Provide Fleet-Wide Improvements to Resolve U.S. Claims for Houston Ship Channel Oil Spill.* September 27. Available at:

1-5.1.2.3 Deepwater Horizon in the Gulf of Mexico (2010)

The Deepwater Horizon oil spill is the largest spill in the history of the United States. On April 20, 2010, an explosion occurred on the Deepwater Horizon drilling platform in the Gulf of Mexico, leading to the largest offshore oil spill in U.S. history. The explosion caused the rig to sink and leaked 134 million to 206 million gallons of oil into the Gulf over three months.[63] The initial explosion killed eleven men. The Deepwater Horizon oil spill killed thousands of marine mammals and sea turtles, and also contaminated their habitats.[64] Containment measures included floating booms, skimmer boats, and sorbents. Chemical dispersants were also used to facilitate oil degradation. During the spill response there was a temporary flight restriction over the area as well as on-the-ground access restrictions.

A major public health impact was air pollution. A study following the incident found four primary sources of pollutants: (a) Hydrocarbons (HCs) evaporating from the oil; (b) smoke from deliberate burning of the oil slick; (c) combustion products from the flaring of recovered natural gas; and (d) ship emissions from the recovery and cleanup operations.[65] Studies have noted that the air pollution impacts could have been much worse for a spill of similar size closer to populated areas, closer to the surface, or in a region with larger NOx sources.

The financial claims were largely settled when a Federal District judge approved the largest environmental damage settlement in United States history – $20.8 billion – on April 4, 2016.[66] In 2016, BP calculated their total cost for the oil spill, including both damages, fines, and economic loss, as $61.6 billion.[67]

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https://www.justice.gov/opa/pr/kirby-inland-marine-pay-49-million-civil-penalties-and-provide-fleet-wide-improvements

[63] United States of America v. BP Exploration & Production, Inc., et al. (2015). *Findings of fact and conclusions of law: Phase Two trial. In re: Oil spill by the oil rig "Deepwater Horizon" in the Gulf of Mexico, on April 20, 2010, No. MDL 2179, 2015 WL 225421.* (Doc. 14021). U.S. District Court for the Eastern District of Louisiana. Retrieved from https://www.gpo.gov/fdsys/pkg/USCOURTS-laed-2_10-md-02179/pdf/USCOURTS-laed-2_10- md-02179-63.pdf

[64] NOAA. (2017). *Deepwater Horizon Oil Spill Longterm Effects on Marine Mammals, Sea Turtles*. Available at: https://oceanservice.noaa.gov/news/apr17/dwh-protected-species.html#:~:text=The%20scientists%20concluded%20that%20the,turtles%2C%20and%20contaminated%20their%20habitats.

[65] Middlebrook, A. M., Murphy, D. M., Ahmadov, R., Atlas, E. L., Bahreini, R., Blake, D. R., & Ravishankara, A. R. (2012). Air quality implications of the Deepwater Horizon oil spill. *Proceedings of the National Academy of Sciences*, *109*(50), 20280-20285.

[66] NOAA. (2017). *Explosion triggered economic, environmental devastation, and a legal battle*. April 20. Available at https://www.noaa.gov/explainers/deepwater-horizon-oil-spill-settlements-where-money-went

[67] BP. (2016). *2Q 2016 Results: Conference Call on July 24, 2016*. Available at: https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/investors/bp-second-quarter-2016-results-presentation-slides-and-script.pdf

1-5.1.2.4 Eagle Otome in Port Arthur, TX (2010)

On January 23, 2010, a barge and its towing vessel collided with the tanker Eagle Otome on the Sabine Neches Canal in Port Arthur, Texas. The Eagle Otome was punctured and an estimated 462,000 gallons of Olmeca crude sour oil was spilled into the canal.[68] The spill caused a shipping lane closure of 16 miles and impacted local residents, 136 of whom were temporarily evacuated from the site. Clean up responses at the crash site were delayed for approximately 12 hours due to high levels of hydrogen sulfide. Air monitoring beyond the immediate area did not indicate the presence of hydrogen sulfide, but there was a strong petroleum odor. The spill resulted in $1.5 million in damages to the Eagle Otome, $35,000 to the towing vessel, and $381,000 to the barge vessel.

1-5.1.2.5 Enbridge Line 6B in the Kalamazoo River, MI (2010)

On July 25, 2010, a rupture in the Enbridge line 6B pipeline caused oil to leak into the wetlands adjacent to the Kalamazoo River in Michigan. The leak consisted of two batches of heavy bituminous crude oil diluted with lighter petroleum products.[69] It was several hours before the leak was discovered in which time several residents had called the local health department complaining from a heavy oil smell in the air. The spill flowed downstream 38 miles.

Containment and recovery were ongoing for the next four years. Responders installed oil absorbent and a boom at two parks near battle Creek and used vacuum trucks to recover oil from the source area. The Kalamazoo River was closed to the public for 1.5 years, then periodically opened and closed for dredging of submerged oil for the next three years. The presence of benzene and other constituents in the oil posed a respiratory threat to public health and safety. The Michigan Department of Community Health issued a Fish Consumption Advisory and a Swimming Advisory, both of which were in place until June 28, 2012.

1-5.1.2.6 DM932 Tanker and Barge Collision near New Orleans, LA (2008)

On July 23, 2008, tanker Tintomara collided with fuel barge DM932 on the Mississippi River near downtown New Orleans. The Tintomara suffered minor damage, but the DM932 barge split into two sections, releasing 270,000 gallons of spilled #6 fuel oil into the Mississippi River. [70] Response to the spill required 2,300 personnel, 130,000 feet of containment boom, 200 boats, and 35 skimmers.[71]

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[68] National Transportation Safety Board. (2010). *Collision of Tankship Eagle Otome with Cargo Vessel Gull Arrow and Subsequent Collision with the Dixie Vengeance Tow Sabine-Neches Canal, Port Arthur, Texas*. January 23. Available at: https://maritimesafetyinnovationlab.org/wp-content/uploads/2015/02/ntsb-eagle-otome-collision-2010.pdf

[69] https://www.fws.gov/midwest/es/ec/nrda/MichiganEnbridge/pdf/FinalDARP_EA_EnbridgeOct2015.pdf

[70] NOAA, Damage Assessment, Remediation, and Restoration Program. (2008). *Fuel Barge DM 932*. Available at: https://darrp.noaa.gov/oil-spills/fuel-barge-dm932

[71] Simmons, R. (2009). *Tank Barge DM 932 Spill: Response from the Perspective of the "Environmental Unit"*. Available at: https://archive.epa.gov/emergencies/content/fss/web/pdf/simmons.pdf

Oil from the barge spread over 100 miles of the lower Mississippi River. More than 130,000 gallons of an oil and water mix were recovered.[72] The river was temporarily closed to vessel traffic for 8 hours to lift the barge out of the water. The incident impacted terrestrial and riparian habitats in the over 100-mile span. In addition, the sediments at the bottom of the river were contaminated.

1-5.1.2.7 M/V Westchester in Plaquemines Parish, Louisiana (2000)

On November 28, 2000, the M/V Westchester tanker lost steerage and grounded in Plaquemines Parish, Louisiana. The initial loss of steerage was due to a crankcase explosion onboard.[73] The grounding punched a hole in the cargo tank and an estimated 550,000 gallons of crude oil spilled into the Mississippi River.

Containment measures included placing booms at key bayous and cuts and deploying skimmers to collect oil from the water surface. The case is notable for its efficient recovery of lost oil which was aided by the riprap on the west bank which trapped the oil. Vessel traffic on the Mississippi River was halted the next day for 21 river miles. The river was reopened to in-bound traffic one day later on November 30, 2000 and was opened to both up-river and down-river traffic on December 1, 2000.[74] Several thousand acres of terrestrial, riparian, and oceanic habitat were impacted by the spill. The spill exposed flora and fauna in these areas to black oil, emulsified oil, and sheen. Approximately 19,000 kilograms of finfish and shellfish biomass were lost through direct kill and lost production. In addition, recreation fishing and waterfowl hunting were affected by closures and limited access to boat launch points.

1-5.1.3 Other Fuel Releases

Failure and fuel releases at the CEI Hub would not only flow into the Willamette River, but also affect the ground resources. The case studies in this section include others at fuel tank farms as well as fuel releases caused by earthquakes. In addition to the effect on terrestrial resources, these incidents also demonstrate the potential for fire and air quality hazards that could result from fossil fuel tank failures.

1-5.1.3.1 Savoonga AVEC Tank Farm in Savoonga, AK (2021)

On February 27, 2021, a bulk oil storage tank located at Savoonga Power Plant, operated by Alaska Village Electric Coop, spilled while fuel was being transported between tanks. The power plant is located on St. Lawrence Island, 450 feet from the Bering Sea. The tank leaked an

[72] NOAA. (2000). *Tanker and Barge Collision in New Orleans, LA Update August 4, 1000 EDT*. Available at: https://incidentnews.noaa.gov/incident/7861/521838/8929

[73] Michel, J., Henry Jr, C. B., & Thumm, S. (2002). Shoreline assessment and environmental impacts from the M/T Westchester oil spill in the Mississippi River. *Spill Science & Technology Bulletin*, 7(3-4), 155-161.

[74] NOAA. (2001). *Final Damage Assessment/Restoration Plan and Environmental Assessment: M/V Westchester Crude Oil Discharge*. Available at: https://www.gc.noaa.gov/gc-rp/west-fnl.pdf

estimated 20,000 gallons of #2 Diesel into secondary containment.[75] A valve left open on a bulk fuel tank caused the leak. The valve was closed and investigators determined there was no environmental impact – oil did not flow into the Bearing Sea or into the nearby wetland tundra.[76] Containment of the spill involved excavating contaminated snow and pumping diesel fuel pooled under the snow. In addition, nine cubic feet of impacted frozen soil was chipped out with a jackhammer. There were no public closures associated with the spill due to its remote location.

1-5.1.3.2 Contra Costa NuStar in Crockett, CA (2019)

On October 15, 2019, an explosion occurred at the NuStar energy fuel storage facility in Crockett, California. The facility stored ethanol, gasoline, diesel, and aviation fuels. The fire damaged two tanks containing 250,000 gallons of ethanol.[77] The explosion started a seven-hour-long fire which had serious health and safety effects on the region. All personnel were evacuated from the site and emergency response services were onsite within minutes. The fire consumed thousands of gallons of fuel and investigators found high levels of smoke particulates, but not unusually high amounts of toxic substances.[78] A small grass area also caught on fire. The fires were put out later that same day.

There was a shelter in place ordered approximately one hour after the explosion for nearby residents of Crockett and Rodeo for approximately 7 hours. Contra Costa County also issued a public health order for people in the neighboring communities of Crockett, Rodeo, and Hercules to stay indoors due to poor air quality.[79] Residents were advised to leave air conditioning and fans off and place damp towels in door and window openings. In addition, the twelve-home community of Tormey (located near the NuStar facility entrance) was evacuated and four schools in the area were closed for two days. Both directions of Interstate 80 near the facility were shut down for six hours to help manage the fire. The fire was eventually contained with foam.

1-5.1.3.3 Great East Japan (Tohoku) Earthquake and Tsunami (2011)

The devastating Great East Japan Earthquake and Tsunami, also known as the Tohoku Event, occurred on March 11, 2011 when a magnitude 9.0 earthquake occurred about 80 miles off the

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[75] Alaska Department of Environmental Conservation. (2021). *Savoonga AVEC Tank Farm Diesel Oil Release*.

[76] McChesney, R. (2018). No *environmental impact from 22,000-gallon heating oil spill in Savoonga*. Alaska Public Media. March 18. Available at: https://www.alaskapublic.org/2018/03/15/no-environmental-impact-from-22000-gallon-heating-oil-spill-in-savoonga/

[77] Associated Press. (2019). *Earthquake probed as possible cause of California fuel fire*. October 16. Available at: https://apnews.com/article/4b2b77c5ecec4b01b8ef6c70beeb7ca6

[78] Sciacca, A. (2019). "Supes consider tightening rules over fuel storage facilities in wake of NuStar explosion". *East Bay Times*. Available at: https://www.eastbaytimes.com/2019/10/22/concerns-about-nustar-explosion-in-crockett-prompt-contra-costa-officials-to-review-safety-ordinance/

[79] Contra Costa Health. (2019). *Data Incident Report: October 15, 2019*. Available at: https://cchealth.org/hazmat/data-incident-report/60548099.pdf

northeast coast of Japan. Over 20,000 people died and over 500,000 were forced to evacuate. The Fukushima nuclear plant disaster is the most well-known hazardous materials release resulting from the event. However, there were also many instances of toxic substance releases, explosions, and fires resulting from failures at other industrial facilities. At some facilities, the cause of the damage was the earthquake, while at others it was the tsunami.[80] Excluding the costs of the Fukushima nuclear power plant failures, the total economic damages of the event exceed $210 billion.

The Great East Japan earthquake also demonstrates the complexities of responding to oil spill events during an environmental disaster. In Ichihara City, liquefied petroleum gas tanks exploded due to ground motion and resulted in fires that spread to asphalt tanks and buildings throughout the facility that took ten days to extinguish.[81] In the Sendai area, a fire at a petrochemical complex, ignited by a spark caused by tank friction, burned a gasoline tank, asphalt tanks, molten sulfur tanks, and oil handling facilities. Many other oil tanks and petrochemical facilities were damaged by the tsunami and often were washed out to sea.

1-5.2 Case Studies Summary

The case studies in this section vary in terms of the amount of the spill, the contents spilled, and where it was spilled at. Accordingly, the extent and costs of damages and secondary effects like fires also vary as well. Of the case studies discussed in this section, the potential releases at the CEI Hub following a CSZ event will be similar to the large events, Deepwater Horizon and the Great East Japan earthquake, in terms of level of releases and resulting damages to the environment, health, and safety. Table 10 summarizes common elements for each case study.

[80] Krausmann, E., & Cruz, A. M. (2013). Impact of the 11 March 2011, Great East Japan earthquake and tsunami on the chemical industry. *Natural hazards*, 67(2), 811-828.

[81] Zama, S., Nishi, H., Hatayama, K., Yamada, M., Yoshihara, H., & Ogawa, Y. (2012). On damage of oil storage tanks due to the 2011 off the Pacific Coast of Tohoku Earthquake (Mw9. 0), Japan. In *Proceedings of the 15th world conference on earthquake engineering (WCEE)* (Vol. 2428, pp. 1-10).

Table 10. Case Study Summary

Case Study	Year	Spill Amount	Type of Oil	Spill Location	Fire Status
Fuel Releases in Oregon					
Oregon Lindsey Lake Tanker Spill	2019	4,400 gallons	Diesel fuel (Light Oil)	Ground and freshwater	None
Columbia River Oil Train Derailment	2016	47,000 gallons	Bakken crude oil (Light Oil)	Ground and freshwater	Fire on ground
Tanker SS MobilOil Spill	1984	170,000 gallons	Number 6 Crude Oil and Industrial Fuel Oil (Light and Medium Oils)	Freshwater and saltwater	None
Fuel Releases into Shipping Channels and Water Resources					
Refugio Incident	2015	123,000 gallons	Crude oil	Freshwater and saltwater	None
TX City Y Spill	2014	168,000 gallons	Intermediate fuel oil (Medium Oil)	Ground, freshwater, and saltwater	None
Deepwater Horizon	2010	134-206 million gallons	Macondo crude oil (Light Oil)	Saltwater	Fire on the drilling platform
Eagle Otome	2010	462,000 gallons	Olmeca crude oil (Light Oil)	Freshwater and saltwater	None
Enbridge Line 6B	2010	Over 1 million gallons	Diluted bitumen (Heavy Oil)	Freshwater	None
DM 932 Tanker	2008	270,000 gallons	Number 6 fuel oil (Heavy Oil)	Freshwater	None
M/V Westchester	2000	550,000	Sweet Nigerian crude oil (Light Oil)	Freshwater	None
Other Fuel Releases					
Savoonga AVEC Tank Farm	2021	20,000 gallons	#2 Diesel (Light Oil)	Ground	None
Contra Costa NuStar	2019	250,000 gallons	Ethanol (Light Oil)	Ground	Fire on the ground
Great East Japan (Tohoku) Earthquake and Tsunami	2011	Large (exact amount unknown)	Multiple fuel types (e.g., diesel, asphalt, crude) (Light, Medium, and Heavy Oils)	Ground, freshwater, and saltwater	Multiple fires at petrochemical and fuel storage facilities

Source: Created by ECONorthwest

1-5.3 Other Evaluations of Fossil Fuel Impacts Near CEI Hub

1-5.3.1 Tesoro Savage Petroleum Terminal at the Port of Vancouver

The Vancouver Energy Distribution Terminal Facility was proposed to be located on the Columbia River, approximately 10 miles north of the CEI Hub and would be owned and operated by the Tesoro Savage Petroleum Terminal LLC. The proposed crude oil terminal facility would have a capacity of 360,000 barrels of crude oil per day that it would receive by train, store onsite, and then load onto marine vessels to be transported to west coast refineries.

Given the proximity and the similar resources that would be transported at the Tesoro Savage Petroleum Terminal compared to what is stored at the CEI Hub, the research conducted as part of this proposal is also relevant to the potential impacts of releases at the CEI Hub due to a CSZ earthquake.

A 2016 report[82] evaluated impacts to fishing and natural resources from the "worst-case scenarios" from the Draft Environment Impact Statement for the proposed Vancouver Energy Distribution Terminal Facility.[83] The two scenarios are a tanker grounding near Vancouver that would spill over 189,845 barrels (bbls) (about 8 million gallons), and for a train derailment near the Bonneville Dam that would spill 20,000 bbls.

The authors assumed that the spill occurred during spring (between mid-April and mid-May), corresponding with peak salmon populations in the Lower Columbia River. Based on the timing assumptions as well as estimates detailed in the report about fate and transport modelling, the estimated damages to Columbia River habitats from the vessel grounding in Vancouver is $171.3 million, including $114.4 million for injured habitats in the river channel and $56.9 million for injuries to floodplain wetlands adjacent to the river. The estimated damages to Columbia River habitats from the upriver train derailment scenario is $84.9 million, including $54.5 million for injured habitats in the river channel and $30.4 million for injuries to floodplain wetlands adjacent to the river.[84]

[82] Abt Associates Inc. and Bear Peak Economics. (2016). Potential Fishing Impacts and Natural Resource Damages from Worst-Case Discharges of Oil on the Columbia River. Submitted to: Matthew Kernutt, Assistant Attorney General Washington Attorney General's Office. May 12.

[83] The Draft Environment Impact Statement is available at: https://www.efsec.wa.gov/efsec-document/Tesoro%20Savage/SEPA/docGroup/Draft%20Environmental%20Impact%20Statement

[84] All dollar values from Abt Associates Inc. and Bear Peak Economics are 2016 values.

1-6 Direct Impacts of a CSZ Earthquake on the CEI Hub

The direct impacts of a CSZ earthquake on the CEI Hub and the resulting effects on the surrounding people, property, and environment will likely be exacerbated by the surrounding destruction of the event. Roads, bridges, and many other infrastructure types will be damaged in the earthquake, which will likely impair access to the site to take actions like fire suppression, rescues, containment, monitoring, and other immediately needed steps to minimize the damage from releases. Absent any failures of the CEI Hub and associated fuel releases, there would still be threats to people, property, and the environments from the earthquake. For example, commercial and recreational river activity would likely be impacted from an earthquake due to accessibility and hazards for a period of time, even without any releases from the CEI Hub. The intent of this analysis is to include only effects that are attributable to containment failures at the CEI Hub, and not impacts from the earthquake in general.

The impacts that could be attributable to releases at the CEI Hub that are evaluated in this analysis include:

- Loss of life and injuries directly related to releases at the CEI Hub site or adjacent parcels;
- Effects on navigation and river-related commercial activity;
- Short-term and long-term effects on the environment;
- Short-term and long-term effects from air quality impacts;
- Impacts to cultural resources.

1-6.1 Earthquake Considerations

Impacts from CEI Hub releases will vary both on the magnitude of the earthquake, the extent of releases, if a fire occurs, and the ability to respond quickly to contain releases. Spill response will be a primary determining factor in how quickly the releases are contained and how far they spread, particularly for releases into the water. Spill responses usually occur as soon as a spill is reported to the spill response team.[85] However, response actions to fuel releases resulting from the CSZ earthquake will likely be substantially delayed due to damaged infrastructure and resource shortages.

The Cascadia Playbook from Oregon Office of Emergency Management suggests that Regional Hazardous Materials Emergency Response Teams (RHMERT) will be contacted within 6 hours

[85] The Lower Columbia Spill Response Plan, as well as all the response plans associated with Region 10 Regional Response Team (RRT) and the Northwest Area Committee (NWAC) is available at: https://www.rrt10nwac.com/GRP/

after an event where oil and hazardous materials need to be controlled and contained. [86] Initiating containment of oil and hazardous materials spills or releases in impacted areas is estimated to begin 24 hours after the event. While these timelines represent best practices, there are potential impediments to a rapid response particularly around access, personnel and resource availability, and other hazards present at the site, each of which are discussed below.

> **Prior Characterizations of Responding to CEI Hub Failures After a CSZ Event from OSSPAC (2019)[87]**
> "Other large-scale catastrophes would be unfolding throughout the City and region. Emergency response personnel would struggle to address the disaster occurring at the CEI Hub because roads, bridges, utilities, and communication systems would be damaged or destroyed. And recovery vehicles would be unable to access and use the very fuel that spills from the CEI Hub's tanks."

1-6.1.1 Access Considerations

Access to the CEI Hub via road or river may be difficult or dangerous due to damage to roads and infrastructure. Following the CSZ earthquake, reopening Tier 1 and Tier 2 state highways in the Willamette Valley will take approximately 1 to 3 days.[88] Access via waterway will also be complicated due to the CSZ earthquake. Structures such as bridges and piers may collapse into the waterway, posing hazards for both access and containment. Access to boat launches may similarly be restricted, causing delays.

1-6.1.2 Personnel and Resource Availability

The CEI Hub will not be the only area with hazardous releases due to a CSZ earthquake. Release of hazardous materials could also occur from train derailments or damage to vessels. Within the Lower Columbia River, there are additional fuel storage facilities at the NuStar and Tesoro terminals in the Port of Vancouver. There are also other fuel storage facilities in surrounding areas which could have spills due to the CSZ earthquake. Accordingly, resources may be thinly spread throughout these response sites and spills either at the CEI Hub or other locations may extend further than they would have if resources were not constrained by the coinciding incidents.

1-6.1.3 Release of Toxic Inhalation Hazard Materials

As defined by the Hazardous Materials Regulations, toxic inhalation hazard materials (TIH materials) are gases or liquids that are known or presumed on the basis of tests to be so toxic to humans as to pose a hazard to health in the event of a release. [89] Chlorine gas and anhydrous ammonia are the most common TIH chemicals. Other TIH chemicals include sulfur dioxide,

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[86] Oregon Office of Emergency Management. (2018). *Cascadia Playbook Version 3.0.* Retrieved from https://www.oregon.gov/oem/emresources/Plans_Assessments/Pages/Other-Plans.aspx

[87] Oregon Seismic Safety Policy Advisory Commission of the State of Oregon (OSSPAC). (2019). *CEI Hub Mitigation Strategies: Increasing Fuel Resilience to Survive Cascadia*. December 31. OSSPAC Publication 19-01.

[88] Oregon Seismic Safety Policy Advisory Commission (OSSPAC). (2013). *The Oregon Resilience Plan: Chapter 5. Transportation*. February.

[89] 49 CFR parts 171-180.

ethylene oxide, hydrogen fluoride, and others. Although not stored at the CEI Hub itself, TIH materials are present within the area near the CEI Hub. Evaluating the effect of these chemical releases is beyond the scope of this study, however, the release of those materials due to a CSZ earthquake could complicate spill response efforts at the CEI Hub. In particular, release of TIH materials could limit access to respond to the spill if the presence of TIH substances renders the area too dangerous for emergency personnel.

1-6.2 Direct Impacts to People and Property

1-6.2.1 Risk of Harm to People Near the CEI Hub

There are 10 companies on 31 properties located at the CEI Hub that vary in size from 0.1 to 31.27 acres for a total of 219.85 acres.[90] On average there, are 0.8 full-year equivalent workers per acre,[91] for a total of approximately 200 people on-site throughout the CEI Hub properties. Including the adjacent properties to CEI Hub parcels there are 1,400 acres of land, suggesting approximately 1,100 workers. More generally, the zip codes where the CEI Hub is located (97231 and 97210) have a total combined population of 16,508 and total employment of 31,517.[92] In addition to the physical presence of these people, there are also people driving through for personal or business reasons and river-related transport that could put people at risk from CEI Hub failures from a CSZ earthquake.

The potential for CEI Hub failures to impact people and cause injury or loss of life will depend in part on when the event happens – if it happens on a weekday or weekend, during the day or at night, and what season – since that will influence how many people are working in and around the site. During weekends and at night, there will be fewer people in the area based on use patterns. Similarly, during the winter there may be fewer people on the water compared to a sunny day at the height of the fishing season.

Industrial fuel fires from other locations provide a sense of the potential scale and damage that could occur from CEI Hub failures due to a CSZ earthquake. One of the largest onshore industrial disasters was the BP America Refinery Explosion in Texas City, Texas in 2005. The series of large explosions and fire was caused by buildup of flammable liquid gas. A total of 18 people were killed and 180 were injured. A shelter-in-place order was issued that required 43,000 people to remain indoors. Houses were damaged as far away as three-quarters of a mile from the refinery.[93] There were 2,600 employees located on the 1,200 acre site at the time of the

[90] See Appendix B for a fill list of properties and their characteristics.

[91] Oregon Quarterly Census of Economics and Wages (QCEW). QCEW contains confidential information and was available for this study through a data use agreement with the Oregon Employment Department. All results are aggregated and reported in a way that maintains confidentiality standards.

[92] IMPLAN 2019 Study Area Data for Combined Zip Codes 97231 and 97210.

[93] U.S. Chemical Safety and Hazard Investigation Board. (2007). *Investigation Report Refinery Explosion and Fire: BP, Texas City, Texas.* March 23. Report No. 2005-04-I-TX. Available at: https://www.csb.gov/bp-america-refinery-explosion/

explosion – meaning that 0.6 percent of people were killed and 6.9 percent of people were injured from the event.

Another oil refinery explosion occurred in 2016 at the ExxonMobil Refinery in Baton Rouge, Louisiana. This incident was caused by the release of isobutane vapors that were ignited by a nearby welding machine. Six workers were injured and/or burned from the explosion. There were 3,000 maximum people on site when the event occurred, suggesting a 0.2 percent injury rate for the 2,100-acre facility.

The CEI Hub and adjacent properties represents an area of approximately 1,500 acres with an estimated 1,200 workers (based on the 0.8 workers per acre estimate).[94] This area is 25 percent lower than the BP site and 40 percent higher than the Exxon Mobile site. Applying the injury and mortality rate from the two incidents to the CEI Hub and adjacent properties suggests that between 0 to 7 people could be killed and 2 to 80 people could be injured.

Table 11. Injury and Morality Rates and Estimates for Number of People Affected in the CEI Hub Area

		Estimate of People Affected in the CEI Hub Area (1,200 people on 1,500 acres)
BP Mortality Rate (Low)	0%	0
Exxon Mortality Rate (High)	0.6%	7
BP Injury Rate (Low)	0.2%	2
Exxon Injury Rate (High)	6.9%	80

Source: Created by ECONorthwest

These two incidents inform potential low and high estimate of injury and mortality that could occur from explosions or fires at CEI Hub due to a CSZ event. However, estimates of injury and mortality are highly uncertain since any explosions or fires are difficult to predict if and when they will occur and be contained. The two example incidents are at oil refineries and are therefore processing facilities, rather than storage facilities like the CEI Hub. Despite these uncertainties, applying the injury and mortality rates provides an order of magnitude estimate of the potential harm to people. A fire that spreads throughout the CEI Hub and any adjoining areas could pose a higher threat of mortality and morbidity. A fire without an explosion that is quickly contained would post a lower threat.

In the event that there are also fires at the CEI Hub or at nearby industrial sites, which are likely to occur, people and property will be further threatened by direct fire risk as well as air quality health impacts. Evacuations will be extremely challenging during this time due to ground damage, potential impacts to the telecommunication network, and strained emergency response resources. Fire response resources may not be able to immediately address the blazes at these locations, which could result in the fire spreading throughout the area. Of note, burning is sometimes a clean-up mechanism used for oil spills, so fuel ignition could decrease the amount of oil that contaminates the environment via land or water. Air quality impacts are discussed further in Section 6.5 of this report.

[94] Oregon Quarterly Census of Economics and Wages, by permission.

A March 12, 2019 fire at NW Metals Inc. in Portland demonstrates the emergency response and potential health effects from fires at industrial sites. During this event the City of Portland and Multnomah County issued an evacuation order for residents between Northeast 60th and 76th avenues and Northeast Columbia Boulevard and Alberta Street, using buses to evacuate residents without personal transportation. Particulate matter was the primary concern from this event, which poses a health risk, particularly to young children, seniors, and people with compromised respiratory systems.[95] Toxic chemicals in the air were also a concern, including asbestos, aldehydes, acid gases, sulfur dioxide, nitrogen oxides, polycyclic aromatic hydrocarbons, benzene, toluene, styrene, metals, and dioxins.

1-6.2.2 Impacts to Properties

CEI Hub property owners will experience the largest property damage resulting from tank failures. Some of the tank failures and lateral spread ground movement has the potential to impact adjacent property owners as private property is displaced throughout the area. Fires can also spread across properties – the extent of the damage will vary by the spread of the fire. For example, if the fire spreads to forest park during drought conditions it could spread through the forest canopy, posing increased challenges for containment.[96]

Fuel releases in the Willamette River from the CEI Hub have the potential to oil shorelines and impact waterfront properties CEI Hub fuel releases that reach the Willamette River or flow downstream will primarily impact the state-owned waterways, since the State of Oregon owns the bed and the banks of navigable rivers up to the high-water mark.[97] This analysis assumes that a spill could impact properties from the I-405 bridge to the Lewis and Clark Bridge between Longview, Washington and Rainier, Oregon. In this section of the Willamette River, Multnomah Channel, and Columbia River there are approximately 1,011 properties spanning four counties in both Oregon and Washington (Table 12).

Table 12. Waterfront Properties between I-405 and Lewis and Clark Bridge, by County

County	Number of Waterfront Properties
Multnomah County (OR)	312
Columbia County (OR)	497
Clark County (WA)	34
Cowlitz County (WA)	168
Total	**1,011**

Source: Calculated by ECONorthwest using geospatial parcel data for each county
Note: Property counts include waterfront properties in the Multnomah Channel

[95] Multnomah County. (2018). *Evacuations expand Monday night in Northeast Portland due to unhealthy smoke from fire.* March 12. Available at: https://multco.us/multnomah-county/news/evacuations-expand-monday-night-northeast-portland-due-unhealthy-smoke-fire

[96] Trout Mountain Forestry and Moore Iacofano Goltsman, Inc. (2009). City of Portland Wildfire Readiness Assessment: Gap Analysis Report. Available at: https://www.portlandoregon.gov/parks/article/238523

[97] Oregon Department of State Lands. (No Date). *Public Use of Oregon's Rivers and Lakes.* Available at: https://www.oregon.gov/dsl/ww/documents/nav_brochure.pdf

1-6.3 Navigation and Commercial Activity Impacts

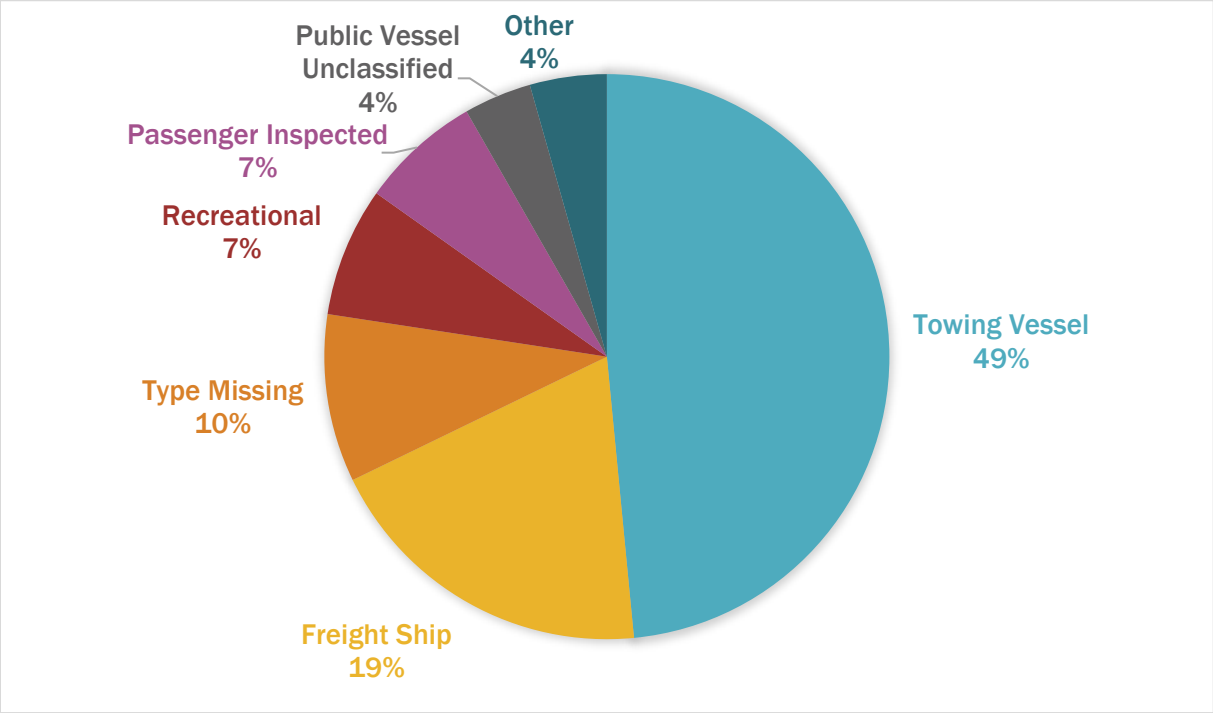
The navigation channel of the Willamette River is a critical shipping area for marine vessels that provides access to the CEI Hub as well as other nearby facilities, including Terminal 2, Terminal 4, the Swan Island Industrial Park, and other private businesses. To understand the extent of navigation and commercial activity, vessel counts were derived from vessel Automatic Identification System (AIS) data provided by the Bureau of Ocean Energy Management (BOEM) and NOAA as of 2017.[98] This data source contains total counts for large vessels, but excludes small vessels not required to have automatic identification systems. Daily counts were calculated for the entire year for the Willamette from the 405 bridge to the Lewis and Clark Bridge (Highway 433) between Longview, Washington and Rainier, Oregon. Each vessel was counted once per day for each day of the year using a unique identifier. Vessel types in the AIS data are standard categories used by the U.S. Coast Guard, NOAA, and the BOEM.[99]

Based on the AIS data, there were 16,065 total vessels that passed by the CEI Hub on the Willamette River and the portion of the Columbia River in 2017 (annual total). Of the total vessels, approximately 49 percent were towing vessels and the remainder where other vessel types including public, commercial, and recreational vessels (Figure 6). Vessel counts vary slightly by day of week, ranging from a low of 42 average vessels per day on Sundays to a high of 45 vessels per day on Mondays. There is some variation by month, with a low of 1,000 vessels in January and a high of 1,476 vessels in July – for an average of 1,339 vessels per month (Figure 7).

[98] Automatic Identification System (AIS) data obtained from: https://marinecadastre.gov/data/

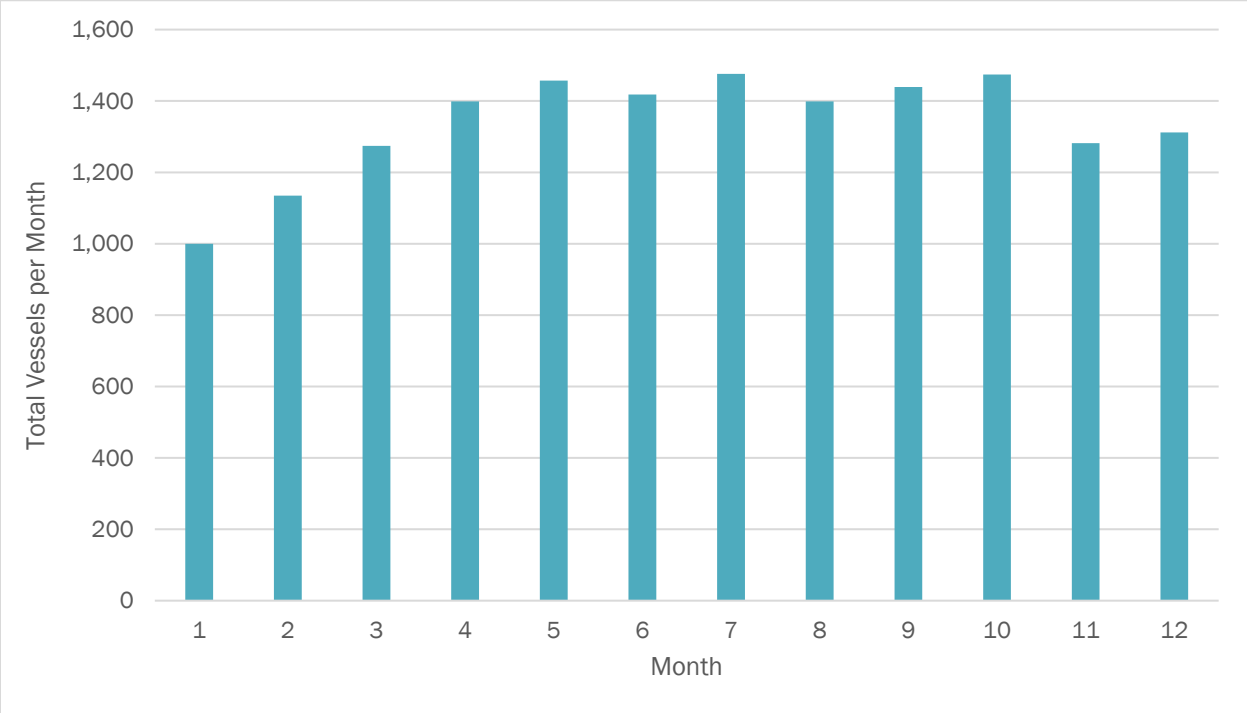
[99] More information on the classification of vessel types is available at: https://coast.noaa.gov/data/marinecadastre/ais/VesselTypeCodes2018.pdf

Figure 6. Annual Vessel Counts by Type, 2017, I-405 to Lewis and Clark Bridge



Source: Automatic Identification System (AIS) data provided by the Bureau of Ocean Energy Management (BOEM). (2017). Retrieved from https://marinecadastre.gov/data/

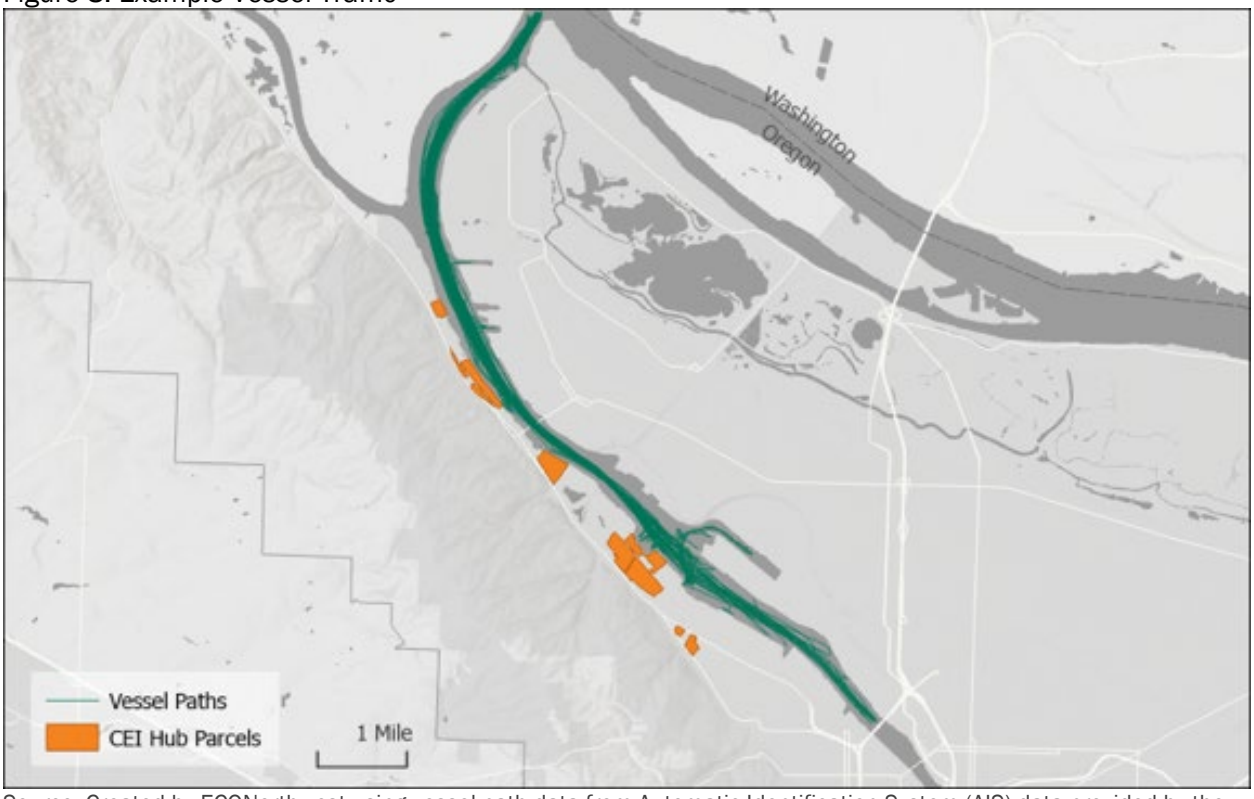
Figure 7. Total Vessel Traffic by Month, 2017, I-405 to Lewis and Clark Bridge



Source: Source: Automatic Identification System (AIS) data provided by the Bureau of Ocean Energy Management (BOEM). (2017). Retrieved from https://marinecadastre.gov/data/

Figure 8 depicts towing vessel traffic paths (in green) for a combination of high volume, average volume, and low volume sample days from 2017 for the Willamette River near the CEI Hub. As demonstrated in the map, the river area immediately adjacent to the CEI Hub and downstream between the CEI Hub and the confluence with the Columbia River are the most heavily used vessel traffic areas of the Willamette River.

Figure 8. Example Vessel Traffic



Source: Created by ECONorthwest using vessel path data from Automatic Identification System (AIS) data provided by the Bureau of Ocean Energy Management (BOEM). (2017). Retrieved from https://marinecadastre.gov/data/

1-6.3.1 Impact of Navigation Closures

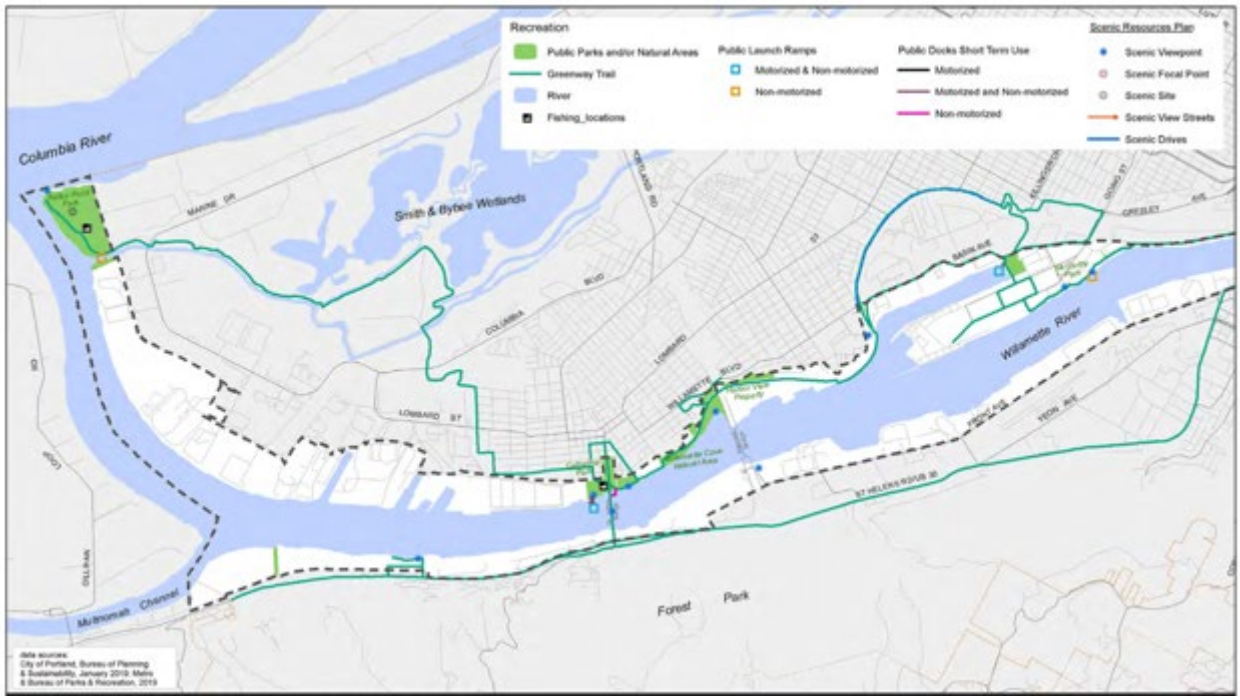
To the extent that navigation impedes commercial activity, it will be impacted by the closure of the shipping channel resulting from failure to contain the materials located at the CEI Hub. The length of time for closures of this shipping channel due to CEI Hub failure will likely extend for days, but debris from earthquake including potential bridge delays could lead to extended closures. Historically, shipping channel closures only last for several days to minimize the impact of closures on transportation and because clean-up actions occur as soon as possible.[100] Following a CSZ earthquake, there may be added delays due to access. For every day of closure there would be on average 42 vessels impacted.

1-6.4 Recreation Impacts

There are multiple recreation resources that could be impacted by releases at the CEI Hub. Water-based recreation would be impacted by discharges, likely resulting in closures to the area for multiple months. Terrestrial recreation would be impacted by air quality impacts as well as any fire that occurs at the site. Figure 9 is a map of recreation resources either on or within immediate proximity to the Willamette River from the City of Portland.

[100] For example, in the Texas City Y spill the shipping channel was open after 3 days.

Figure 9. Recreation Resources in Proximity to the CEI Hub



Source: City of Portland, Bureau of Planning and Sustainability. (2020). *Willamette River Greenway Inventory*. December 16.

In addition to the recreation resources in the immediate vicinity of the CEI Hub there are also popular recreation sites that could be impacted by released materials at the CEI Hub. Forest Park, a 5,200 urban forest owned by the Portland Parks and Recreation, is located Northwest of the CEI Hub in the upland area on the opposite side of Highway 30/NW Saint Helen's Road. Visitation at Forest Park is most likely to be impacted by air quality hazards, particularly during any fire that occurs. The Cascadia earthquake will also likely affect visitation at Forest Park due to the damage to roads and other infrastructure, as well as downed trees and other hazards within the park itself.

Downstream of the CEI Hub is Sauvie Island, an island located between the Willamette River and Columbia River that hosts a large wildlife refuge, agricultural farms, and private residences. During the summer, boat access and beaches are popular recreation sites. During the fall and early winter, Sauvie Island Wildlife Refuge is used for waterfowl hunting. Impacts from CEI Hub failure and releases would temporarily impact Sauvie Island recreation sites and activities from airborne releases caused by burning in the event of a fire. Water contamination could also impact Sauvie Island boating and swimming. The extent of water contamination would vary depending on containment actions in the spill response. Fishing and waterfowl hunting at Sauvie Island are likely to be impaired immediately and in the years following the spill due to lingering environmental toxins. The Cascadia earthquake will also likely affect visitation at Sauvie Island due to the damage to roads and other infrastructure, as well as downed trees and other hazards within the park itself.

1-6.4.1 Water-Based Recreation

The water-based recreation resources in and around the CEI Hub are primarily boat ramps with access to the Willamette River. Within the anticipated closure area from the confluence with the Columbia River and the I-405 bridge, there are two boat ramps that provide both motorized and non-motorized boat access, Swan Island boat ramp and Cathedral Park boat ramp, and two boat ramps that only allow non-motorized access, at McCarthy Park and Kelley Point Park. There is also the fishing dock at Cathedral Park, which is a short-term tie-up dock. Visitation counts are not maintained at any of these sites. However, estimates from Portland Parks and Recreation for Swan Island boat ramp suggest that there are 2,500 launches and retrievals each year from this site alone.[101]

River recreation in the Willamette River is primarily for motorized fishing vessels (Table 13). For this reason, use is especially pronounced in the fishing season for salmon and steelhead, beginning in May and extending through the summer months. Motorized personal watercraft also uses this stretch for boat tours along the Willamette River near the City Center. People also launch kayaks, paddleboards, sailboats, and other dingeys from these locations.

Table 13. Activity Days by Waterbody and Activity Type (2008)

	Columbia River		Willamette River	
Activity Type	Number of Activity Days	Percent of Total	Number of Activity Days	Percent of Total
Fishing	231,955	61%	210,020	55%
Sailing	30,131	8%	5,007	1%
Personal Watercraft	9,239	2%	11,730	3%
Waterskiing	12,482	3%	48,425	13%
Cruising	91,071	24%	104,829	27%
Hunting	8,071	2%	3,965	1%
Total	**382,949**	**100%**	**383,976**	**100%**

Source: Created by ECONorthwest with data from Oregon State Marine Board. (2011). Waterbodies in Rank Order. Available at: https://data.oregon.gov/Recreation/Waterbodies-In-Rank-Order/rqyv-cfng

More specific fishing use data is available for the Lower Columbia River (from the mouth to Bonneville dam) and the Lower Willamette River (Willamette Falls to the confluence with the Columbia River, including the Multnomah Channel). In total for both rivers there were 322,717 salmonid anglers, which averages approximately 40,923 per month throughout the season. There is variation in number of anglers year over year and it correlates to the size of the fishing run, which has been declining in recent years compared to the high in 2010 (Table 14).

[101] Email communication from Maya Agarwal, Portland Parks & Recreation, on March 16, 2021.

Table 14. Recreational Salmonid Anglers on the Lower Columbia River and Lower Willamette River

	Lower Columbia River		Lower Willamette River		Total	
Year	Annual Salmonid Anglers	Average per Month	Annual Salmonid Anglers	Average per Month	Annual Salmonid Anglers	Average per Month
2020	236,205	23,621	86,512	17,302	322,717	40,923
2019	194,797	19,480	73,267	14,653	268,064	34,133
2018	254,304	25,430	68,910	13,782	323,214	39,212
2017	313,166	31,317	57,836	11,567	371,002	42,884
2016	413,143	41,314	71,528	14,306	484,671	55,620
2015	441,421	44,142	99,352	19,870	540,773	64,013
2014	450,771	45,077	80,286	16,057	531,057	61,134
2013	368,940	36,894	111,393	22,279	480,333	59,173
2012	402,553	40,255	115,456	23,091	518,009	63,347
2011	427,465	42,747	136,186	27,237	563,651	69,984
2010	423,378	42,338	135,802	27,160	559,180	69,498

Source: Oregon Department of Fish and Wildlife, *Columbia River Fisheries, Recreation data*, available at: https://www.dfw.state.or.us/fish/OSCRP/CRM/index.asp
Note: Data is collected for the Lower Columbia River for the months of February to October. Data is collected for the Willamette River is for the months of March to July. Species with data collected are Shad, spring chinook, steelhead, sturgeon. Due to annual changes in fisheries management (e.g., closures, bag limits), there are not necessarily the same opportunities for fishing year over year. This data does not include tributaries of the rivers.

Immediate impacts to river recreation from failure of the CEI Hub would be the closure of these access points while clean-up occurs. Based on the timeline for the Refugio Incident in California (which was smaller than what would likely occur at the CEI Hub), clean-up will likely last multiple months. Some of these closures as well as voluntary ends to use may occur regardless of the CEI Hub spill due to the damage from the CSZ earthquake. Depending on liquefaction at other sites, roads and access points likely would not be usable anyways for an extended period of time. Water quality of the Willamette River will likely also be impacted due to the sediment loading resulting from the earthquake, which would impact fishing conditions in particular.

1-6.4.2 Fish Consumption

Longer term, the residual contaminants from the CEI Hub failures could result in fishing advisories to limit consumption of aquatic species in this area. However, there are currently fishing advisories in place for resident fish in this stretch of the Lower Willamette.[102] Resident fish should not be eaten at all due to their high concentrations of polychlorinated biphenyls (PCBs) that pose a risk to human health. Resident fish include carp, brown bullhead, bass, walleye, and other fish that live their whole lives in the Lower Willamette. The advisory does not apply to migratory fish like salmon, steelhead, and shad.

[102] The April 11, 2018 Lower Willamette fish advisory is available from the Oregon Health Authority at: https://www.oregon.gov/oha/PH/HEALTHYENVIRONMENTS/RECREATION/FISHCONSUMPTION/Pages/Lower-Willamette-Fish-Advisory.aspx

1-6.4.3 Terrestrial Recreation

The terrestrial recreation sites located near the CEI Hub, between the confluence with the Willamette River and I-405 and with views of the river, include the following sites, as well as informal use along the banks of the river, particularly on the Northern side:

- Cathedral Park
- Forest Park
- Kelley Point Park
- Greenway Trail
- Willamette Cove Natural Area
- Harbor View Property
- McCarthy Park
- Swan Island Park
- St. Johns Bridge Viewpoint
- Railroad Bridge Viewpoint

Many of these are popular sites for people throughout the Portland metro area and beyond. Like water-based recreation, terrestrial recreation will be impacted by the earthquake due to access and potential hazards. There will likely be temporary air-quality impacts to these sites resulting from the smoke from the fire and hazardous aerosol chemical releases that—in absence of CSZ earthquake closures—could affect recreation at these sites, but there will likely already be recreation closures at these sites due to other CSZ earthquake impacts.

1-6.5 Air Quality Impacts

With tank failure, the fuels, additives, gasses, and other materials stored at the CEI Hub could ignite, releasing a toxic plume into the air. Even if it did not ignite, volatilization of harmful components of the materials would also travel beyond the site. This air would spread throughout the area, posing health risks to people, pets, livestock, and wildlife. The health impacts of these releases would be most immediate and severe for the people working in and around the CEI Hub. There are populated areas located primarily north, south, and east of the CEI Hub, and depending on wind conditions there could be extreme risks to human health from this harmful plume. This section focuses on the physical changes in air quality – health effects and costs are discussed in detail in the next chapter.

1-6.5.1 Types of Chemicals and Particulates Released

Air quality in the Portland metro region is, at times, already hazardous, primarily the result of wildfire and wood burning stove smoke with stagnate air (ozone and particulate matter),[103] as

[103] More information about smoke related DEQ air quality advisories is available at: https://www.oregon.gov/deq/aq/Pages/Air-Pollution-Advisories.aspx

well as releases from manufacturing facilities.[104] Any air quality impacts from a release at the CEI Hub would only compound any existing concerns. Petrochemicals that are not burned are toxic and contain chemicals such as benzene, toluene, xylene, ethylbenzene, and others. Burning petrochemicals produce several types of air pollutants including VOCs, NOx, sulfur dioxide (SO_2), and particulate matter ($PM_{2.5}$). All of these pollutants can have negative effects on human health and quality of life, from shortness of breath to respiratory infections, blood diseases, and cancer.[105] Local populations will be vulnerable to the adverse health effects of these pollutants, which may lead to increases in illnesses, reduced quality of life, and increased costs of treatment. These types of air quality impacts have been observed in other major oil spills.[106]

1-6.5.2 Dispersion of Releases

The areas immediately surrounding the spill site may be subject to acute hazardous levels of airborne chemicals. As gasoline quickly evaporates from the fuel spill site, the surrounding air becomes highly concentrated with chemical compounds found in gasoline, often including butane, pentane, benzene and toluene.[107] At high concentrations, the particulates in these gasoline vapor clouds may lead to a variety of acute adverse health effects for exposed individuals (see Section 6.5.2 for specific acute health risks). The Department of Labor's Occupational Safety and Health Administration (OSHA) has set the maximum allowable air pollution standards for gasoline at 300ppm over an 8-hour time-weighted average concentration and 550 ppm for a 15-minute exposure[108].

Figures 11 and 12 show a map of the projected area of toxic vapor risk under two prevailing wind conditions for the area surrounding the CEI Hub[109]. Dark shaded areas are likely to exceed or greatly exceed the OSHA 8-hour time-weighted average limits for gasoline particulate exposure. The yellow zones immediately surrounding each tank area represent the zones at risk of a fire ignition. Depending on the severity, location

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[104] More information about industrial air quality concerns is available from Oregon Department of Environmental Quality at: https://www.oregon.gov/deq/aq/Pages/Air-Quality-Map.aspx

[105] National Institute of Health. (2019). "Chemicals and Contaminants". *Tox Town: U.S National Library of Medicine*. Retrieved from: https://toxtown.nlm.nih.gov/chemicals-and-contaminants.

[106] Middlebrook, A. M., Murphy, D. M., Ahmadov, R., Atlas, E. L., Bahreini, R., Blake, D. R., & Ravishankara, A. R. (2012). Air quality implications of the Deepwater Horizon oil spill. *Proceedings of the National Academy of Sciences*, *109*(50), 20280-20285.

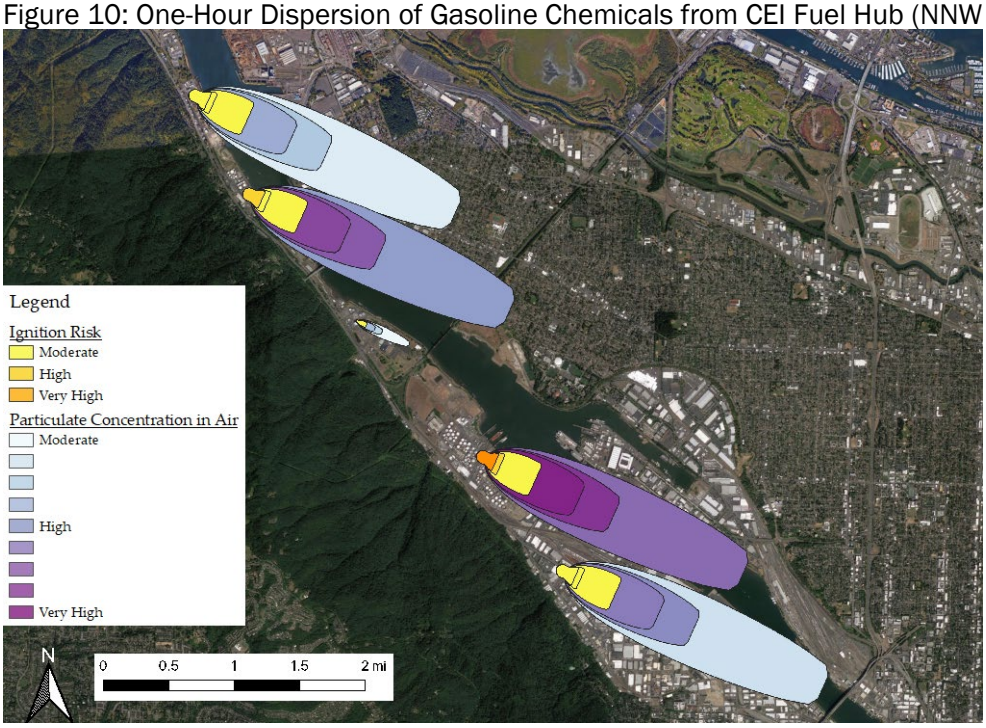
[107] U.S. Department of Health and Human Services. (1995). *Toxicological Profile for Gasoline*. Atlanta, GA: Agency for Toxic Substances and Disease Registry. https://www.atsdr.cdc.gov/toxprofiles/tp72.pdf.

[108] CFR 1910.1000: https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.1000

[109] The area of hazardous air quality was modeled using software developed by the NOAA Emergency Response Division and the EPA Office of Emergency Management that evaluates the short-term air dispersion of chemicals from a spill site. The software, called ALOHA (Areal Locations of Hazardous Atmospheres), was used to generate a map of the one-hour dispersion of particulates from the gasoline release site using climate characteristics for Portland, OR and information regarding the chemical composition of a generic gasoline mixture from HHS (1995).

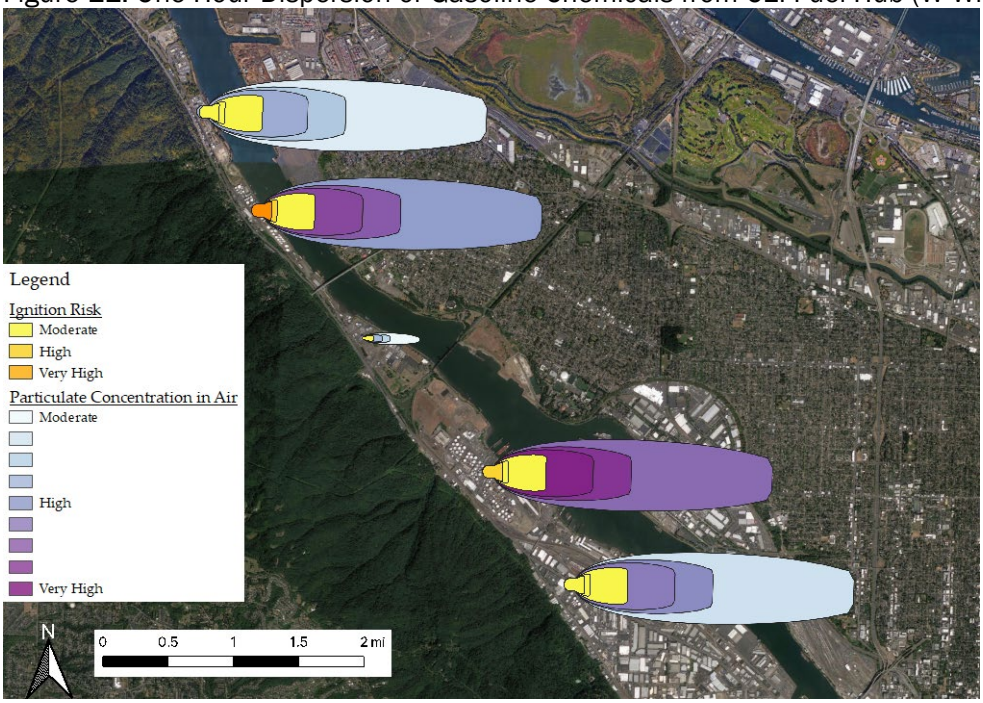
and spread of the spill, the concentration of hazardous gasoline vapor may extend beyond these regions. Figure 13 shows the levels of risk of mild to severe burns. The highest zone of risk from a burning gas fire represents a high probability of death within 60 seconds of exposure.

Figure 10: One-Hour Dispersion of Gasoline Chemicals from CEI Fuel Hub (NNW Wind Direction)



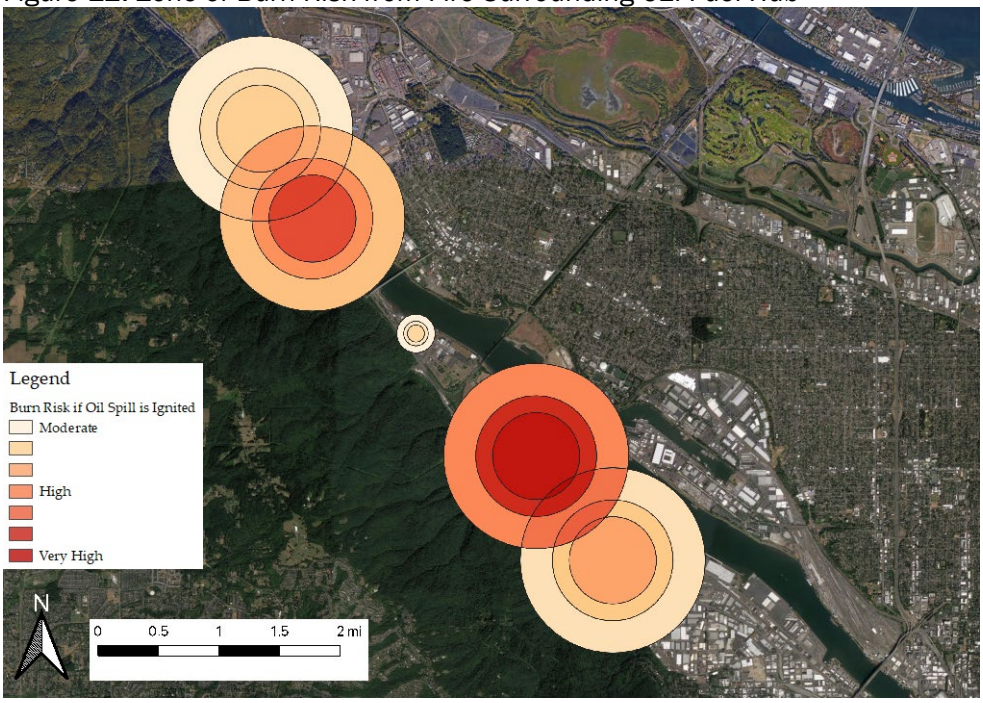
Source: NOAA and EPA ALOHA software, output created by ECONorthwest

Figure 11: One-Hour Dispersion of Gasoline Chemicals from CEI Fuel Hub (W Wind Direction)



Source: NOAA and EPA ALOHA software, output created by ECONorthwest

Figure 12: Zone of Burn Risk from Fire Surrounding CEI Fuel Hub

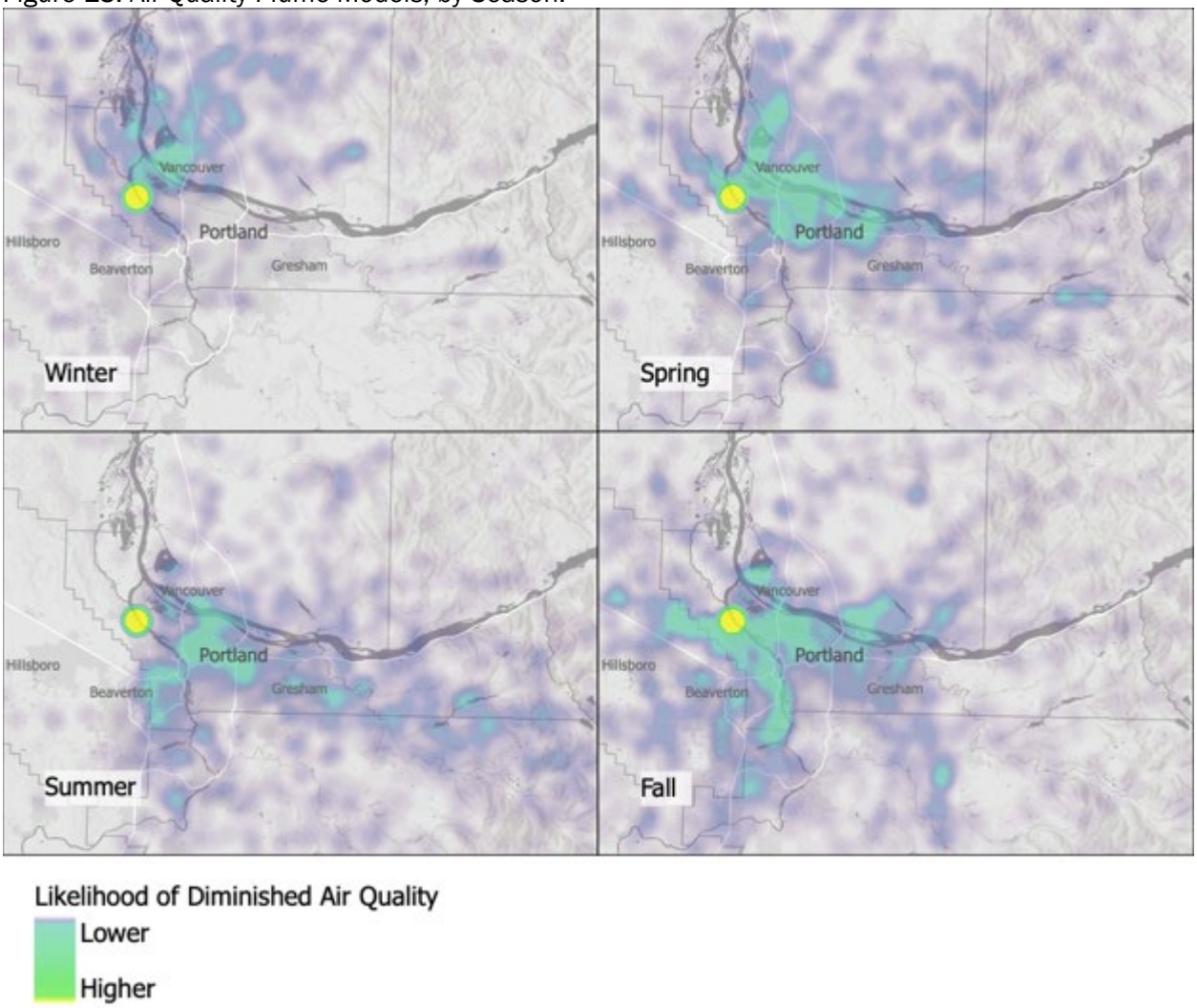


Source: NOAA and EPA ALOHA software, output created by ECONorthwest

The ultimate direction of any air plume from releases at the CEI Hub are very weather specific and can vary from day to day. Nevertheless, there are seasonal trends that put certain portions of the Portland Metro region's population at higher risk. NOAA's Air Resources Laboratory's Hybrid Single-Particle Lagrangian Integrated Trajectory model (HYSPLIT) is one of the most

widely used models for atmospheric trajectory and dispersion calculations.[110] A series of scenarios modeling 24 hour releases during a systematic sample of 12 days per season in 2020 show that the Portland area experiences high weather variability in fall and spring, but more consistent trends in the winter and summer. Should the CSZ event occur in the summer, residents to the south and east of the CEI Hub are likely to experience the greatest air-quality decreases, while residents in the north are likely to experience greater harms in the winter (Figure 10).

Figure 13: Air Quality Plume Models, by Season.



Source: NOAA HYSPLIT analysis performed by ECONorthwest

[110] Stein, A. F., Draxler, R. R., Rolph, G. D., Stunder, B. J., Cohen, M. D., & Ngan, F. (2015). NOAA's HYSPLIT atmospheric transport and dispersion modeling system. *Bulletin of the American Meteorological Society*, 96(12), 2059-2077.

The length of time when there is hazardous air quality will depend on containment and response options. Burning petrochemicals will persist for as long as materials are burning – which is also a function of the extent of any fire spread. If the fire spreads to other industrial, residential, or forested areas then there will be additional chemicals released into the smoke plume and the fire will likely last longer and be more difficult to contain. Materials that are not burned will only be hazardous in the immediate release area and will dissipate after they breakdown naturally.

1-6.5.3 Evacuations

These results show the locations of populations likely to be at the greatest risk of danger from chemical exposure or burns. Evacuation would likely be recommended (though not necessarily feasible) for parts or all of the communities of Linnton and Cathedral Park, as well as the adjacent industrial zones, particularly in any areas approaching the lower explosive limit for gasoline (14,000 ppm).

1-6.5.4 Impacts on Other Emergency Response Efforts

Fuel releases from the CEI Hub and any associated fires, needed evacuations, and spill response activities will strain emergency service resources in the aftermath of the earthquake. The additional risks to human health caused by infrastructure failures at the CEI Hub will take away from emergency response resources that are needed for other earthquake impacts. This increase in demand for emergency services will increase the costs of providing those services. In the worst-case scenario, there may not be enough resources to meet all of the needs for emergency response. Fire response, evacuation, hospital, emergency transportation, law enforcement, and environmental response capacity will all be required to respond to fuel releases from the CEI Hub. These resources may not be available for the CEI Hub, causing the effects to spread without containment. Any resources dedicated to the CEI Hub are taking away from emergencies elsewhere and this scarcity will likely cause added injury and mortality.

1-6.6 Habitat Impacts

1-6.6.1 Effect of Substance Releases on Fish and Wildlife

Oil spills from CEI Hub failures have the potential to cause direct mortality and long-term harm to fish and wildlife in both the immediate area of the spill as well as in water resources as materials are transported downstream. Oil releases can affect wildlife not only through the initial direct exposure, but also through impacts to habitats and clean-up activities. Oil contamination can also degrade habitats and limit food supplies, which could cause secondary

mortality or other harm to species and indirect mortality.[111] These factors of toxicity and habitat impairment, as well as the physiological stress from oil spills, can also affect the reproductive success of species. [112] Lastly, clean-up actions can also be disruptive, particularly more invasive actions like suctioning, dredging, and burning contaminated vegetation. Specific concerns from oil spills for different types of species include:[113]

- **Birds:** Birds are likely to be exposed to oil as they float on the water's surface. Oiled birds can lose the ability to fly, dive for food, or float on the water which could lead to drowning. Oil interferes with the water repellency of feathers and can cause hypothermia. Oil ingestion has been shown to cause suppression to the immune system, organ damage, skin irritation and ulceration, and behavioral changes. Damage to the immune system can lead to secondary infections that cause death, while behavioral changes may affect an animal's ability to find food or avoid predators.
- **Shellfish**: Oil can be toxic to shellfish including bottom dwelling (lobsters, crabs, etc.) and intertidal (clams, oysters, etc.) species. The bottom dwelling species may be particularly vulnerable when oil becomes highly concentrated along the shoreline.
- **Fish:** Fish can be impacted directly through uptake by the gills, ingestion of oil or oiled prey, effects on eggs and larval survival, or changes in the ecosystem that support the fish. Adult fish may experience reduced growth, enlarged livers, changes in heart and respiration rates, fin erosion, and reproductive impairment when exposed to oil. Oil has the potential to impact spawning success as eggs and larvae of many fish species are highly sensitive to oil toxins.

Because oil has the potential to persist in the environment long after a spill event, it can have long-term impacts on fish and wildlife populations. Accordingly, injuries can persist well beyond the direct clean-up from an incident.

Anadromous fish species in the Columbia River and Willamette River are species of particular concern for impacts from fuel releases at the CEI Hub because they are listed as threatened or endangered under state and federal law. An oil spill in these river systems would present an additional stressor on salmon and steelhead, in addition to the other stressors the populations face from habitat degraded by dams and reservoirs, as well as climate change and the resulting high water temperature conditions.[114] An oil spill could also interfere with the anadromous fish species' ability to find their way back to their spawning grounds due to significant changes in the environmental conditions of the rivers.

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[111] National Research Council. (2003). *Oil in the Sea III: Inputs, Fates, and Effects*. Washington, DC: The National Academies Press. https://doi.org/10.17226/10388.

[112] NOAA, Office of Response and Restoration, *How Toxic is Oil*?. Available at: https://response.restoration.noaa.gov/oil-and-chemical-spills/significant-incidents/exxon-valdez-oil-spill/how-toxic-oil.html

[113] U.S. Fish and Wildlife Department. (2010). *Effects of Oil on Wildlife and Habitat*.

[114] Testimony of Dr. Zachary Penney in Columbia Riverkeeper, et al. Final Adjudication Brief: Tesoro Savage, LLC. Vancouver Energy Distribution Terminal. Case Number 15-001.

1-6.6.2 Habitat Types in and Around CEI Hub

NOAA maintains environmental sensitivity maps that identify natural resources that are potentially at-risk if an oil spill occurs nearby. The NOAA environmental sensitivity maps for the Columbia River include mapping of the CEI Hub.[115] Resources immediately near the CEI Hub include birds, fish, and reptiles, such as:

- **Birds:** Bald eagle, osprey, and other waterfowl.
- **Fish:** Chinook salmon, coho salmon, sockeye salmon, steelhead, white sturgeon, eulachon, and others.
- **Reptiles:** Western pond turtle and western painted turtle.

The lower Columbia River supports 74 populations of salmon, steelhead, and bull trout.[116] Many of these species are listed as threatened or endangered under state and federal law. In 2020 there were 7.0 million adult and jack species counted at Bonneville dam and 70,000 counted at Willamette Falls.[117, 118]

The largest Caspian Tern and Double-crested Cormorant colonies in the Western United States nest in the Columbia River Estuary. An oil spill during nesting season could wipe out a significant portion their population.

Downstream of the CEI Hub, there are additional environmentally sensitive resources. The downstream area of the Willamette River, Columbia River, and their tributaries includes the Sauvie Island Wildlife Area, Ridgefield National Wildlife Refuge, Julia Butler Hansen Refuge for The Columbian White-Tailed Deer, and the Lewis and Clark National Wildlife Refuge.[119, 120] These refuge areas support wintering and migrating concentrations of waterfowl and shorebirds, provide juvenile salmonid rearing habitat, and contribute to the food supply for a wide swath of environmental resources. There are also multiple areas of Freshwater Forested/Shrub Wetland habitat located downstream of the CEI Hub that are hydrologically connected to the Willamette or Columbia Rivers.[121] Because they are downstream of the CEI

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[115] The CEI Hub is mapped as "ESI20" for the Columbia River, available at: https://response.restoration.noaa.gov/esi_download#Oregon

[116] State of Salmon in Watersheds. (2020). *Lower Columbia River*. Available at: http://teststateofsalmon.wa.gov/regions/lower-columbia-river/salmon/

[117] Columbia Basin Fisheries Agencies and Tribes, *Fish Passage Center Website*. Available at: https://www.fpc.org/

[118] Counts include Chinook salmon (Adult and Jack), Coho salmon (Adult and Jack), Steelhead, Sockeye salmon, Pink salmon, Chum salmon, Lamprey, and Shad.

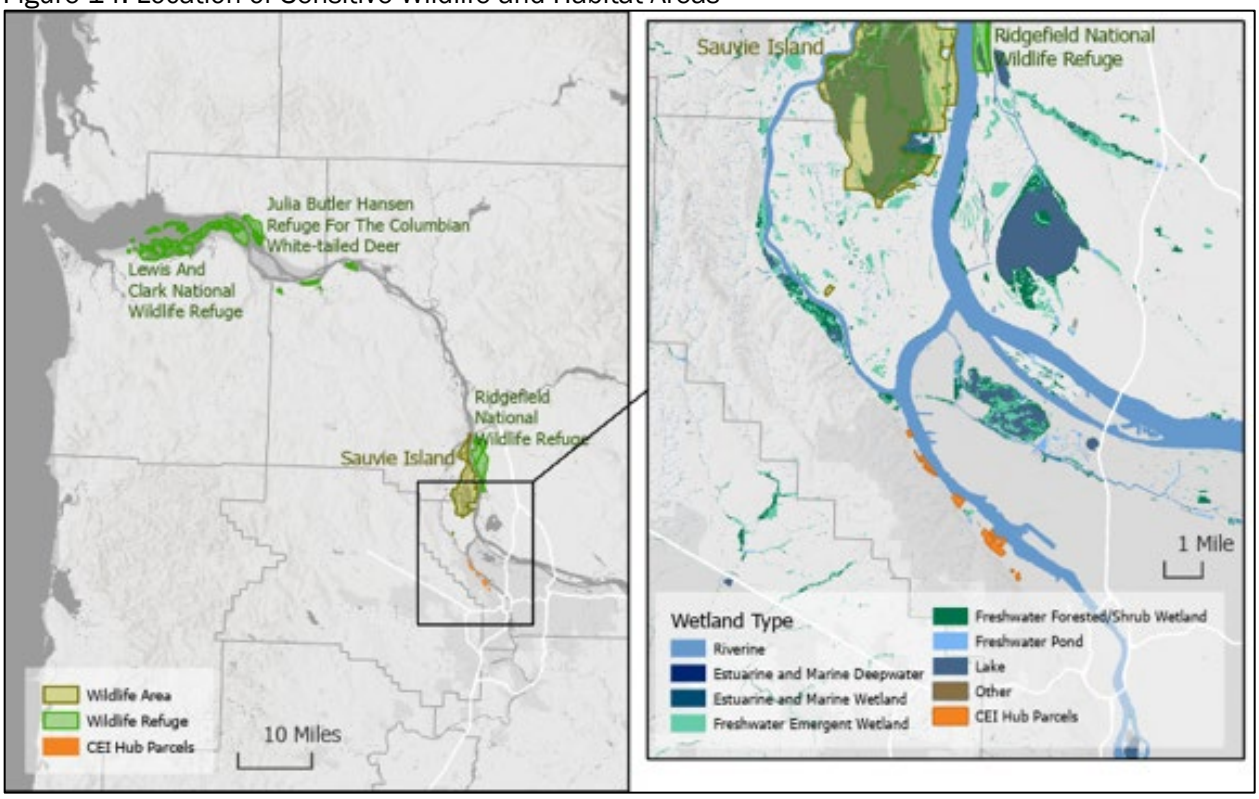
[119] Abt Associates Inc. and Bear Peak Economics. (2016). *Potential Fishing Impacts and Natural Resource Damages from Worst-Case Discharges of Oil on the Columbia River.* Submitted to: Matthew Kernutt, Assistant Attorney General Washington Attorney General's Office. May 12.

[120] Region 10 Regional Response Team (RRT) and the Northwest Area Committee (NWAC). (2015). *Lower Columbia Spill Response Plan*. October. Available at: https://www.rrt10nwac.com/GRP/

[121] U.S. Fish and Wildlife Service, *National Wetland Inventory Mapper*. Available at: https://www.fws.gov/wetlands/data/mapper.html

Hub, all of these resources have the potential to be impacted depending on river conditions and spill response activities. Figure 11 displays the location of these sensitive habitat and wildlife areas.

Figure 14. Location of Sensitive Wildlife and Habitat Areas



Source: Created by ECONorthwest using information from U.S. Fish and Wildlife Service, National Wetland Inventory mapper

1-6.6.3 Extent of Releases from CEI Hub

The impact on habitats and species from tank failures at the CEI Hub is based primarily on the amount of material that flows into the water. Because the CEI Hub is an industrial area, releases only onto the ground are not likely to cause extensive habitat impacts. Fires and the chemical vapors that they produce could impact wildlife in the same way that they can impact humans.

As discussed in Section 3, between 40.8 million to 82.5 million gallons of oil and hazardous materials could potentially flow into the Willamette River due to a CSZ earthquake and subsequent tank failures. This level of spill would be between one-quarter to one-half of what was released over three months in the Deepwater Horizon oil spill. When the oil is released into the Willamette River, it will flow with the river current until it is contained or until it reaches the Pacific Ocean. Table 11 details the seasonal average river currents for the Willamette and Columbia Rivers at the closest upstream gages to the CEI Hub. As demonstrated in these values, the river current (i.e., velocity) can be more than to six times faster in the winter compared to the summer and is faster in the Columbia River than the Willamette River.

Table 15. Seasonal Average Water Velocity (feet per second)

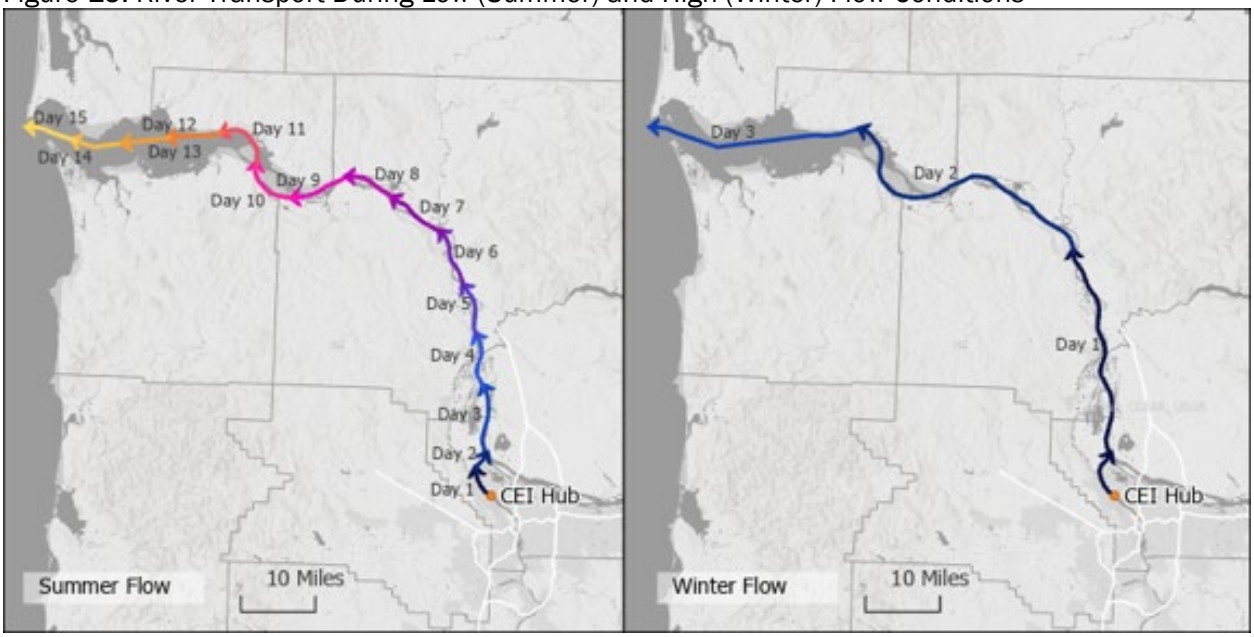
	Willamette River at Broadway Bridge, Portland, OR	Columbia River at Vancouver, Washington
Winter	1.58	2.45
Spring	0.48	1.20
Summer	0.24	0.47
Fall	0.56	1.09

Source: Calculated by ECONorthwest based on information from USGS, *National Water Information System: Web Interface*, available at: https://nwis.waterdata.usgs.gov/nwis

The river currents describe how fast remaining materials will flow downstream. As discussed in Section 4.2, because materials evaporate and disperse over time, there are fewer remaining materials each day. Heavier fuels will remain longer in the water without dispersing or evaporating. Modelling current and weathering information also informs the extent of contamination based on when containment and clean-up activities commence.

Based on the current in the summer it will take approximately 15.5 days for materials released from the CEI Hub into the Willamette River to reach the Pacific Ocean (Figure 12). In contrast, during the winter when currents are faster, it will take approximately 3 days for remaining materials released from the CEI Hub into the Willamette River to reach the Pacific Ocean. These timelines are without containment actions. With containment actions the flow of released materials would be stopped where the containment occurs. Of note, fuels and industrial containments are likely to also enter the Willamette River and Columbia River from other sites due to the CSZ earthquake, so containment actions will be needed at other locations as well. Containment before releases reach the ocean may not be possible due to the damages to infrastructure following the earthquake and other complications.

Figure 15. River Transport During Low (Summer) and High (Winter) Flow Conditions



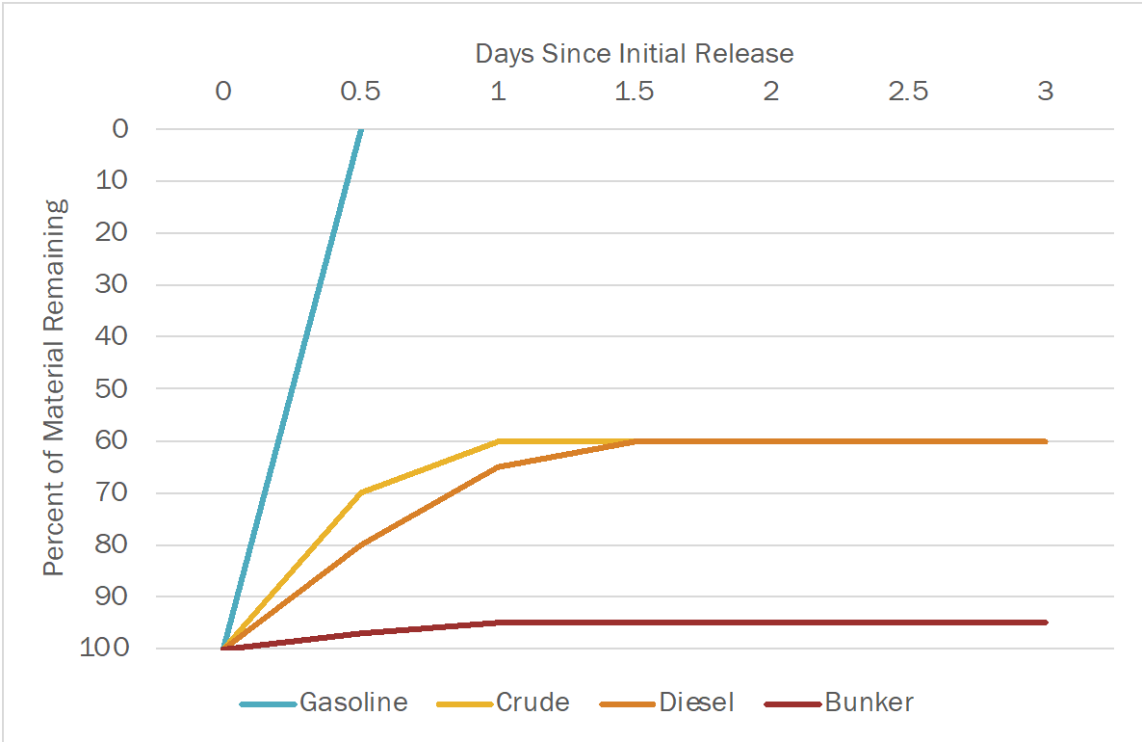
Source: Created by ECONorthwest using data from USGS

As discussed in section 4.2, not all the materials released from the CEI Hub will remain in the water for the length of time it would take to reach the Pacific Ocean. After 10 hours, almost of all the gasoline, ethanol, and aviation fuel will have evaporated into the air, particularly during hotter days when evaporation rates are higher and more sunlight and microbes can break down the chemicals.[122] Diesel and crude oil will evaporate in part, but up to 60 percent could be remaining when the materials reach the Pacific Ocean.[123] Because these light fuels float on top of the water they will largely flow with the river. Heavier oils like asphalt and bunker crude oil will sink in the water and largely remain in any environment that they come in contact with on riverbeds and shorelines. Despite sinking, heavier oils will continue to be transported by the water velocity, although at a slower rate than non-sinking lighter oils that remain on the water surface. Figure 13 models sample evaporation rates for gasoline, crude, diesel, and bunker fuels over time for the first three days.

[122] National Research Council. (2003). *Oil in the Sea III: Inputs, Fates, and Effects*. Washington, DC: The National Academies Press. https://doi.org/10.17226/10388.

[123] National Research Council. (2003). *Oil in the Sea III: Inputs, Fates, and Effects*. Washington, DC: The National Academies Press. https://doi.org/10.17226/10388.

Figure 16. Evaporation Rates



Source: Created by ECONorthwest using information from National Research Council (2003) and NOAA ADIOS model results.

Applying the evaporation rates described previously to the materials that could be potentially released at the CEI Hub results in the finding that after three days between 20.9 million and 42.3 million gallons of diesel, medium, and heavy oils could be remain in the water (excluding additives and unknown materials). Because most evaporation occurs early, in the low flow scenario in the summer these levels of materials are likely to remain about as high for the remaining days and be transported to the Pacific Ocean. This level of contamination is likely to result in significant mortality among aquatic species throughout the lower Willamette and Columbia Rivers. Mortality and impacts to sensitive species will be particularly pronounced if the spill occurs during the salmon spawning seasons in the late spring to early fall.

1-6.6.4 Effect of Ground Spills on Properties

The habitat impacts of spills onto the ground at the CEI Hub will not be as severe as the water resources because materials will not be transported on the ground and there are not sensitive habitats in the terrestrial area of the CEI Hub. However, releases on to the ground will contaminate the soil and require clean-up efforts and site remediation, such as soil removal. Oil sheens on the ground are possible for years afterwards even with remediation actions.

1-6.7 Impacts to Cultural Resources

The CEI Hub is located on the native lands of the member tribes of the Confederated Tribes of the Grande Ronde and the Confederated Tribes of the Siletz. Historically, the Willamette River

has been used by local tribes for subsistence, transportation, commerce, and ceremonial purposes. Impacts to aquatic species from fuel releases at the CEI Hub would result in a reduction of these values for local tribes.

The Cultural Resources Analysis Report for the Portland Harbor Superfund Site (2005) details some of the specific cultural resources near the CEI Hub:[124]

> "Some Tribes retain treaty rights to salmon and other fish including lamprey, not only as a source of food but also as part of their culture and spirituality. Wetlands in this region are also culturally important because wetlands support wapato, a harvested item that was traded between Chinookans in the Portland Basin and other Native peoples at the coast. The only known location that currently supports wapato is a small riverine wetland located in the Swan Island Lagoon. Native vegetation was also gathered for food and tools."

Water provides important cultural value by sustaining fish and ecosystems that tribal and non-tribal members depend on; riparian vegetation used as food, medicine, and fiber for clothing, baskets, and tools; and other organic and non-organic materials used for subsistence and cultural purposes.

The impacts from releases at the CEI Hub on migratory species, in particular salmon and steelhead, would also impact tribal nations that rely on Columbia Basin salmon throughout Oregon and Washington, both upstream and downstream of the CEI Hub site on the Willamette River and Columbia River. Reductions in salmon populations due to CEI Hub fuel releases could threaten tribal treaty rights to continue to take fish both on their reservations and at all usual and accustomed fishing places. The Columbia River tribes' treaty fishing rights are property rights and require compensation under the Fifth Amendment of the United States Constitution if their rights are infringed upon.[125]

Some non-tribal members would also experience cultural loss from harm to the environment caused by fuel releases at the CEI Hub. Pioneering research on *solastalgia*, the grief that people feel when a landscape that they are connected to is dramatically altered, suggests that loss of the functions of a natural resource can cause feelings of isolation from others, less community participation, perceptions of loss of nature, and worsened mental health.[126]

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[124] Ellis, D.V., Allen, J.M., and Hajda, Y. (2005). *Cultural Resource Analysis Report for the Portland Harbor Superfund Site, Portland, Oregon*.

[125] The legal precedent for compensation was established in "Confederated Tribes of the Umatilla Reservation v. Alexander" in 1977.

[126] Eisenman, D P., Kyaw, M.T., Eclarino, K. (2021). *Review of the Mental Health Effects of Wildfire Smoke, Solastalgia, and Non-Traditional Firefighters.* UCLA Center for Healthy Climate Solutions, David Geffen School of Medicine at UCLA, & Climate Resolve.

The Willamette River has been the site of tremendous investment through the Portland Harbor Superfund Clean Up,[127] and those efforts have been working to improve the environmental conditions to support cultural values related to habitats and the species they support. Particularly for tribes, restoring this ecosystem is of particular importance to correct historic loss of cultural value.

[127] More information about the Portland Harbor Superfund Site is available at: https://cumulis.epa.gov/supercpad/SiteProfiles/index.cfm?fuseaction=second.Cleanup&id=1002155#bkground

Chapter 2: Costs of Impacts from Cascadia Subduction Zone Earthquake at CEI Hub

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Prepared for:

Multnomah County Office of Sustainability

and City of Portland Bureau of Emergency Management

Prepared by:

ECONorthwest
ECONOMICS · FINANCE · PLANNING

Enduring Econometrics

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2-1 Introduction

2-1.1 Chapter Overview

Fuel releases from the CEI Hub because of a Cascadia Subduction Zone (CSZ) earthquake will impose substantial economic costs on the region. These costs accrue both as financial costs of responding to the spill, cleaning it up, and restoring the environment, as well non-market economic losses to individual welfare. This chapter builds upon the physical description of direct impacts from the CEI Hub discussed in the previous chapter by calculating the costs of both the immediate and downstream effects of the fuel releases. In addition to the costs of the direct physical effects of the releases, this chapter also describes the costs to the fuel market as well as the costs of cleanup and restoration activities.

2-1.2 Scenario Modeling and Uncertainty

There is inherent uncertainty associated with estimating the economic costs of CEI Hub fuel releases due to a CSZ earthquake. A key factor is the quantity of fuel released, which, as discussed in the prior chapter, is predicated by assumptions about the integrity of the tanks and underlying soils, as well as the magnitude of the earthquake. While the Columbia River Area Contingency Plan lays out a framework for a quick response to an oil spill, the CSZ's impacts to roads, bridges, and other infrastructure will impair response times and further affect how far the fuels will spread, particularly in the river.[1] Economic costs are also dependent on the ultimate fate of the fuels. If fuel releases catch fire, there will be additional impacts to property and air quality. However, burning could minimize the amount of fuel that is released into the ground and water and limiting habitat impacts. Additional uncertainty is inherent in the analysis due to the variation based on the environmental conditions of when the spill occurs (e.g., what time of year, the temperature, wind patterns, etc.).

Uncertainty also accrues from the fact that the CEI spill would co-occur with a major earthquake. The interaction of these incidents includes many physical unknowns. What is certain is that the earthquake will increase the difficult of responding to the spill of materials from CEI Hub. An earthquake is more likely to compound harms by delaying clean-up efforts, delaying efforts to re-open shipping, and reducing access to fuels exactly when they are needed for emergency generators and clean-up equipment.

For these reasons, this analysis does not present a single estimate of the costs of fuel releases. Instead, each section describes the specific assumptions and methodologies used to obtain any monetary cost estimates. The assumptions are based upon the best available information to

[1] USCG Sector Columbia River. (2020). *Columbia River Area Contingency Plan*. Available at: https://homeport.uscg.mil/Lists/Content/Attachments/60907/SCR%20ACP%202020-Signed%20LOP%20USCG.pdf. Accessed November 30, 2021.

model the most likely scenario of the magnitude and extent of the impact and corresponding costs. Not all impacts have monetary cost estimates. When possible, costs are described in per unit estimates to provide the information needed to scale the costs based on the magnitude of impacts to demonstrate how costs could change if impacts are more or less severe than modelled. Some impacts, such as impacts to cultural resources, are intentionally not monetized because monetization implies that such values are fungible – but because they are specific to place and history these values are generally not interchangeable with any other good or service.

The costs and damages calculated and described in this chapter are those that are attributable to the release of fuels from the CEI Hub. This distinction between what is attributable to the fuel releases and what is not is determined by establishing the baseline scenario and calculating damages that are in addition to that baseline. The baseline scenario is what would have occurred but for the CEI Hub fuel releases. In the case of CEI Hub fuel releases due to a CSZ earthquake, all damages caused by the earthquake are included in the baseline scenario, and therefore not included as costs and damages attributable to fuel releases from the CEI Hub.

2-2 Cost of Direct Impacts to People

The spill and any resulting fires have the potential to cause direct physical impacts to people working at or near the CEI Hub when the earthquake occurs.[2] This analysis estimates the costs of direct impacts to people by estimating mortality and morbidity rates from explosions and fires at other fuel storage locations. Section 1-6.2.1 of Chapter 1 details the specific scenarios that could result in between 0 to 7 people killed, and 2 to 80 people injured. These mortality and morbidity rates do not consider any delays in emergency response or earthquake-related confounding factors that could result in higher rates of death and injury. These values do not include any mortality and morbidity caused by fires or people other than on-site workers being harmed by the event.[3] The values also do not include instances of suicide or mental health, which have been seen after other oil spills.[4,5] For this reason these values should be considered minimum estimates of total direct costs to people.

The standard approach for valuing changes in risk of mortality is the value of a statistical life (VSL). This approach relies on labor market data to decouple the marginal change in pay for working in a profession with a higher risk of mortality. Extrapolating these marginal changes into the value of a whole life produces a single dollar value that is regularly used in economic analysis. The current VSL used by the Federal Government in benefit-cost analysis is $10.3 million.[6,7]

Estimates of injury (i.e., morbidity) are more difficult to discern than mortality because impacts can vary significantly by the type of harm incurred. The most appropriate equivalence to the injuries expected at the CEI Hub are workers compensation claims that include lost wages, medical expenses, and damages from pain and suffering. In 2016, the average worker's compensation payment was $24,900.[8]

[2] Other potential harms to people from impacts to air quality and water quality are discussed in later sections.

[3] Health effects from air quality are discussed in Section 2-7 of this Chapter.

[4] Hennessy-Fiske, M. (2010). "Suicide is called another casualty of BP oil spill". *The Los Angeles Times*. June 24. Available at: https://www.latimes.com/archives/la-xpm-2010-jun-24-la-na-oil-spill-grief-20100625-story.html

[5] Rung, A. L., Oral, E., Fontham, E., Harrington, D. J., Trapido, E. J., & Peters, E. S. (2019). The long-term effects of the Deepwater Horizon oil spill on women's depression and mental distress. *Disaster medicine and public health preparedness*, *13*(2), 183-190.

[6] U.S. Environmental Protection Agency. (2016). *Guidelines for Preparing Economic Analyses*.

[7] All dollar values are reported in October 2021 terms using the Bureau of Labor Statistics' Consumer Price Index for all Urban Consumers (CPI-U). https://www.bls.gov/cpi/. Accessed November 30, 2021.

[8] Martindale-Nolo Research. (2016). *2016 Worker's Compensation Trends*. Available at: https://www.lawyers.com/legal-info/workers-compensation/workers-compensation-settlements-awards/workers-compensation-settlements-and-awards-how-much-will-i-get-for-my-injury-or-illness.html

Applying these values to the estimates of mortality and morbidity due to fuel releases from the CEI Hub that cause explosions and fire produces estimates that range from $49,800 to $74.1 million, summarized in Table 1 below.

Table 1. Costs to People due to an Explosion from CEI Hub Fuel Releases

	Low Rates of Mortality and Morbidity	High Rates of Mortality and Morbidity
Injury	$49,800	$1,992,000
Mortality	$0	$72,100,000
Total	**$49,800**	**$74,092,000**

Source: Calculated by ECONorthwest

2-3 Cost of Impacts to Property

2-3.1 Impacts to Waterfront Properties

Environmental quality is a key component of the price of residential real estate. Impairments to environmental quality can lead to reductions in property values, however, the transient nature of oil spills means that price changes are normally more pronounced during the period of maximum uncertainty that occurs immediately following an incident.[9] The measured drops in price for river- or ocean-front properties from oil spills range between 0 and 16 percent reductions in property value, with the effects typically disappearing after cleanup.[10,11,12] Persistent drops in home values after a spill cleanup may be attributable to changes in perceived risk of future spills.[13,14] This implies that for any risks of a spill about which homebuyers are already aware, the risk of a spill may be factored into property values. Changes in perceived risk that occur after a prominent spill may then result in more persistent declines in property values.

[9] Winkler, D. T., & Gordon, B. L. (2013). The effect of the BP Oil spill on volume and selling prices of oceanfront condominiums. *Land Economics*, *89*(4), 614-631.

[10] Cano-Urbina, J., Clapp, C. M., & Willardsen, K. (2019). The effects of the BP Deepwater Horizon oil spill on housing markets. *Journal of Housing Economics*, 43, 131-156.

[11] Simons, R. A. (1999). The effect of pipeline ruptures on noncontaminated residential easement-holding property in Fairfax County. *Appraisal Journal*, *67*, 255-263.

[12] Simons, R. A., Winson-Ceideman, K., & Brian, A. (2001). The Effects of an Oil Pipeline Rupture on Single-Family House Prices. *Appraisal Journal*, 410-418.

[13] Hansen, J. L., Benson, E. D., & Hagen, D. A. (2006). Environmental hazards and residential property values: Evidence from a major pipeline event. *Land Economics*, *82*(4), 529-541.

[14] Roddewig, R. J., Brigden, C. T., & Baxendale, A. S. (2018). A pipeline spill revisited: how long do impacts on home prices last?. *The Appraisal Journal*, 86(1), 23-47.

Home values along the southern gulf coast dropped between 4 and 8 percent following the Deepwater Horizon oil spill in 2010, with effects lasting until 2015.[15] Earlier peer-reviewed work found a reduction in home values between $21-$28 per square foot, or 10.1 to 13.5 percent of sale prices, in gulf coast condominiums in Alabama in the 100 days following the same spill, while another study found only an 8.8 percent drop in prices during the summer months prior to the capping of the spill and no net price change following the capping.[16]

Other studies have examined the effect of spills on non-coastal properties. A 2001 study found a 10 percent drop in value of homes with property rights adjacent to the Patuxent River in Maryland following a major spill in April 2000.[17] This work was later expanded in 2018 to show that the negative effects on property values were not persistent, and no price difference was found for affected properties after 18 months following the incident.[18] Following a 1993 rupture of the Colonial Pipeline in Fairfax County, Virginia, homes within 2 miles of the pipeline decreased in value by up to 5.5 percent.[19] There was also a strong negative relationship found between home prices and proximity to the Olympic Pipeline in northwest Washington in the five years following a major rupture in 1999.[20]

2-3.1.1 Potential Property Value Impacts

Downstream riverfront properties between the I-405 and Longview bridges on the Columbia River, as well as properties on the Willamette River, Multnomah Channel, and Scappoose Bay could experience declines in real property value due to CEI Hub fuel releases. Applying a range of estimates from the empirical literature produces impacts that range from $11.7 to $35.4 million, summarized in Table 2.

Table 2. Estimated Residential Property Value Losses for Columbia Riverfront Properties

Loss Scenario	Clark	Multnomah	Cowlitz	Columbia	Total
4%	$1,489,000	$7,644,000	$1,253,000	$1,408,000	**$11,793,000**
6%	$2,047,000	$10,511,000	$1,722,000	$1,936,000	**$16,216,000**
8%	$2,977,000	$15,288,000	$2,505,000	$2,816,000	**$23,587,000**
10%	$3,722,000	$19,110,000	$3,132,000	$3,520,000	**$29,483,000**
12%	$4,466,000	$22,932,000	$3,758,000	$4,224,000	**$35,380,000**

[15] Cano-Urbina, J., Clapp, C. M., & Willardsen, K. (2019). The effects of the BP Deepwater Horizon oil spill on housing markets. *Journal of Housing Economics*, *43*, 131-156.

[16] Winkler, D. T., & Gordon, B. L. (2013). The effect of the BP Oil spill on volume and selling prices of oceanfront condominiums. *Land Economics*, *89*(4), 614-631.

[17] Simons, R. A., Winson-Ceideman, K., & Brian, A. (2001). The Effects of an Oil Pipeline Rupture on Single-Family House Prices. *Appraisal Journal*, 410-418.

[18] Roddewig, R. J., Brigden, C. T., & Baxendale, A. S. (2018). A pipeline spill revisited: how long do impacts on home prices last?. *The Appraisal Journal*, 86(1), 23-47.

[19] Simons, R. A. (1999). The effect of pipeline ruptures on noncontaminated residential easement-holding property in Fairfax County. *Appraisal Journal*, *67*, 255-263.

[20] Hansen, J. L., Benson, E. D., & Hagen, D. A. (2006). Environmental hazards and residential property values: Evidence from a major pipeline event. *Land Economics*, *82*(4), 529-541.

Source: ECONorthwest analysis of assessor data from Clark, Multnomah, Cowlitz, and Columbia counties.

These values exclude commercial, industrial, and agricultural properties. Given that negative price effects have also been seen in properties near, but not adjacent to, rivers, it is possible that additional properties could experience temporary property value declines. In addition, due to the complexity of clean-up following a CSZ earthquake it is possible that the effects will persist longer than the two years of expected effects. Impacts of oiling would also occur to houseboats in the Multnomah Channel. Property value impacts to these in-water homes would likely be larger than the literature values used to calculate the losses. Given these considerations, the property value impact values in Table 2 should be considered minimum values of property value impacts.

These effects are likely to persist for approximately two years following the spill event, and do not include any other property value declines as a result of the CSZ earthquake. Most of the impacts to property values (65 percent) are in Multnomah County while the remaining 35 percent is split relatively evenly across Clark, Cowlitz, and Columbia counties. Realized market losses would be experienced by property owners who choose to sell during the period of depressed values. Even if a homeowner chooses not to sell and their property values eventually rebound, they will experience a loss of ability to enjoy the riverfront amenity of their property or may feel their enjoyment of living there will diminish due to the fear of future spills.

Most of the riverfront properties in the area are commercial, industrial, and other non-residential properties (about $2.5 billion in total riverfront property value). Although these markets operate differently than residential markets, these properties could be subject to additional reductions in property value.

There are over 30 marinas or ports downstream of the CEI Hub but upstream of the Longview Bridge that would likely be oiled based on river transport from the spill site, particularly during higher winter river flow periods. There are over 4,000 boat slips on these properties and hundreds of floating houses. These in-river properties would experience direct oiling of their built property, in addition to oiling of the shoreline. We do not explicitly value the additional property damages from oiling, but acknowledge that it is a likely additional cost.

2-3.2 Impacts to Water Users

Downstream of the CEI Hub, the Columbia River is not a direct primary municipal water source. As such, there are not expected to be direct effects to water users from CEI Hub fuel releases. There are groundwater sources downstream of the CEI Hub that could have a hydrological connection with contaminated surface water. Because of these groundwater-surface water interactions, the groundwater supply may be contaminated in sites downstream from the spill. Heavy oils would post particular risks to groundwater resources as they are more likely to sink, infiltrate, and remain in the environment over time.

Due to the risk of contamination, it is likely that downstream groundwater sources would need to be tested for volatile organic compounds and other hazardous materials. For example, the Ranney collector wells that supply water to the City of St. Helens are adjacent to the Columbia River and would likely require testing to ensure the water is not contaminated with residual fuels. Groundwater testing costs approximately $380 per test.[21] Modern filtration systems should be able to remove any residual fuel materials. If water treatment systems fail to remove the fuel materials, then the costs of additional treatment methods would be in the millions of dollars.

Other permit holders for wastewater discharge and water intake could be affected, particularly those downstream of the spill. There are 153 permits for wastewater release into the Lower Columbia River for Oregon and 41 for Washington. For the duration of the cleanup period, these permit holders may be affected by not being allowed to discharge over this period.

[21] Melstrom, R. T., Reeling, C., Gupta, L., Miller, S. R., Zhang, Y., & Lupi, F. (2019). Economic damages from a worst-case oil spill in the Straits of Mackinac. *Journal of Great Lakes Research*, 45(6), 1130-1141.

2-4 Cost of Impacts to Navigation

Major oil spills often lead to closures of navigational shipping channels. The 2014 Texas City Y oil spill led to a five-day closure of the Houston Ship Channel, stranding nearly 100 vessels at the ports of Houston and Texas City.[22] Similarly, releases of fuel into the Willamette River, Multnomah Channel, or Columbia River would impact vessels that rely on these shipping channels for navigation when the channels are closed during the cleanup period. These vessels will incur costs due to increased expenses during the time of the delay. Additional operating expenses from delays include the costs of crew, maintenance and repair, and fuel costs.

The length of delays due to closure of the navigation channels depends on the length of cleanup. The most likely closure period is between three to seven days – but harm from the earthquake will complicate cleanup activities and could extend this timeframe further. This analysis provides estimates for one day and one week. The analysis uses the number of vessels that use navigation channels between the I-405 bridge on the Willamette River to the Longview Bridge located downstream on the Columbia River, as described in Section 1-6.3 in Chapter 1.

Vessel operating costs are based on hourly estimates from Nathan Associates (2012)[23] that are multiplied by 24 and inflated to 2021 dollars to obtain a daily closure cost on low, average, and high traffic days. Table 3 summarizes the average daily and weekly costs for the three types of volume days. A one-week closure of the navigation channel would result in operating costs of approximately $16.2 million during a period of average vessel traffic.

Table 3. Average Daily Vessel Operating Costs in Area of Analysis (2021 Dollars)

Vessel Traffic	Count of Vessels	Average Daily Operating Cost	Average Weekly Operating Cost
Low	33	$1,690,000	$11,830,000
Average	42	$2,315,000	$16,205,000
High	47	$2,552,000	$17,864,000

Source: Calculated by ECONorthwest
Note: Values have been rounded to the thousands.

[22] ESI Inc. (2014). Case Study – Houston Ship Channel Oil Spill. Available at: http://www.green-marine.org/wp-content/uploads/2014/06/ESI-Case-Study-Houston-Shipping-Channel-Oil-Spill-V-1.01.pdf. Accessed November 30, 2021.

[23] Nathan Associates Inc. (2012). *Economic Analysis of North Atlantic Right Whale Ship Strike Reduction Rule*. Prepared for the National Oceanic & Atmospheric Administration. December.

2-5 Costs of Impacts to Commercial Fisheries

Fuel releases into the Willamette River from the CEI Hub have the potential to cause harm to aquatic species (see Section 1-6.6.1 in Chapter 1 for information about how species can be harmed by fuel releases). Many aquatic species in Oregon are sources of economic value because they contribute to commercial enterprises or contribute value to tribal and subsistence fisheries.[24]

Coastal commercial fisheries in Oregon have an annual harvest value of $153.8 million (2017 dollars, excluding distant water fisheries).[25] Washington commercial fisheries generate approximately $65.1 million in sales (2006 dollars).[26] This economic activity supports personal income for employees and owners who patriciate in harvest, as well as wholesalers, processors, and the many other supply chain operations that rely on catch from coastal waters. The Port of Astoria at the mouth of the Columbia River alone supports $209 million in annual economic activity (i.e., output) from the direct and secondary effects of the commercial fishing industry.[27] Cowlitz County, which includes the Port of Longview on the Columbia River, had a commercial fishing value of $380,000 in 2006.[28] Commercial fishing in the Lower Columbia River is dominated by salmon fishing. The Lower Columbia River accounts for 1.8 percent of the commercial fisheries sales in Washington and had a value of $1.2 million in 2006.[29] There is limited commercial fishing in the Upper Columbia River, but the area does support recreational and tribal fishing. There is limited commercial fishing on the Willamette River. In addition to commercial harvest, fisheries in Oregon and Washington also support commercial charter fishing enterprises.

Tribal fisheries will be impacted in the same way as commercial fisheries. However, tribal fisheries could experience disproportionate adverse impacts because tribal fishing occurs in-river and is reliant on fish populations that are more likely to travel through the Lower Columbia River and be exposed to CEI Hub fuel releases. The residual contaminants from the CEI Hub failures could result in fishing advisories to limit consumption of aquatic species in

[24] Impacts of fuel releases to recreational fishing is discussed in Section 2-6, impacts to tribal fisheries are discussed in Section 2-10.

[25] ECONorthwest. (2019). *Economic Contributions of Oregon's Commercial Marine Fisheries*. Prepared for Oregon Department of Fish and Wildlife. October.

[26] TCW Economics. (2008). *Economic Analysis of the Non-Treaty Commercial and Recreational Fisheries in Washington State.* Prepared for Washington Department of Fish and Wildlife. December.

[27] ECONorthwest. (2019). *Economic Contributions of Oregon's Commercial Marine Fisheries*. Prepared for Oregon Department of Fish and Wildlife. October.

[28] TCW Economics. (2008). *Economic Analysis of the Non-Treaty Commercial and Recreational Fisheries in Washington State.* Prepared for Washington Department of Fish and Wildlife. December.

[29] TCW Economics. (2008). *Economic Analysis of the Non-Treaty Commercial and Recreational Fisheries in Washington State.* Prepared for Washington Department of Fish and Wildlife. December.

this area.[30] These advisories are more likely to apply to resident, non-anadromous fish species such as trout, carp, brown bullhead, bass, and walleye. These species are also sources of food for people who participate in subsistence fishing – including both tribal and non-tribal populations.

To the extent that fuel releases impact harvestable catch there will be declines in economic activity (e.g., the income for operators and employees, number of jobs supported through direct and secondary effects, and contribution to economic value added in Oregon) and value for tribal and subsistence fisheries. The impact on commercial fisheries and charter operations will be proportional to any increases in the difficulty of catch. The Lower Columbia River commercial fisheries are the most likely to experience loss of revenue caused by declines in salmon populations because they are reliant on Columbia River Basin species. At-sea and coastal off-shore commercial fisheries have access to a range of species from other river basins.

If releases of fuel from the CEI Hub cause less reproduction of certain anadromous fish species during the spawning season that could reduce the population of the species in later years when they would have otherwise been available to be commercially harvested. Fish populations are also likely to be impacted by sedimentation from the earthquake and experience additional stresses that could harm survival and reproduction in the aftermath of the event.

[30] There are currently fishing advisories for resident fish populations in the Lower Willamette River due to high concentrations of PCBs.

2-6 Cost of Impacts to Recreation

Recreation could be impacted by fuel releases from the CEI Hub due to contamination of water resources as well as any harm caused by fires ignited by the fuel releases. As discussed in Section 1-6.4 of Chapter 1, fishing, hunting, swimming, and boating are the most likely to be affected due to fuel releases. The impact to recreation will be closures initially until cleanup is complete, followed by water quality advisories and fish consumption advisories.

The cost to recreation is the value of the cancelled trips that cannot occur because of the fuel releases. The effects of the earthquake will also impact recreation because of harm to infrastructure like roads, docks, boat ramps, parking lots, as well as hazard trees. The lingering effects of fuel releases could lead to additional fish consumption and swimming advisories due to residual toxins in the water. Long-term impacts to recreation due to CEI Hub fuel releases would also occur if a fire damages recreational sites – particularly Forest Park because burned trees would take decades to replace with regrowth.

Recreational use associated with public goods is a source of two distinct types of economic value. The first, known as 'consumer surplus' accrues to recreators and is a measure of the difference between an individual's willingness to pay to engage in outdoor recreation, and the amount they actually have to pay. Because many types of outdoor recreation do not have access fees that are competitively priced, these consumer surplus values can be substantial. Past empirical research has estimated an average consumer surplus value for motorized boating of $68.14 per person per day. If the river is closed or contaminated as a result of releases from the CEI Hub, recreational boaters would do something else, and this value represents the loss to the participant that would be incurred from being unable to engage in their preferred activity.

Table 4. Per Person per Day Consumer Surplus Values by Activity Type (2021 Dollars)

Activity	Consumer Surplus Value
Fishing	$83.50
Hiking	$98.60
Hunting	$90.37
Motorized boating	$68.14
Nature related	$70.20
Nonmotorized boating	$127.17
Average	**$80.13**

Source: Rosenberger, R. S., White, E. M., Kline, J. D., & Cvitanovich, C. (2017). Recreation economic values for estimating outdoor recreation economic benefits from the National Forest System. Gen. Tech. Rep. PNW-GTR-957. US Department of Agriculture, Forest Service, Pacific Northwest Research Station. Table 3.
Note: Inflated to 2021 dollars using the CPI Inflation Calculator. Values are for Forest Service Region 6: Pacific Northwest.

The second type of economic value that accrues from recreation is the economic activity that occurs. Recreators spend money on food, gasoline, lodging (if overnight), equipment purchases, and entry fees. During a spill, this economic activity would not accrue to these businesses. Average per trip expenditures are summarized in Table 5. These values represent the per trip spending that could be lost if trips do not occur due to fuel releases from the CEI Hub. This spending supports economic activity by supporting owners and workers where the spending

occurs and through supply chain effects. As an example of the magnitude of the importance of recreational spending, in 2019 the recreational fishing industry for the Lower Columbia River supported a total of $7.29 million in economic contributions to Oregon.[31,32]

Table 5. Per Trip Expenditures by Activity Type (2021 Dollars)

Activity	Per Trip Expenditures
Fishing	$195.74
Hunting	$386.95
Shellfishing	$478.49
Wildlife Viewing	$97.89

Source: Dean Runyan. (2009). *Fishing, Hunting, Wildlife Viewing, and Shellfishing in Oregon, 2008*. Prepared for Oregon Department of Fish and Wildlife and Travel Oregon.
Note: Inflated to 2021 dollars using the CPI Inflation Calculator.

The impacts on fuel releases from the CEI Hub will be impacted by the damage caused by the earthquake to other infrastructure. In the short-term (days to weeks after the event) recreation will be limited due to access and potential contaminants from other sources. Fishing advisories after the event are most likely to cause long term impacts that are specific to CEI Hub fuel releases. A one-month closure of the Lower Columbia River and Lower Willamette River for salmonid fishing would result in a loss of consumer surplus of $3.4 million and a loss of $3.2 million in direct trip spending (2021 dollars), based on the number of anglers for 2020. These values do not account for any substitute trips to other sites or any additional fishery closures beyond the salmonid values provided in the recreational data (see Table 14 in Section 1-6.4.1 of Chapter 1). These values also do not account for non-fishing boating trips that could also be lost due to recreational access closures, or any other type of impacted recreation, such as closures due to fire damage.

[31] The Research Group, LLC. (2021). *Oregon Commercial and Recreational Fishing Industry Economic Activity Coastwide and in Proximity to Marine Reserve Sites for Years 2018 and 2019.* Prepared for Oregon Department of Fish and Wildlife, Marine Reserve Program and Marine Resource Program. June.

[32] The Lower Columbia River is defined as downstream of Bonneville Dam to the mouth of the Columbia River.

2-7 Cost of Impacts to Human Health

Regardless of whether the fuel released from the CEI Hub would volatilize or burn, there are potential substantial acute air quality impacts to nearby residents, workers, and first responders. These air quality impacts present themselves as health effects, and due to the substantial volume of fuel spill, may be unavoidable.

2-7.1 Deepwater Horizon Health Costs

For people in the immediate area of fuel releases the primary risk is death or injury from explosions and fires. These potential harms are discussed in Section 2-2. Health impacts to people in the immediate area can also accrue from exposure to petrochemical fumes, both from vapor as well as fire plumes. The immediate area is the area where the fumes are located with the highest density during and immediately after the fuel releases. Workers and first responders are most at-risk to health effects from exposure in this area.

The Deepwater Horizon Oil Spill incident provides an example of health costs that can arise from large fuel spills. The Deepwater Horizon incident exposed response workers, volunteers, and residents to hazardous chemicals in the form of burning crude oil and from the clean-up chemicals, including Corexit oil dispersant. Many of the response workers were people who lived and work in the area, including fishermen who were valuable to use for their boats and labor.

The Gulf Long-term Follow-up Study (GuLFSTUDY) is a study overseen by the National Institute of Environmental Health Sciences to study the health of individuals who helped with the oil spill response and clean-up, took training, signed up to work, or were sent to the Gulf to help in some way after the Deepwater Horizon disaster.[33] A study of medical records for responses workers seven years after the event found that people involved in the oil spill cleanup operations still experience persistent alterations or worsening of their hematological, hepatic, pulmonary, and cardiac functions.[34]

In January 2013, a settlement was approved to compensate workers and residents for health effects from the oil spill. The medical settlement was included in the $7.8 billion settlement for all private claims.[35] Not all people are allowed to file medical claims under this settlement agreement – people must have been either a "clean-up worker" or "resident" for at least 60 days during the timeframe of the spill and response. People who experienced acute conditions were eligible for a lump-sum payment amount of $1,300 for response workers and $900 for residents.

[33] More information about the GuLFSTUDY is available at: https://gulfstudy.nih.gov/en/index.html

[34] D'Andrea, M. A., & Reddy, G. K. (2018). The development of long-term adverse health effects in oil spill cleanup workers of the Deepwater Horizon offshore drilling rig disaster. *Frontiers in Public Health*, 6, 117.

[35] NOAA, *Deepwater Horizon oil spill settlements: Where the money went*, Available at: https://www.noaa.gov/explainers/deepwater-horizon-oil-spill-settlements-where-money-went

As of 2019, BP has paid $67 million toward medical claims and has funded an additional $105 million effort to operate community-based health programs along the Gulf Coast.[36] There are report of lump-sum values not being sufficient, difficultly navigating the process to submit medical claims, long timeframes to receive compensation, and difficultly obtaining compensation for chronic injuries among claimants. For these reasons, the $172 million is not the full health costs of the Deepwater Horizon Oil Spill incident, but rather only the amount that was compensated out of much larger costs to human health. Despite the many, ongoing efforts to study health effects, there is no estimate of the total costs to human health from Deepwater Horizon.

2-7.2 Health Risks from Exposure to Toxins

Acute exposure to high levels of airborne gasoline chemicals has been shown to cause adverse respiratory, cardiovascular, and hematological outcomes. Respiratory illnesses have been observed in animals subject to prolonged exposure to concentrations of only 100 ppm over twelve weeks.[37] Cardiovascular and neurological issues have also been observed after prolonged exposure in animals and humans. Symptoms such as headaches, dizziness, eye irritation, breathing difficulties, and nausea can occur from acute gasoline exposure. Chemical pneumonia also is one of the primary risks of exposure to very high concentrations. A 2019 review of 26 studies on the effect of gasoline exposure on pulmonary function found a significant negative relationship between lung function and length of chemical exposure.[38] As demonstrated in the follow up studies from the Deepwater Horizon incident, long-term health effects for clean-up workers and nearby residents include disorders and diseases of the blood, liver, and heart.[39]

In addition to physical health effects there are also mental health costs of oil spills. The most common mental health symptoms of large oil spill events are depression, anxiety, and post-traumatic stress disorder (PTSD).[40] Other mental health effects can include stress, suicide, domestic violence, and substance abuse.[41] There is also evidence of inequities in how mental

[36] Sneath, S. (2019). "8 years after BP oil spill, thousands of medical claims still not paid". *NOLA*. Available at: https://www.nola.com/news/environment/article_50997394-26d7-50c2-9a64-1a7d1eec1d45.html

[37] U.S. Department of Health and Human Services. (1995). *Toxicological Profile for Gasoline*. Atlanta, GA: Agency for Toxic Substances and Disease Registry. https://www.atsdr.cdc.gov/toxprofiles/tp72.pdf.

[38] Moghadam, S. R., Afshari, M., Moosazadeh, M., Khanjani, N., & Ganjali, A. (2019). *The effect of occupational exposure to petrol on pulmonary function parameters: a review and meta-analysis.* Reviews on environmental health, 34(4), 377-390.

[39] D'Andrea, M. A., & Reddy, G. K. (2018). The development of long-term adverse health effects in oil spill cleanup workers of the Deepwater Horizon offshore drilling rig disaster. *Frontiers in Public Health*, 6, 117.

[40] Weir, K. (2012). "Class Act: The Oil Spill's Reverberations". *American Phycological Association*. Available at: https://www.apa.org/gradpsych/2012/03/oil-spill

[41] MDB Inc. (2013). *Mental Health Following the Deepwater Horizon Oil Spill.* Prepared for the National Institute of Environmental Health Sciences. December.

health is experienced - lower income individuals are more likely to report a higher level of overall distress.[42]

In addition to acute health risks from exposure, there is also a risk of fatality in the immediate zones surrounding the potential fire location. Fatalities have occurred from inhalation of gasoline vapor at very high concentrations, above 5,000 ppm.[43]

2-7.3 Health Costs from Hazardous Air Quality

Airborne pollutants from CEI Hub fuel releases and fuel ignition are likely to lead to adverse health outcomes for the areas with high levels of immediate acute exposure to gasoline chemicals and the broader area of lower levels of particulate matter exposure. Exposure to particulate matter can cause a range of acute health impacts, which include non-fatal heart attacks, hospital admissions, emergency department visits, bronchitis, respiratory symptoms, asthma exacerbation, lost workdays, and minor restricted activity days. [44]

Each of these health impacts cause increases in health care costs, as well as decreases in welfare for the individuals affected. The EPA uses both components when evaluating the economic benefits and costs of air quality regulations. The economic cost per case for each ailment is summarized in Table 6. Column two of the table shows the derived rates of incidence of exposure to $PM_{2.5}$ levels for 4,000 tons of airborne gasoline chemicals based on scenario modelling for a fuel spill incident in California. Assuming a similar release of particulate matter from the CEI Hub spill (likely a conservative assumption, given that the magnitude of oil spilled would likely exceed 4,000 tons of airborne gasoline chemicals), the health costs to the population affected by exposure to the airborne gasoline would be approximately $8.9 million based on exposure to all populations in Multnomah and Clark Counties. Additional long-term outcomes that could lead to more severe chronic health outcomes or mortality are possible but not quantified. As such, this estimated health cost should be taken as a lower bound estimate.

Table 6. Costs from Acute Exposure to Air Pollution from Oil Spill

Health Effect	Cost per Case	Cases per 1,000 Exposures	Cost of Exposure in Multnomah and Clark Counties
Non-Fatal Heart Attacks	$157,540	0.02	$4,969,000
Hospital Admissions-Respiratory (all ages)	$37,366	0.01	$165,000
Hospital Admissions-Cardiovascular (over age 18)	$51,868	0.01	$578,000
Emergency department visits for asthma (all ages)	$596	0.01	$9,000

[42] Drescher, C. F., Schulenberg, S. E., & Smith, C. V. (2014). The Deepwater Horizon Oil Spill and the Mississippi Gulf Coast: Mental health in the context of a technological disaster. *American Journal of Orthopsychiatry*, 84(2), 142.

[43] U.S. Department of Health and Human Services. (1995). *Toxicological Profile for Gasoline*. Atlanta, GA: Agency for Toxic Substances and Disease Registry. https://www.atsdr.cdc.gov/toxprofiles/tp72.pdf.

[44] U.S. Environmental Protection Agency [U.S. EPA]. (2012). *Regulatory Impact Analysis for the Final Revisions to the National Ambient Air Quality Standards for Particulate Matter.* EPA-452/R-12-005.

Health Effect	Cost per Case	Cases per 1,000 Exposures	Cost of Exposure in Multnomah and Clark Counties
Acute bronchitis (age 8-12)	$661	0.05	$38,000
Lower respiratory symptoms (age 7-14)	$30	0.67	$23,000
Upper respiratory symptoms (asthmatics age 9-11)	$46	0.97	$53,000
Asthma exacerbation (asthmatics ages 6-18)	$79	2.42	$210,000
Lost workdays (ages 18-65)	$212	4.30	$333,000
Minor restricted-activity days (ages 18-65)	$95	25.43	$2,520,000
Total Avoided Morbidity Benefit			**$8,898,000**

Source: Created by ECONorthwest using data from U.S. Environmental Protection Agency. (2012). *Regulatory Impact Analysis for the Final Revisions to the National Ambient Air Quality Standards for Particulate Matter*. Available at: https://www3.epa.gov/ttnecas1/regdata/RIAs/finalria.pdf. Tables 5-18, 5-19 and 5-20.
Note: Values have been inflated to 2021 dollars using the BLS CPI-U. Level of exposure relates to a reduction of 4,000 tons of $PM_{2.5}$ in a seven-county area of California.

Estimating both acute and chronic medical costs can be done by taking a proportional value based on the Deepwater Horizon settlement claims. This is an imperfect and likely lower bound estimate because it is based on the environmental conditions and clean up that occurred in Deepwater Horizon, which was an event at-sea, rather than in a large urban metropolitan area. As discussed above, the values are for medical claims, rather than medical costs. For these reasons the estimates are likely a lower-bound value and actual health costs would be higher. Based on a value of $1.28 per gallon from Deepwater Horizon (including $105 million for community-based health programs) the total compensated costs for acute and chronic conditions would be between $121 million to $248 million, depending on the extent of fuel releases.

Table 7. Compensated Health Costs of CEI Hub Fuel Releases, Deepwater Horizon Transfer Method

	Gallons Released	Cost
Low	94,634,005	$121,470,514
High	193,687,251	$248,613,486

Source: Created by ECONorthwest

2-7.4 Evacuation Costs

The air and water pollutant hazards and fire risk or possibility of active fires would trigger emergency evacuations in affected areas surrounding the CEI Hub. Based on the modeling of air pollutant dispersal (and depending on the weather and wind conditions during the spill), the areas likely facing toxic levels of pollutants would be immediately surrounding the tanks in the Linnton neighborhood, as well as the neighborhoods west and east of the St. John's Bridge (portions of the St. Johns, University Park, Cathedral Park and Portsmouth neighborhoods). If all census tracts areas within the outer extent of the air plume shown in the map are evacuated, this means a population of about 89,500 people will need to evacuate either to emergency shelter, friends and family, outside lodging, or other locations. Additional evacuations could occur as a precautionary measure. The harm to transportation infrastructure could increase the costs of evocations or make evacuations infeasible, which would increase health costs.

Costs accrue through a combination of providing emergency services, temporary lodging, gas, food, and other essentials. Other costs include those associated with missed work or additional physical or emotional health consequences. A 2003 study on the costs of a 1998 hurricane in North Carolina found that the direct costs to evacuees ranged from $81 for households who moved to shelters and $418 for residents who stayed in a hotel.[45] Although the length of stays away from home varied across survey respondents, the average length of time was 5 days.

Table 8: Evacuation Costs Per Household from Hurricane Bonnie

Expenditure	Hotel	Friends/Family	Shelter	Other
Lodging	$247	$0	$0	$0
Food	$143	$95	$70	$26
Entertainment	$19	$1	$4	$0
Other	$8	$35	$7	$3
Total Direct Costs	$418	$131	$81	$30
Percent of Cases	16%	6%	70%	9%

Source: Whitehead, J. C. (2003). One million dollars per mile? The opportunity costs of hurricane evacuation. *Ocean & coastal management*, 46(11-12), 1069-1083. Inflated to 2021 dollars using consumer price index data from the US Bureau of Labor Statistics.

Applying the costs breakdown from Table 6 to the 89,500 number of potentially evacuated residents (35,800 households) results in an estimated total cost of $4.7 million in private costs borne by evacuees. This excludes the cost of providing shelter and emergency services during the evacuation, in addition to time and travel costs to residents and the costs of missed work.

2-8 Cost of Impacts to Habitats and Species

When hazardous chemicals and oil spill into the environment, natural resource Trustees are authorized by several federal and state laws to assess and recover damages for injury to natural resources and their supporting habitats.[46] These laws have outlined a Natural Resource Damage Assessment (NRDA) process that identifies the extent of harm as well as the amount of compensation necessary to make the public whole. The NRDA process relies on well-established environmental and economic measurement techniques under a strict legal and regulatory framework to ultimately determine the monetary damages as a result of environmental harm. This section of this report describes the potential magnitude, extent, and

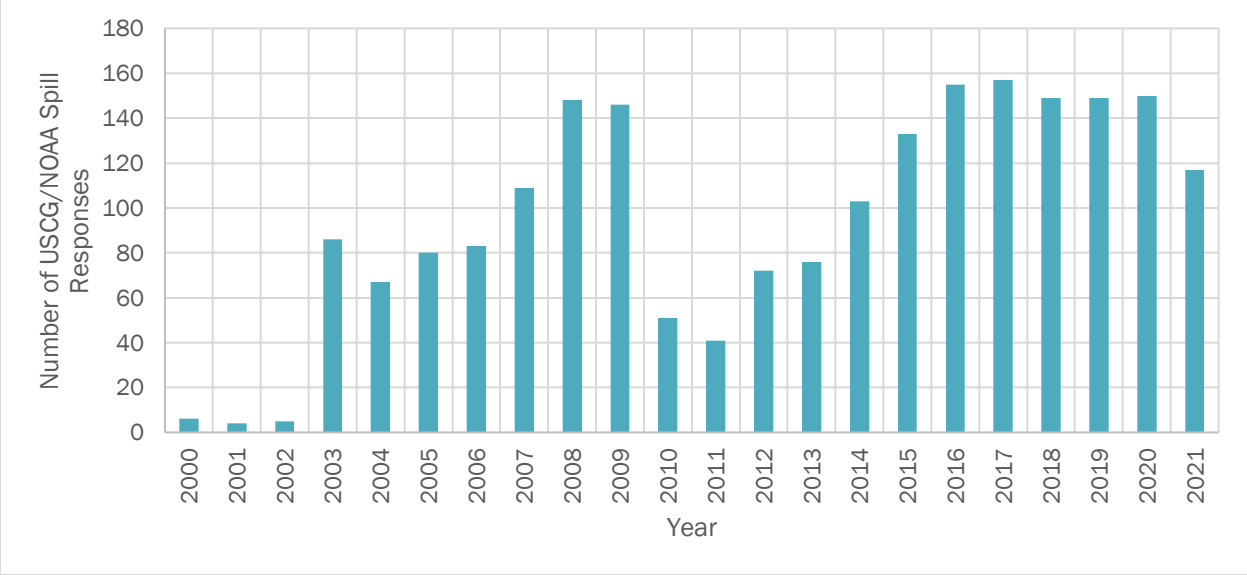
[45] Whitehead, J. C. (2003). One million dollars per mile? The opportunity costs of hurricane evacuation. *Ocean & coastal management*, 46(11-12), 1069-1083.

[46] Comprehensive Environmental Response, Compensation and Liability Act of 1980, 42 USC §9601, et seq. (CERCLA) and the Oil Pollution Act of 1990, 33 USC. §2701, et seq. (OPA).

duration of the environmental injury caused by a potential spill at the CEI Hub and the expected damages as determined by the NRDA process.

Unfortunately, oil spills in marine waters are not a particularly uncommon occurrence. Anytime there is a spill or potential spill in U.S. waters, the U.S. Coast Guard is notified and depending on the size of the spill, will engage NOAA's Emergency Response Division to provide emergency scientific support to aid in projecting the trajectory of the oil and identify potential resources at risk. From 2000 through 2021, NOAA's Emergency Response Division provided support for over 2,000 potential spills, with the last five years averaging approximately 150 incidents per year (Figure 1).[47]

Figure 1. Number of USCG/NOAA Oil Spill Responses per Year



Source: NOAA Office of Response and Restoration, Raw Incident Data. https://incidentnews.noaa.gov/raw/index. Accessed 11/17/21.

While this frequency of spills may seem discouraging from an environmental-quality perspective, it has resulted in a well-developed system for responding to and assessing oil spills in U.S. waters. Due to a combination of State and Federal statutes (including ORS 468 and the Oil Pollution Act of 1990), this same mechanism would be enacted following a spill at the CEI Hub. Following the release of oil into the environment, all NRDAs are structured to:

1. Evaluate the pathway by which the oil interacts with natural resources;
2. Measure the degree to which those resources are exposed to the oil;
3. Quantify the degree to which those resources are injured by the oil;
4. Identify a set of restoration projects that will adequately compensate the public; and

[47] NOAA Office of Response and Restoration, *Raw Incident Data*, available at: https://incidentnews.noaa.gov/raw/index.

5. Determine the damages as either the loss of value or the cost of restoration.

Most natural resources and ecosystems recover to their baseline state following an oil spill. This can be aided by cleaning up the contamination or implementing other techniques (i.e., primary restoration) to accelerate this recovery. However, even if an ecosystem fully recovers from a spill several years into the future, there is still a period of interim loss, during which the ecosystem was impaired because of the spill, and as a result, the public lost value. This interim loss can be addressed through compensatory restoration actions that "provide services of the same type and quality, and of comparable value as those injured."[48] For example, constructed or enhanced wetlands can serve as compensatory restoration for oiled wetlands. They can also serve as compensation for oiled birds by supplementing necessary habitats that may otherwise be regionally limited.

Determining the sufficient quantity of restoration is performed through one of several scaling techniques. When damages are determined via the cost of restoration that provides equivalent ecological services or resources, the appropriate amount of restoration is calculated using service-to-service or resource-to-resource methods.

When applied to habitats, techniques such as Habitat Equivalency Analysis (HEA) or the Habitat-Based Resource Equivalency Method (HaBREM) use metrics representing the set of ecological services or biological productivity flowing from a habitat (and their relative change as a percentage of total services provided) over time as inputs.[49] Using a fixed discount rate r, the present value stock of services, S, from a given habitat, h, is calculated as the integral of discounted service flows over time, t, multiplied by the spatial area, A_h, from which those services are generated.[50] This value, for a given habitat, is referred to as discounted service acre years ($DSAYs_h$) and is calculated as:

$$DSAYs_h = A_h \cdot \int_t^T e^{-rt} \cdot \left(S_{h,0}(t) - S_{h,1}(t)\right) dt$$

The HEA/HaBREM approach measures both the loss of ecological services caused by an injury as well as the gain in services from a given restoration project.

When applied to resources (e.g., fauna), the Resource Equivalency Analysis (REA) method functions in a similar framework to HEA/HaBREM; however, it now captures the flow of ecological services provided by an animal over its lifetime. For instance, the general set of ecological services provided by an animal for any year related in present value terms is a discounted-species-year, or DSY. These services are provided in a binary condition by the

[48] 15 CFR Part 990.53(c)(2)

[49] The HaBREM approach is a similar habitat-based assessment technique that can be applied to the measurement of ecological injury; however, the scaling metric applied is some objective measure of habitat productivity rather than the degree of ecological services provided. Additional discussion can be found in Baker et al. (2020).

[50] A description of the choice of the discount rate in HEA and REA can be found in Julius (1999).

existence of the animal, so marginal declines in services are not applied in a REA. *DSYs* for a given species are calculated:

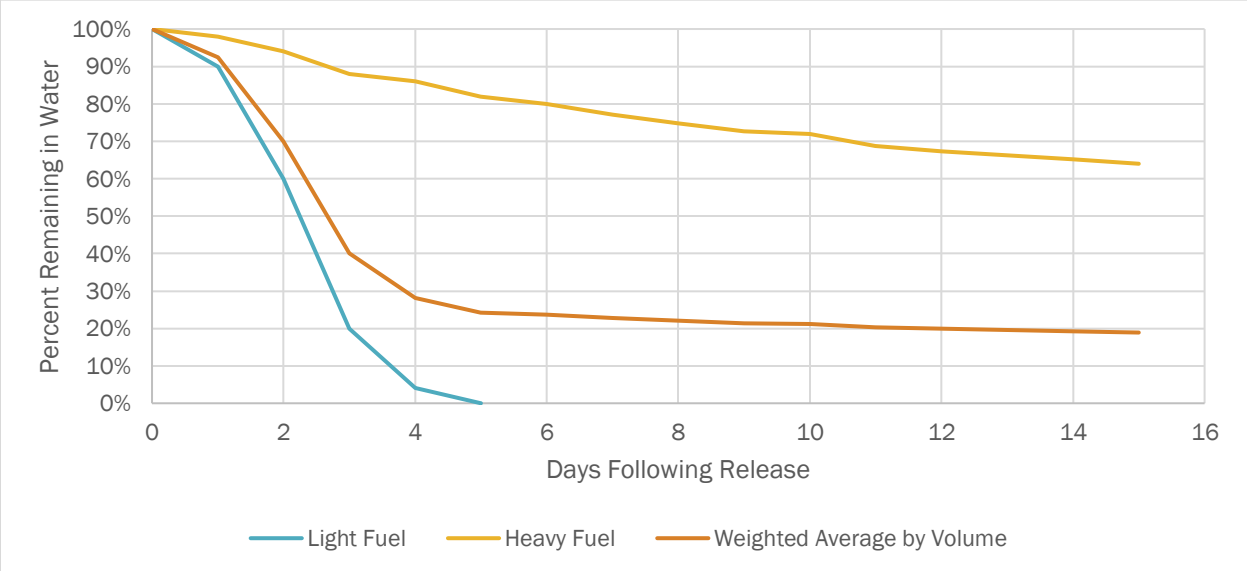
$$DSYs_a = \int_t^T e^{-rt} \cdot \left(Q_{a,0}(t) - Q_{a,1}(t)\right) dt$$

where $Q_a(t)$ is the quantity of animal-years in a given state. This approach can also incorporate information on the life history (e.g., survival and fecundity) of the species and incorporate population-level indirect measures of injury.

2-8.1 Release, Pathway, Exposure

As described in Section 1-4.2 of Chapter 1 of this report, oil released as a result of a failure at the CEI Hub will undergo both weathering and transport in the days following the spill. The degree of weathering – through dispersion or evaporation – is dependent on the type of oil, with lighter, more volatile fuels disappearing from the Willamette and Columbia Rivers more quickly than heavier fuels. While lighter fuels are more detrimental to air quality impacts, they are relatively less harmful in an aquatic environment. Figure 2 shows the percent of the oil that is expected to remain in the waters of the Willamette and Columbia Rivers, by day, following the release.

Figure 2. Percent of Released Oil Remaining in Water, by Day



Source: Enduring Econometrics

In a marine environment, oil spills tend to disperse across the surface of the water, with physical processes determining the ultimate thickness of the surface sheen and potential for accumulation on shorelines. In marine spills, oil sheens are generally categorized by thickness and visual characteristics, with "rainbow sheens" approximately less than 0.005 millimeters thick, "thin metallic-appearance films" between 0.005 and 0.08 millimeters thick, "emulsified

oil" between 0.08 and 1 millimeters thick, and strands of "thick, emulsified oil" that are generally greater than 1 mm in thickness.[51]

A riverine environment is fundamentally different, particularly when a sufficient volume of oil is released into a constrained area, leading to an increased thickness of the surface sheen and greater shoreline oiling. Current estimates of the quantity of oil expected to reach the Willamette and Columbia rivers (between 40.7 and 82.5 million gallons) divided by the total surface area where the oil is expected to travel (~89,405 acres) indicates that the release from the CEI Hub is large enough to generate sheens of nearly continuous emulsified oil through the rivers, even when accounting for the seasonal effects of river flow and weathering (Table 9).

Table 9. Expected Thickness of Oil Sheen on the Willamette and Columbia Rivers

Season	Low-Release Estimate	High-Release Estimate
Winter	0.30 (emulsified oil)	0.60 (emulsified oil)
Summer	0.08 (emulsified oil)	0.16 (emulsified oil)

Source: Enduring Econometrics

2-8.2 Injury to Habitats

This comparatively thick oil sheen will travel down the Columbia and Willamette rivers and accumulate along shorelines and in the river (Table 10). These habitats are essential in the life history of many animals, with wetlands and benthic environments providing particularly productive ecological services.

Table 10. Acres, by Habitat Type, Potentially Affected by CEI-Hub Release

Habitat Type	Acres
Wetlands	
Freshwater Emergent	19,948
Freshwater Forested/Shrub	19,475
Estuarine and Marine	22,140
In-Stream (Benthos)	
Freshwater Pond	1,485
Lake	7,123
Riverine	26,099
Estuarine and Marine Deepwater	54,698

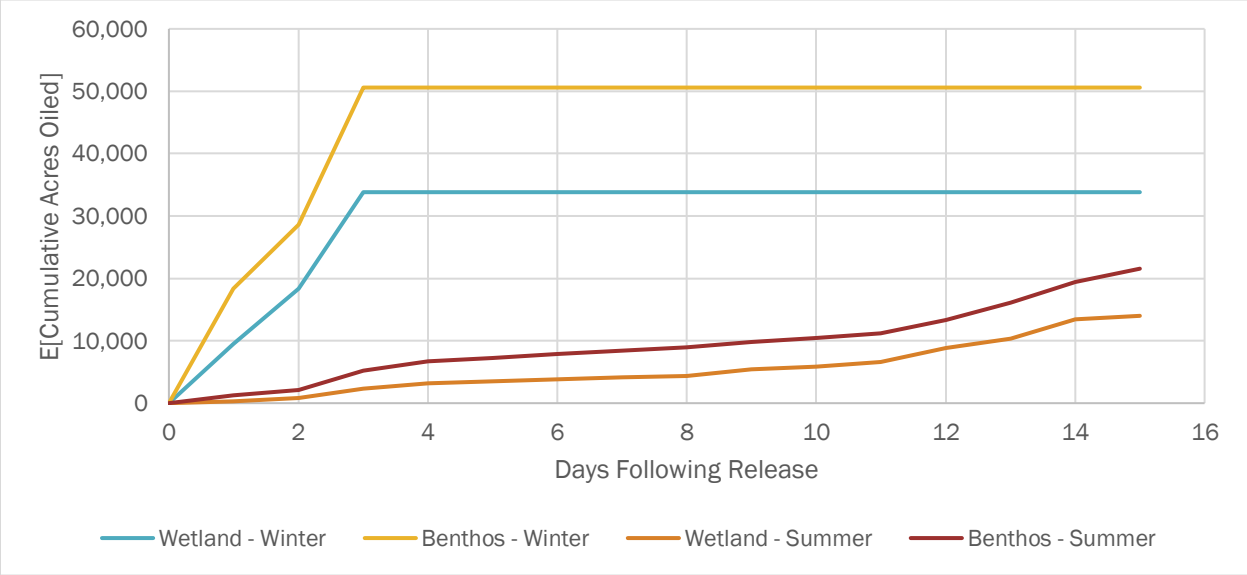
Source: Created by ECONorthwest using information from U.S. Fish and Wildlife Service, National Wetland Inventory mapper

The degree of oiling of these habitats is dependent on the fate and transport of the oil on the rivers, which, as described earlier, is dependent on the mix of oil released and the seasonal velocity of the rivers. In winter, higher river velocity will cause a larger density of oil to reach

[51] Svejkovsky, J., Hess, M., Muskat, J., Nedwed, T. J., McCall, J., & Garcia, O. (2016). Characterization of surface oil thickness distribution patterns observed during the Deepwater Horizon (MC-252) oil spill with aerial and satellite remote sensing. *Marine Pollution Bulletin*, *110*(1), 162-176.

habitats further downstream before natural weathering of the released oil can occur. The comparative acres oiled by day following the release by habitat type are displayed in Figure 3. Due to the higher river flows, a release from the CEI Hub in winter will lead to a larger expected number of acres of habitat oiled compared to a release in summer.

Figure 3. Expected Cumulative Acres Oiled, by Day, Season, and Habitat Type

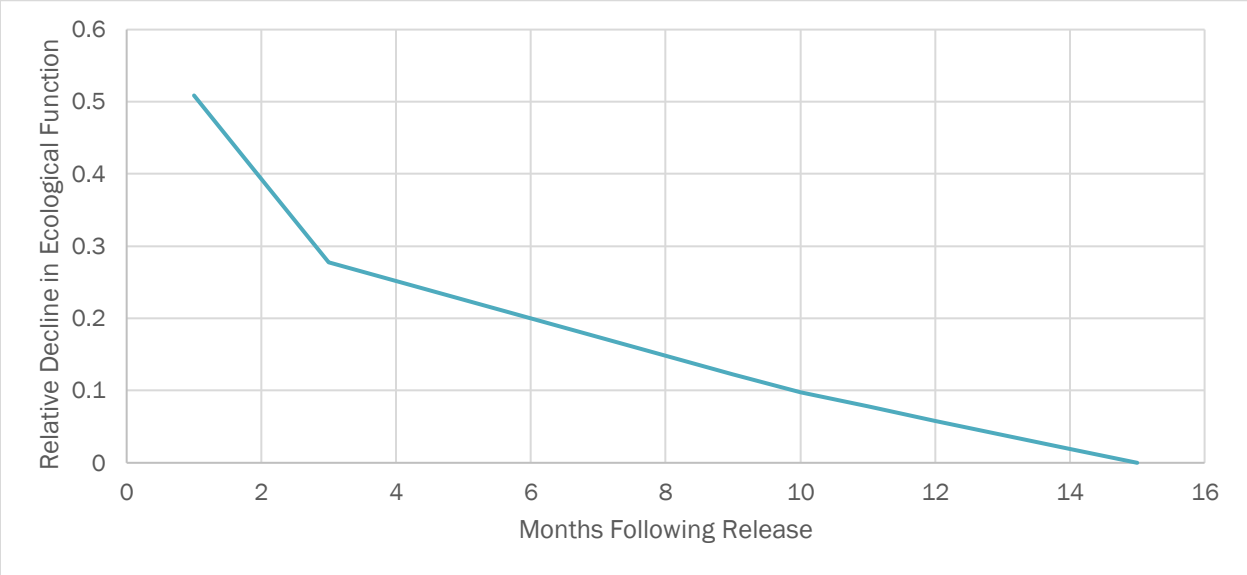


Source: Enduring Econometrics

After the oil accumulates in wetlands and along the river bottom, it causes both a physical injury and chemical injury to the ecological function of those habitats. Fortunately, these impairments are not permanent, and evaluations following other oil spills in estuarine environments found that the decline in function following an oil spill tends to resolve approximately 15 months following the release. While the initial injury can be profound (exceeding a 50 percent decline in ecological function) in the first months after a spill, as the oil weathers and moves around in a dynamic riverine environment, the initial injury slowly dissipates, and the habitats recover to a point where they eventually reach baseline conditions, as shown in Figure 4.[52] These effects can be exacerbated or mitigated by the initial baseline function of the habitat and other co-occurring anthropogenic stressors or cleanup activity.

[52] NOAA, et al. (2009). *Final Restoration Plan and Environmental Assessment for the November 26, 2004, M/T Athos I Oil Spill on the Delaware River near the Citgo Refinery in Paulsboro, New Jersey.*

Figure 4. Recovery of Loss in Ecological Function of Wetland Habitat Following an Oil Spill



Source: NOAA, et al. (2009). *Final Restoration Plan and Environmental Assessment for the November 26, 2004, M/T Athos I Oil Spill on the Delaware River near the Citgo Refinery in Paulsboro, New Jersey*.

2-8.2.1 Habitat Restoration as Compensation for Habitat Injury

The combination of the magnitude, extent, and duration of the injury to wetland and benthic habitats, applied to a HEA or HaBREM framework, provides a calculated value of either DSAYs or some other present value measure of lost ecological productivity. This value is then compared to the gains from potential restoration projects, measured using an equivalent or comparable metric. While wetlands and benthic habitats provide different types of ecological services, their relative productivity can be scaled to a single type of wetland restoration project. Specifically, an acre of wetland generally contributes 2.5 times as much productivity to ecological function as an acre of riverine benthic habitat.[53] Applying this scaling factor allows a single restoration type (constructed wetland) to compensate for both types of injured habitat.

Constructed wetland restoration generally takes areas that (prior to human involvement) were historically naturally occurring wetlands and reverts them to wetlands by improving the underlying hydrology and introducing native plant species. This can occur either through filling dredged river areas, removing levees or berms, or removing fill that had been used to elevate former wetlands. Following the construction of a wetland, it still takes several seasons (and up to 18 years) for the habitat to become fully colonized and begin producing ecological services of the same type and function as the habitat it was designed to replace.[54] These

[53] NOAA, et al. (2009). *Final Restoration Plan and Environmental Assessment for the November 26, 2004, M/T Athos I Oil Spill on the Delaware River near the Citgo Refinery in Paulsboro, New Jersey.*

[54] Baker, M., Domanski, A., Hollweg, T., Murray, J., Lane, D., Skrabis, K., ... & DiPinto, L. (2020). Restoration scaling approaches to addressing ecological injury: the habitat-based resource equivalency method. *Environmental management*, 65(2), 161-177.

constructed habitats require extensive monitoring and adaptive management to ensure they become fully established.

These constructed habitats themselves, however, are not immune to the effects of climate change and sea-level rise and are generally expected to cease producing ecological benefits at some point in the future. The ecological service flows produced by the habitat from its construction to its eventual cessation of services can be similarly calculated in present value as a number of DSAYs or some other measure of productivity gained over time. Dividing the present value of ecological services or productivity lost as a result of the spill by the services or productivity gained from an acre of restoration determines the number of acres of restoration needed to fully compensate the public for the spill. Using a common set of injury and restoration metrics, a restoration project that is anticipated to be constructed five years following the spill, take 18 years to reach full function (per Baker et al., 2020) and produce compensatory ecological services for a total of thirty years, results in between 175 - 418 acres of constructed wetland necessary to compensate for the injury from the spill at the CEI Hub.

Table 11. Summary of Habitat Injury and Restoration Requirements from CEI Hub Spill

	Wetland-Equivalent DSAYs Lost due to Injury	Wetland DSAYs Gained from an Acre of Restoration	Acres Wetland Needed
Winter	4,505	10.8	418
Summer	1,885	10.8	175

Source: Enduring Econometrics

2-8.3 Injury to Resources

The oil released into the environment causes additional direct and indirect mortality to birds, fish, and mammals that utilize and rely on the Willamette and Columbia Rivers. While the habitat is necessary for their vitality, the direct injury to animals as a result of oiling is an additive component of an NRDA injury assessment. There are many species of birds, fish, and marine mammals that are particularly susceptible to injury from a spill at the CEI Hub. NOAA Environmental Sensitivity Index (ESI) data identify the species and numbers of animals that utilize the Willamette and Columbia Rivers by river mile and time of year.[55] Cleanup costs for rescue and rehabilitation of species are included in "Response and Cleanup Costs" in Section 2-9 of this Chapter.

2-8.3.1 Avian Injury

Many birds use the rivers downstream of the CEI Hub for foraging, nesting, and as a stopover during seasonal migration. Birds are generally cannot discern oil from water and often become coated in oil if it is in waterways. This oil causes both a physical and chemical injury to the birds, with some dying soon after exposure to oil. For other birds, the oil disrupts their ability to shed water from their plumage, impairing foraging behavior and leading to starvation and

[55] NOAA Office of Response and Restoration, *Environmental Sensitivity Index Maps and Data*, available at: https://response.restoration.noaa.gov/resources/environmental-sensitivity-index-esi-maps.

eventual death.[56] A common visual following oil spills is the extensive cleanup and rehabilitation of oiled birds; however, following their release, these birds still exhibit high rates of mortality and generally do not re-enter the breeding population.[57, 58, 59]

The expected avian injury from a spill at the CEI Hub is a function of both the degree of oiling, by river mile, and the seasonal population of birds. Table 12 below lists the potential population of birds exposed to oil by guild and river mile in summer, while Table 13 lists potential populations exposed in winter. The source of this data is the Environmental Sensitivity Index (ESI) classification system, which is environmental data designed and collected specifically to inform oil spill planning and response. ESI data characterize the marine and coastal environments and wildlife by their sensitivity to spilled oil.

[56] Burger, A. E. (1993). Estimating the mortality of seabirds following oil spills: effects of spill volume. *Marine pollution bulletin*, 26(3), 140-143.

[57] De La Cruz, S. E., Takekawa, J. Y., Spragens, K. A., Yee, J., Golightly, R. T., Massey, G., ... & Ziccardi, M. (2013). Post-release survival of surf scoters following an oil spill: an experimental approach to evaluating rehabilitation success. *Marine Pollution Bulletin*, 67(1-2), 100-106

[58] Anderson, D.W., F. Gress, and D.M. Fry. 1996. Survival and dispersal of oiled brown pelicans after rehabilitation and release. *Marine Pollution Bulletin*. 32(10): 711-718;

[59] Anderson, D.W., S.H. Newman, P.R. Kelly, S.K. Herzog, and K.P. Lewis. 2000. An experimental soft-release of oil-spill rehabilitated American coots (Fulica americana): I. Lingering effects on survival, condition and behavior. *Environmental Pollution.* 107: 285- 294.

Table 12. Potential Bird Populations Exposed to Oil by River Mile (Day), Summer

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
River Mile	7.2	14.4	21.6	28.8	36	43.2	50.4	57.6	64.8	72	79.2	86.4	93.6	100	108
Degree Oiling	92%	70%	40%	28%	24%	24%	23%	22%	21%	21%	20%	20%	20%	19%	19%
Population Potentially Exposed															
Ducks	-	-	1,000	1,300	1,000	-	-	-	300	20,250	40,000	6,000	1,000	1,000	-
Gulls	-	-	-	-	-	-	-	-	-	-	450	900	-	41,300	-
Cormorants	-	-	-	-	-	-	-	-	-	-	-	-	220	17,920	200
Herons	-	-	-	1,007	-	-	-	100	100	120	700	-	-	-	-
Bald Eagle	2	2	8	22	-	2	8	12	-	44	16	62	44	38	16

Source: NOAA ESI Maps and Data, Available at: https://www.fisheries.noaa.gov/inport/item/40258.

Table 13. Potential Bird Populations Exposed to Oil by River Mile (Day), Winter

Day	1	2	3
River Mile	36.0	72.0	108.0
Degree Oiling	92%	70%	40%
Population Potentially Exposed			
Ducks	595,700	42,550	155,100
Gulls	-	-	22,850
Cormorants	-	-	18,340
Herons	1,007	320	700
Shorebirds	31,000	-	2,000
Bald Eagle	32	66	176
Brown Pelican	-	-	20,000
Sandhill Crane	4,575	-	-

Source: Enduring Econometrics

Applying measures of the percent mortality of birds, by oiling category, from past spills to expected oiled populations by season in the Willamette and Columbia Rivers produces estimates of the direct injury from a spill at the CEI Hub. A REA evaluation of the life-histories of these species produces a discounted present value indirect injury of both future fledgling mortality and decreased reproductive success.[60] The resulting direct and indirect injury to birds as a result of a spill at the CEI Hub is presented in Table 14 and Table 15 below. The greater extent of oiling and increased presence of birds in winter results in a greater injury.

Table 14. Expected Bird Injury, Summer

	Ducks	Gulls	Cormorants	Herons	Bald Eagle
Direct Injury	826	645	261	17	2
Discounted Lost Productivity - Mortality	1,621	929	519	24	3
Discounted Lost Productivity - Reproductive Failure	788	199	76	5	-

Source: Enduring Econometrics

Table 15. Expected Bird Injury, Winter

	Ducks	Gulls	Cormorants	Herons	Shorebirds	Bald Eagle	Brown Pelican	Sandhill Crane
Direct Injury	35,159	719	544	50	5,386	5	281	148
Discounted Lost Productivity - Mortality	68,981	1,035	1,081	70	7,737	7	393	207
Discounted Lost Productivity - Reproductive Failure	33,532	222	159	15	-	-	-	-

Source: Enduring Econometrics

[60] NOAA, et al. (2009). *Final Restoration Plan and Environmental Assessment for the November 26, 2004, M/T Athos I Oil Spill on the Delaware River near the Citgo Refinery in Paulsboro, New Jersey.*

2-8.3.2 Habitat Restoration as Compensation for Avian Injury

Bird populations are often habitat or food limited, and appropriate habitat restoration can serve as direct compensation for an injury to bird populations. This approach relies on directly relating the biological productivity of habitats to specific bird species and making adjustments based on their ecological efficiency (ability to convert wetland biomass into bird biomass).[61] Values vary by bird guild based on their average weight, the type of food they eat (vegetation, insects, or fish), and the ability of an acre of wetland habitat to provide sufficient additional food to support additional birds. This approach is regularly used to calculate the additional acres of wetland needed to compensate for a bird injury and utilizes a standard set of REA criteria in measuring benefits across time as the injury.[62] The full set of inputs necessary are listed in Table 16 below and result in an additional restoration requirement of between 39 – 1,219 acres of constructed wetland, depending on the season of the spill.

[61] French McCay, D.P and Rowe, J.J. (2003). Habitat Restoration as Mitigation for Lost Production at Multiple Trophic Levels. *Marine Ecology Progress Series*. 264:233- 247.

[62] NOAA, et al. (2009). *Final Restoration Plan and Environmental Assessment for the November 26, 2004, M/T Athos I Oil Spill on the Delaware River near the Citgo Refinery in Paulsboro, New Jersey.*

Table 16. Habitat Restoration Scaling for Bird Injury, by Guild

	Ducks	Gulls	Cormorants	Herons	Shorebirds	Bald Eagle	Brown Pelican	Sandhill Crane
Average Wet Weight (kg)								
Adult	1.21	0.53	2.3	2.3	0.06	4.79	3.5	4.295
Juvenile	1.09	0.36	2.3	2.3	0.06	4.79	3.5	4.295
Ecological Efficiency	0.02	0.04	0.04	0.04	0.02	0.04	0.04	0.04
Dry Weight to Wet Weight	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Dry Weight to AFDW	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Compensatory Production Required								
Summer	31,899	3,292	8,674	474	-	109	-	-
Winter	1,357,669	3,667	18,058	1,372	6,929	259	10,369	6,708
Spartina Marsh Secondary Productivity	1,153	1,153	1,153	1,153	1,153	1,153	1,153	1,153
Compensatory Acres Marsh Required								
Summer	28	3	8	0	-	0	-	-
Winter	1,178	3	16	1	6	0	9	6

Source: NOAA, et al. (2009). *Final Restoration Plan and Environmental Assessment for the November 26, 2004, M/T Athos I Oil Spill on the Delaware River near the Citgo Refinery in Paulsboro, New Jersey*.; French McCay, D.P and J.J. Rowe. 2003. Habitat Restoration as Mitigation for Lost Production at Multiple Trophic Levels. Marine Ecology Progress Series. 264:233- 247.

2-8.4 Aquatic Injury and Restoration

The lower Columbia River is an important habitat for a number of fish, including several species whose populations are threatened or endangered. Anadromous fish types expected to be harmed by the spill include both juvenile and adult sockeye, fall and spring chinook, Coho, chum, and summer and winter steelhead. Other species with high utilization of the spill area include starry flounder and white sturgeon. Due to the life histories of many of these species, direct mortality from an oil spill can result in substantial population impacts for many subsequent generations. Particularly at risk are juvenile migrating fry and embryos, with studies following the Exxon Valdez spill finding that elevated egg mortality continued for at least four years after the spill.[63]

Existing anthropogenic stressors on wild populations of fish make quantifying a potential aquatic injury particularly complex. Existing habitat degradation, impairment due to hydropower dams, competition with hatchery fish, and ongoing harvest are known as the "four Hs" impeding the recovery of these threatened and endangered species.[64] A spill from the CEI Hub will exacerbate these dynamics and potentially lead to a greater injury than would otherwise be observed in a non-threatened population.

Table 17 summarizes the threatened and endangered species that are present in the Lower Columbia River. The summer months have the highest returning populations, but species return throughout the year – meaning fuel releases from the CEI Hub could impact reproduction for these species no matter when the event occurs.

Table 17. Threatened and Endangered Species Present in the Lower Columbia River

Species	Federal Status	Freshwater Entry Period
Snake River Sockeye	Endangered	April to October
Snake River Chinook	Threatened	February to October
Lower Columbia River Chinook	Threatened	February to October
Upper Willamette River Chinook	Threatened	February to October
Upper Columbia River Chinook	Endangered	February to October
Columbia River chum salmon	Threatened	October to December
Upper Columbia River steelhead	Threatened	Year-round
Snake River Basin steelhead	Threatened	Year-round
Lower Columbia River steelhead	Threatened	Year-round
Upper Willamette River steelhead	Threatened	Year-round

[63] Rice, S. D., Thomas, R. E., Carls, M. G., Heintz, R. A., Wertheimer, A. C., Murphy, M. L., ... & Moles, A. (2001). Impacts to pink salmon following the Exxon Valdez oil spill: persistence, toxicity, sensitivity, and controversy. *Reviews in Fisheries Science*, *9*(3), 165-211.

[64] Hoekstra, J. M., Bartz, K. K., Ruckelshaus, M. H., Moslemi, J. M., & Harms, T. K. (2007). Quantitative threat analysis for management of an imperiled species: Chinook salmon (Oncorhynchus tshawytscha). *Ecological Applications*, *17*(7), 2061-2073.

Species	Federal Status	Freshwater Entry Period
Middle Columbia River steelhead	Threatened	Year-round
Pacific Eulachon/Smelt	Threatened	December to May
Bull Trout	Threatened	Not Anadromous
Pacific Lamprey	None (State Species of Concern)	Parasitic (varies by host)

Source: Oregon Department of Fish and Wildlife, Threatened, Endangered, and Candidate Fish and Wildlife Species, available at: https://www.dfw.state.or.us/wildlife/diversity/species/threatened_endangered_candidate_list.asp

Early studies have estimated that the total cost of salmon recovery in the lower Columbia River is $1.6 billion (in 2021 dollars), yet only approximately 22 percent of these costs have been fully funded.[65,66] While an estimate of the restoration costs of an aquatic injury are complex and very scenario-dependent, they may require sufficient funding of upwards of $1.2 billion to minimally place fish in the lower Columbia River on a recovery trajectory, with a likelihood that the assessed restoration costs for just the impacts from the spill would be much lower. Surveys in Oregon and beyond suggest that households are willing to pay up to $179 per year for recovery of salmon populations (2019 dollars).[67]

In past spills in riverine environments, aquatic restoration amounted to 3 percent of the cost of habitat and bird restoration. These estimated based on prior spills suggests a habitat injury restoration cost of $580,000 to $4.5 million, with a median value of $2.5 million (Table 18). Fuel releases are less common in the Pacific Northwest, meaning that there are fewer empirical examples of the effect of large-scale fuel releases on native fish populations in this location. The actual costs are likely to be closer to the higher end of the range of the restoration costs due to the importance of aquatic species to the riverine ecosystems of the Columbia River and Willamette River.

Table 18. Estimated Aquatic Injury Habitat Restoration Costs

Restoration	Total Cost		Median Cost
	Summer	Winter	
Aquatic Injury (3% of habitat restoration)	$587,912	$4,497,248	$2,542,580

Source: Enduring Econometrics

[65] Dennis Canty, Funding for Salmon Recovery in Washington State, Evergreen Funding Consultants, Olympia WA, March 2011, p. 6, https://rco.wa.gov/wp-content/uploads/2019/07/GSRO-SalmonRecoveryFundingEvergreen-2011.pdf. Accessed on 11/29/21.

[66] Washington State RCO (2020). State of Salmon in Watersheds in 2020. https://stateofsalmon.wa.gov/statewide-data/funding/. Accessed on 11/29/21.

[67] Lewis, D.J., Dundas, S.J., Kling, D.M., Lew, D.K., and Hacker, S.D. 2019. The non-market benefits of early and partial gains in managing threatened salmon. *PLoS ONE* 14(8): e0220260. https://doi.org/10.1371/journal.pone.0220260

2-8.5 Marine Mammal Injury and Restoration

Many marine mammals spend time in the lower Columbia River, including summer populations of approximately 1,100 California sea lions and 90 Stellar sea lions; and a year-round population of harbor seals that exceeds 1,800 animals.[68] While adult marine mammals rarely exhibit direct mortality from oil spills, they do exhibit serious health effects that cause an increased risk of death from disease, as well as loss of reproductive success following exposure to oil. Following the Deepwater Horizon Oil Spill, dolphins living in areas with higher concentrations of oil were more likely to exhibit hypoadrenocorticism, moderate to severe lung disease, and higher rates of early fetal loss and late-term abortions.[69]

Conversely, however, many marine mammals in the lower Columbia River are considered a nuisance species due to their predation of threatened and endangered salmonids. The Endangered Salmon Prevention and Predation Act of 2018 amended the Marine Mammal Protection Act (MMPA) to allow the removal of up to 540 California sea lion and 176 Steller sea lions between 2020 and 2025.[70] This population control measure is a direct response to the already depleted salmon populations. Thus, following an oil spill, it is unlikely that restoration will be conducted to enhance marine mammal populations that are already considered to be at nuisance levels. However, the amendments to the MMPA do not authorize other types of mortality to sea lions in the Lower Columbia, and any mortality due to an oil spill would still be a compensable injury. One possibility for compensating for the unpermitted take of marine mammals could be supplemental funding for salmonid restoration.

2-8.6 Restoration Costs

Scaling approaches used allow all habitat and resource injuries to be compensated through additional wetland restoration. These restoration costs can vary wildly by the type of restoration action, the availability of suitable acreage, and regional cost differences. Recent projects in the lower Columbia River range from $31,500 to $151,600 per acre.[71,72] Large restoration projects performed as compensation for an oil spill would likely land at the upper end of this range due to the scarcity of available restoration sites and expansive monitoring and

[68] NOAA ESI Maps and Data. https://www.fisheries.noaa.gov/inport/item/40258. Accessed 11/19/21.

[69] Lane, S. M., Smith, C. R., Mitchell, J., Balmer, B. C., Barry, K. P., McDonald, T., ... & Schwacke, L. H. (2015). Reproductive outcome and survival of common bottlenose dolphins sampled in Barataria Bay, Louisiana, USA, following the Deepwater Horizon oil spill. Proceedings of the Royal Society B: Biological Sciences, 282(1818), 20151944.; Schwacke, L. H., Smith, C. R., Townsend, F. I., Wells, R. S., Hart, L. B., Balmer, B. C., ... & Rowles, T. K. (2014). Health of common bottlenose dolphins (Tursiops truncatus) in Barataria Bay, Louisiana, following the Deepwater Horizon oil spill. Environmental science & technology, 48(1), 93-103.

[70] National Marine Fisheries Service (2020). https://www.fisheries.noaa.gov/feature-story/noaa-fisheries-authorizes-states-and-tribes-remove-sea-lions-preying-protected-fish. Accessed 11/19/21.

[71] NOAA Restoration Center Community-based Restoration Program (2006). "Ramsey Wetland Complex Off-channel Habitat Design and Restoration."

[72] Crest (2020). Otter Point Restoration and Enhancement Project. LCREP Grant #03-2011.

adaptive management requirements. The expected total costs for habitat restoration are $39.7 million should the spill occur in the summer, and $304.3 million if it occurs in the winter.

Table 19. Estimated Habitat Restoration Costs

Restoration	Acres Required		Average Cost per Acre	Total Cost	
	Summer	Winter		Summer	Winter
Habitat Injury	175	418	$91,575	$16,025,625	$38,278,350
Avian Injury	39	1,219	$91,575	$3,571,425	$111,629,925
Total Habitat Restoration				$19,597,050	$149,908,275
Aquatic Injury (3% of habitat restoration)				$587,912	$4,497,248
Marine Mammal Injury				Included in Aquatic Restoration	
Total Restoration Costs				**$39,782,012**	**$304,313,798**

Source: Enduring Econometrics

2-8.7 NRDA Assessment Costs

In addition to the restoration required as compensation, the Oil Pollution Act of 1990 requires responsible parties to pay Trustee assessment costs while also paying for their own consultants, attorneys, and contractors to navigate the NRDA process and implement restoration. As a share of total expenditure by PRPs, these assessment costs can be substantial. Following 1996 T/V Julie N oil spill in Portland, Maine, total costs of designing, implementing, and managing restoration amounted to $1.8 million, while assessment costs totaled $2.4 million (a multiplier of 1.2).[73] Including assessment costs and restoration costs, total damages from injury to habitats and natural resources are expected to range between $87 million in the summer to $669 million in the winter.

Table 20. Total Habitat and Resource Restoration and Assessment Costs

Category	Total Cost	
	Summer	Winter
Total Restoration Costs	$39,782,012	$304,313,798
Expected Assessment Costs	$47,738,413	$365,176,557
Total Habitat and Resource Damages	**$87,520,425**	**$669,490,356**

Source: Enduring Econometrics

2-9 Response and Cleanup Costs

While the total NRDA costs are substantial, they only play a minor burden in the ultimate expenditure by responsible parties following an oil spill. Although sizable, past evaluations of

[73] Mauseth, G. S., & Csulak, F. G. (2003). Damage Assessment and Restoration Following the JULIE N Oil Spill: A Case Study. In *International Oil Spill conference* (Vol. 2003, No. 1, pp. 409-412). American Petroleum Institute.

oil spill response and NRDAs have estimated these total costs to amount to only 26 percent of the total known costs of an oil spill.[74] Other costs include penalties, third-party damages, and response and cleanup costs. This section focuses on the expected costs of responding to the spill, including the costs of cleaning up the oil using best practices to minimize harm to the environment.

There are many factors that affect the cost of responding to an oil spill. Magnitude of the spill, geography, type of oil, and the time of year all affect costs.[75] The concurrent effects of a CSZ event and the oil spill will severely limit agencies and companies from responding to an oil spill in a way they might in any other state of the world. Thus, these costs should be inferred as a substantial lower bound that do not take into account the broader response efforts expected in the days and weeks following the earthquake.

The amount of fuel spilled has a non-linear effect on cleanup costs. Larger spills are more logistically complex and may require additional technologies and resources that are not regionally available.[76] In addition to volume, the length of the shoreline oiled also has a dramatic, non-linear effect on cleanup costs for the same reasons.[77]

Aside from volume and linear shoreline, the type of oil spilled is a substantial determinant of cleanup costs. Lighter oils are easier to remove from the water; however, they produce significant health and safety hazards for response workers. On the other hand, heavier oils, while less volatile, are more persistent and produce a greater physical challenge for cleanup efforts. Combined, however, cleanup costs for lighter oils tend to be lower.[78]

Empirically analyses have evaluated past spills by volume and shoreline extent of oiling to determine a per-gallon cost of fuel spilled.[79] Applying those estimates to the projected oil-in-water estimate from the CEI Hub results in a range of costs that vary between $109 million to $1.4 billion, depending on the methodology applied (Table 21). The value of costs for fuel releases at the CEI Hub will likely be between these values because less booming/staging would be needed than for an open-water spill, but extensive shoreline treatment will still be required. The higher proportion of light fuels – compared to the heavier fuels that cause more oiling of shorelines – could result in lower levels of clean-up costs compared to the $16.60 per gallon.

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[74] Helton, D., & Penn, T. (1999). Putting response and natural resource damage costs in perspective. In *International Oil Spill Conference* (Vol. 1999, No. 1, pp. 577-583). American Petroleum Institute.
[75] Etkin, D. S. (1999). Estimating cleanup costs for oil spills. In *International oil spill conference* (Vol. 1999, No. 1, pp. 35-39). American Petroleum Institute.
[76] Montewka, J., Weckström, M., & Kujala, P. (2013). A probabilistic model estimating oil spill cleanup costs–a case study for the Gulf of Finland. *Marine pollution bulletin*, *76*(1-2), 61-71.
[77] Etkin, D. S. (2000). Worldwide analysis of marine oil spill cleanup cost factors. In *Arctic and marine oilspill program technical seminar* (Vol. 1, pp. 161-174). Environment Canada; 1999.
[78] Moller, T. H., Parker, H. D., & Nichols, J. A. (1987). Comparative costs of oil spill cleanup techniques. In *International Oil Spill Conference* (Vol. 1987, No. 1, pp. 123-127). American Petroleum Institute.
[79] Moller, T. H., Parker, H. D., & Nichols, J. A. (1987). Comparative costs of oil spill cleanup techniques. In *International Oil Spill Conference* (Vol. 1987, No. 1, pp. 123-127). American Petroleum Institute.

These cleanup costs are in addition to all aforementioned costs in the prior sections for impacts to habitats.

Table 21. Expected Range of Response and Cleanup Costs

		Volume Estimate		Total Response Cost	
Source of Cost Estimate	**Cost per Gallon**	**Low**	**High**	**Low**	**High**
All Large Marine Spills	$2.67	40,751,753	82,503,352	$108,807,181	$ 220,283,950
Marine Spills with Similar Shoreline Oiling Extent	$16.60	40,751,753	82,503,352	$676,479,100	$1,369,555,643

Source: Enduring Econometrics

2-10 Impacts to Cultural Values

Traditional monetary measures of economic importance are inappropriate to describe the value of cultural and tribal use of natural resources that could be impacted by fuel releases from the CEI Hub. Monetization implies substitutability (i.e., that monetary compensation at some level can make whole the loss of the service, because equivalent services may be purchased). Given that many, if not all, cultural services are defined by place, tradition, and continuity of use and practice, no alternative resource could provide a sufficient substitute for the resources in question. Because of the uncertainty, complexity, and inadequacy involved with identifying a monetary measure for cultural values, they are not monetized or quantified – but should be considered to have significant economic value and importance.

Federally recognized tribes do have Trustee authority to claim losses to cultural values, and several NRDA settlements include restoration projects to specifically address these injuries, separate from those designed to compensate for losses to habitats and resources. The federally recognized tribes that rely on the resources of the Willamette River and Columbia River include the:

- Confederated Tribes of the Warm Springs Reservation of Oregon,
- Confederated Tribes and Bands of the Yakama Nation,
- Nez Perce Tribe,
- Confederated Tribes of the Umatilla Indian Reservation,
- Confederated Tribes of Grand Ronde, and
- Confederated Tribes of Siletz.

2-11 Cost of Impacts to Fuel Prices

An indirect effect of fuel releases at the CEI Hub is a loss of the primary liquid fuel supply source for Oregon. The CEI Hub stores approximately 90 percent of Oregon's liquid fuel

supply, including all of the jet fuel for the Portland International Airport and the gasoline and diesel for the Portland metropolitan region. The loss of the fuel supply would occur at the same time as other impacts from the Cascadia earthquake. As a result, pipelines, roads, tankers, barges, and other infrastructure would be impeded from delivering more fuel to the region. Because of the impacts to roads and transportation infrastructure, there will be less transportation, suggesting less demand for fuel. Fuel shortages caused by CEI Hub fuel releases will also result in delays and shortages for earthquake recovery efforts.

There will be fuel shortages after the fuel supply at the airport and commercial fueling stations is depleted. Much of Oregon will likely run out of gasoline and diesel within 1 week (based on the average six-day delivery cycle for pipeline transfers to the CEI Hub).[80] The Portland International Airport requires approximately 500,000 gallons of jet fuel per day and has limited storage on site.[81] The airport will likely run out of jet fuel in 1 to 2 days if pipeline deliveries stop due to damage or fuel releases. Truck capacities for jet fuel are only 10,000 gallons maximum, which would not be sufficient to replace the pipeline supply. Natural gas stored at the CEI Hub is used to address peak winter fuel demand – so there will potentially be higher natural gas costs if the CSZ earthquake occurs when demand for natural gas is high.[82]

The resulting shortage of fuel supply will likely result in price increases. While these price increases will be a response to increased scarcity, these changes tend to be "sticky" and relatively slow to respond, thus leading to shortages of fuel. Additional fuel will likely need to arrive by road or barge. Due to earthquake damage to transportation infrastructure, it will likely not be possible in the short-term to deliver fuel supplies to the Portland area or the Oregon coast. Areas of Oregon that are able to access alternative fuel supplies will experience higher fuel costs due to the costs of transportation and reduction in supply.

The disruption of the fuel supply will impose direct costs on all businesses that are reliant on commercial transportation. Some of these businesses will already be harmed by the effects of the earthquake because the roads are inaccessible for transportation. Other businesses will incur costs if their goods are not able to be delivered to them or if their products are not able to be distributed to their customers. Other business activities that are reliant on liquid fuel, such as manufacturing machines, may not be able to operate while the fuel shortage occurs.

[80] Wang, Y., Bartlett, S.F., Miles, S.B. (2012). *Earthquake Risk Study for Oregon's CEI Hub. Prepared for Oregon Department of Geology and Mineral Industries (DOGAMI)*.

[81] Port of Portland. (2014). *Regular Commission Meeting Agenda*. January 8. Available at: http://cdn.portofportland.com/pdfs/Jan14_AG_Fin.pdf

[82] Only a maximum 10 percent of the supply from the natural gas tank at NW Natural is expected to be released. However, connection failures and other impacts from the earthquake could impede natural gas delivery to customers.

2-11.1 Price Effects

Although no perfect comparisons exist for the specific case of the Cascadia Subduction Zone Earthquake oil spills from the CEI Hub, several similar large-scale protracted supply shocks offer a good comparison for understanding the potential impact on fuel prices and fuel-dependent business activity.

The 2011 Great East Japan Earthquake caused fuel supply to be shut off to 1.66 million households in three prefectures of the Tohoku region in northern Japan for nearly six weeks.[83] After early periods of fuel buying following the earthquake, demand dropped by 30 percent after the earthquake. However, supply shutdowns due to earthquake damage in the Tohoku region (accounting for about a 30 percent drop in crude oil processed in the month after the earthquake) led to an overall jump in prices following the earthquake of about 1.1 to 3 yen per liter (about 4 to 12 cents per gallon in USD). The impacts of fuel shortages were alleviated by importing oil tank trucks from other regions to aid with long-distance oil transportation. This, coupled with the easing of regulatory restrictions by the government (such as lowering stockpiling requirements and promoting sharing of resources) allowed the supply and prices to rebound to pre-earthquake levels within about 3 months after the disaster.

2-11.1.1 Retail Gasoline Price Effects of Shutoff

The Colonial Pipeline, which provides refined petroleum products for nearly half of the eastern U.S., was forced to shut off service between May 7 and May 12, 2021, due to security and privacy concerns from a ransomware attack.[84] A gasoline shortage ensued across the mid- and lower-Atlantic, with rising prices seen throughout the pipeline's service area between New Jersey and Houston. Because the shortage was uncorrelated to other economic indicators, it provides a useful case study in the price and consumer effects of a pipeline failure. The analysis that follows uses the Colonial Pipeline shortage as a case study on the effects of a pipeline failure on fuel prices and consumer demand for gasoline.

Many East Coast states experienced acute price jumps in gasoline in the week or and week following the Colonial Pipeline service outage. Figure 5 shows data from Gas Buddy, a fuel price tracking app that publishes daily price data at the state- and metro-level for retail gasoline. Prices in Virginia and North Carolina jumped by about 7.5 percent, or 20 cents per gallon, between May 7, when the shutoff began, and May 16, when prices peaked following the shortage.[85] Oregon prices, which were unaffected by the shortage, are shown for reference.

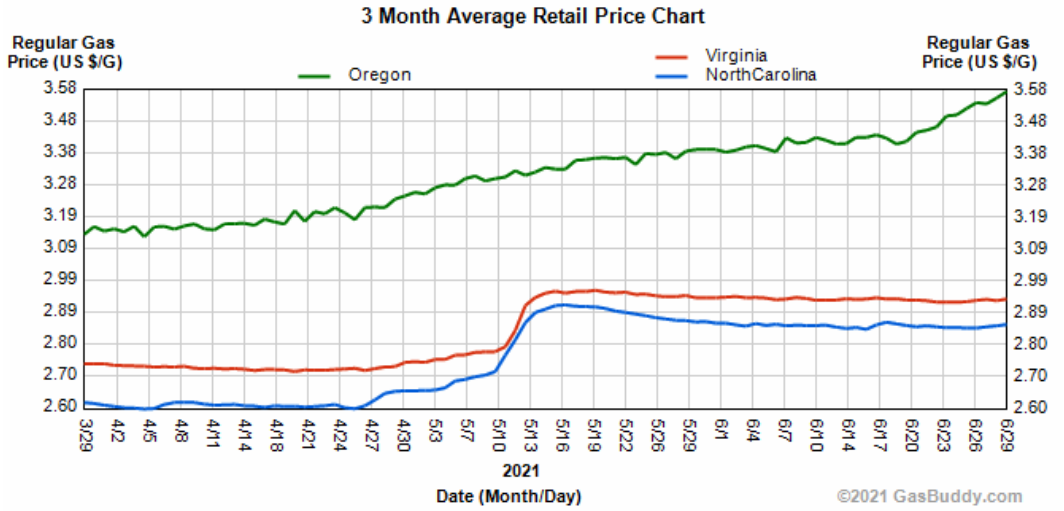
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[83] Asia-Pacific Energy Research Center. (2015). *The Impact on Oil Distribution by the Great East Japan Earthquake, and future issues and countermeasures.*

[84] Hall, M. (2021). "The Colonial Pipeline is back up, but gas shortages have gotten worse and it'll take time to make up the shortfall". *Business Insider*. Available at: https://www.businessinsider.com/when-will-colonial-pipeline-gas-shortages-end-2021-5

[85] GasBuddy, *18 Month Average Retail Price Chart*, available at: https://www.gasbuddy.com/charts

Figure 5: Retail Gasoline Prices in VA, NC, and OR: April to June 2021



Source: GasBuddy, *18 Month Average Retail Price Chart*, available at: https://www.gasbuddy.com/charts

Data from the Energy Information Administration (EIA), which is reported weekly at the regional level, shows a similar trend across the Atlantic Region (which includes all East Coast states between Maine and Florida). Gas prices rose 8.6 and 16.1 cents per gallon in the region during the week of and week following the service shutoff, or a 5.6 percent net jump in prices[86] (Figure 5). During the last 10 years in this period, the average price change in the same period of May has been -0.2 percent, suggesting that all of this price increase is likely attributable to the service shortage.

The Colonial Pipeline shutoff had a differential effect on gas prices in states based on their reliance on the pipeline for their total fuel supply. The pipeline provides refined petroleum products to 45 percent of the East Coast US, but across states there is a large variation in the overall dependence on the pipeline for gasoline supply. Across much of the lower Atlantic, for example, over 70 percent of the supply of liquid fuel comes from the pipeline, while in Mississippi and the North Atlantic, less than 30 percent of gasoline is supplied by the pipeline Table 22. Factors such as the presence of port cities to receive fuel shipments and abundance of refineries in each state affects their overall dependence on the Colonial Pipeline for supply. The Plantation Pipeline, which runs parallel with much of the Colonial Pipeline, supports a smaller portion of the petroleum supply in each state.

The gulf coast states of Mississippi, Alabama and Georgia have a low, medium, and high level of reliance on the pipeline, respectively, and each experienced different gas price effects (Table 22). As shown in Figure 5, the higher reliance on the pipeline for gasoline supply was associated with a greater rise in gas prices. Although other factors may have contributed to this relationship, it suggests that states with a greater diversification of fuel supply sources may

[86] U.S. Energy Information Administration, *Gasoline and Diesel Fuel Update*, available at: https://www.eia.gov/petroleum/gasdiesel/

have been better able to maintain supply and avoid greater price surges during the pipeline shutoff.

Table 22: Gasoline Prices in Gulf Coast States During Colonial Pipeline Shutoff

State	Proportion of Liquid Fuel Provided by Colonial Pipeline	May 5 ($/gal)	May 8 ($/gal)	May 11 ($/gal)	May 14 ($/gal)	Total 11-day Price Increase ($)
Mississippi	Less than 30%	$2.57	$2.59	$2.64	$2.71	$0.14
Alabama	Between 30% and 70%	$2.65	$2.68	$2.73	$2.84	$0.19
Georgia	Over 70%	$2.69	$2.72	$2.85	$2.92	$0.23

Source: GasBuddy and Colonial Pipeline

2-11.1.2 Market Implications of Pipeline Shutoff

Although primarily a supply-side phenomenon, the price effects were driven both by the reduced supply and increased demand for gasoline over concerns of a long-term shortage. According to data from GasBuddy, demand rose by 1.5 percent on the East Coast after the shutoff[87].

The shutoff likely had other implications. The shutoff led to gas station outages in fifteen states and the District of Columbia during the weeks following the shutoff. Up to 88 percent of gas stations in DC had fuel outages at the height of the shortage, according to tracking by GasBuddy[88]. These outages, as well as long lines waiting for gasoline driven by jumps in demand, led to lost wages and productivity for those waiting to buy gas or those unable to fuel commuter vehicles. Additionally, some airlines altered their flight paths and were forced to find alternative sources of fuel[89]. The temporary high costs of fuel, gas outages, and effects on fuel-dependent sectors of the economy also likely had ripple effects on supporting industries.

2-11.1.3 Summary of Economic Effects of Colonial Pipeline Service Outage

In summary, a brief pipeline outage led to a prolonged two-week shortage of retail gasoline in the East Coast US, due to a supply crunch and the resultant panic-buying. This outage drove a roughly 16 cent increase in East Coast gasoline prices, with price jumps increases exceeding 20 cents per gallon in some states. This led to an estimated $35 million in surplus prices paid by retail gasoline consumers on the East Coast over two weeks and may have imposed additional economic losses on workers, transportation industries and other fuel-dependent sectors. States

[87] GasBuddy. (2021). *National Average Sees Big Jump Thanks to Colonial Outage*. Available at: https://www.gasbuddy.com/go/national-average-sees-big-jump-thanks-to-colonial-outage

[88] GasBuddy. (2021). *Colonial Pipeline Shutdown: Fuel Outages by State*. Available at: https://www.gasbuddy.com/go/colonial-pipeline-shutdown-fuel-outages-by-state

[89] Krauss, C., Chokshi, N., and Sanger, D.E. (2021). "Gas Pipeline Hack Leads to Panic Buying in the Southeast". *The New York Times*. May 12. Available at: https://www.nytimes.com/2021/05/11/business/colonial-pipeline-shutdown-latest-news.html

that were less reliant on the pipeline for their fuel supply may have experienced less of a price drop in response to the shutoff.

2-11.1.4 Estimating the Fuel Price and Consumption Effects in CEI Hub

The Oregon Department of Environmental Quality reported that about 1.738 million gallons of gasoline and 789.1 million gallons of diesel were consumed in Oregon in 2019. Given the nature of the projected fuel shutoff from a CEI Hub disaster, it is estimated that two primary forces will impose a cost for gasoline users. First, the loss of fuel will result in a temporary loss in ability to consume gasoline, particularly in any portions facing severe infrastructure damage. These losses will primarily be faced by residents in the Portland metro area. Second, the loss of fuel supply for the rest of the state will force other cities to meet fuel demand through importing from more costly sources. This means the rest of the state is likely to face higher prices of gasoline during the period of supply adjustment or potentially the entire duration that the CEI Hub is offline. These two portions of the total economic cost are quantified here.

First, the period of near total shutdown of fuel supply in the hardest-hit areas of Portland is expected to last anywhere from several days to weeks or even months. Conservatively assuming a loss of three days' worth of fuel supply to Portland, this translates to about 2.2 million gallons of lost gasoline consumption and 895,000 gallons of diesel consumption. Since the price of gasoline reflects the level of benefits people receive from its use, the value of the lost gasoline consumption reflects a lower boundary on the direct economic costs of the shutoff. At average current fuel prices in Oregon, this cost would be about $11.7 million (Table 23).

Table 23: Value of Lost Fuel Consumption in Portland Following Spill

Fuel Type	Price per Gal	Lost Consumption in Portland Over 3 Days (gal)	Value of Lost Consumption
Gasoline	$3.80	2,183,000	$8,297,000
Diesel	$3.80	895,000	$3,400,000
Total	$3.80	3,078,000	$11,697,000

Source: Created by ECONorthwest using gas price data from American Automobile Association, available at https://gasprices.aaa.com/?state=OR, and 2021 Clean Fuels Forecast by the Oregon Office of Economic Analysis and Oregon Department of Environmental Quality, available at: https://www.oregon.gov/deq/ghgp/Documents/cfp-Forecast2021.pdf.

Second, the fuel price effects are likely to be seen statewide as demand is met from more costly sources. Given the length of time for prices to adjust after the Japan earthquake and the Colonial Pipeline shutoff, it is likely that consumers across the state would face higher prices for the duration of time the CEI Hub is offline. The price increases seen in Georgia, which was over 70 percent dependent on the Colonial Pipeline for fuel supply, during the May 2021 shutoff were about $0.23 per gallon, with prices remaining high even after the pipeline returned back to service. With average daily statewide gasoline consumption of 4.8 million gallons of gasoline and 1.95 million gallons of diesel, assuming only a temporary drop in demand, this means the total economic cost to consumers of the higher fuel prices may be between $18.8 million (for a

two-week duration as during the Colonial Pipeline shutoff) and $120.8 million (for a three-week duration as during the Great Japan Earthquake) (Table 24).

Table 24: Fuel Price Effects of CEI Hub Supply Interruption

Fuel Type	Assumed Increase in Fuel Price	*Two-Week Interruption*		*Three Month Interruption*	
		Statewide Fuel Consumption	Cost of increased prices to consumers (assuming highly inelastic demand)	Statewide Fuel Consumption	Cost of increased prices to consumers (assuming highly inelastic demand)
Gasoline	$0.20	66,663,000	$13,333,000	428,548,000	$85,710,000
Diesel	$0.20	27,317,000	$5,463,000	175,611,000	$35,122,000
Total	$0.20	93,980,000	$18,796,000	604,159,000	$120,832,000

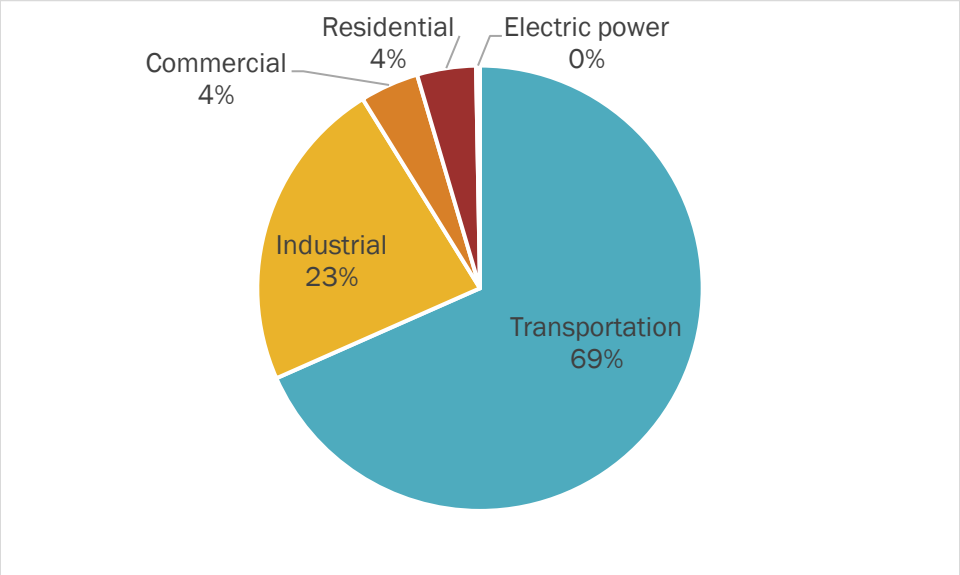
Source: ECONorthwest analysis of data from GasBuddy for states impacted by the Colonial Pipeline Shutoff and the 2021 Clean Fuels Forecast by the Oregon Office of Economic Analysis and Oregon Department of Environmental Quality, available at: https://www.oregon.gov/deq/ghgp/Documents/cfp-Forecast2021.pdf.

These costs do not include any costs caused by an inability to perform earthquake recovery efforts due to fuel shortages. To the extent that fuel scarcity impedes emergency response activities, there will be financial and non-financial costs, including injury and loss of life.

2-11.2 Business Responses

The direct effect of lost fuel supply would mean fuel-dependent businesses would likely face a temporary halt in operations until a replacement fuel source became widely available. Based on data collected by the Energy Information Administration, the transportation sector is the largest consumer of petroleum fuel (24 quadrillion btu annually in the U.S.), compared to about 8 quadrillion btu by the industrial sector and less than 2 btu for the commercial and residential sectors (Figure 6).

Figure 6. Petroleum Consumption by Sector, U.S. Total



Source: Created by ECONorthwest using data from the U.S. Energy Information Administration, *Gasoline and Diesel Fuel Update*, available at: https://www.eia.gov/petroleum/gasdiesel/

Although the transportation sector is most directly reliant on petroleum fuel, the commercial, retail and manufacturing sectors all rely on the transportation sector, in addition to many of the crucial emergency response activities. Because it is difficult to project infrastructure damage, it is uncertain how much the transportation sector and businesses that depend on transportation infrastructure to operate will be impacted. However, the Oregon Resilience Plan identifies transportation as a key sector to ensure an efficient and effective response to a Cascadia earthquake[90]. Fuel may be prioritized through directing initial resources to fuel depots for emergency and critical transportation use.

Fuel shortages, or higher-priced fuel, are both likely to compound the structural damages caused by the earthquake. About 80 percent of buildings in the Portland metro area are projected to suffer damage from the earthquake according to FEMA[91]. Since many retail and commercial businesses rely on electricity from non-petroleum fuel sources, these sectors would likely suffer more indirectly from supply chain disruptions or added costs from shipping and moving of intermediate and final goods.

[90] Oregon Seismic Safety Policy Advisory Commission (OSSPAC). (2013). *The Oregon Resilience Plan*. February. Available at: https://www.oregon.gov/oem/documents/oregon_resilience_plan_final.pdf

[91] U.S. Department of Homeland Security. (2011). *National Infrastructure Simulation and Analysis Center Homeland Infrastructure Threat and Risk Analysis Center Office of Infrastructure Protection National Protection and Programs Directorate.* November 18. Available at: https://www.bluestonehockley.com/wp-content/uploads/2016/01/FEMA-earthquake-study.pdf

2-11.3 Non-Commercial Costs

The fuel shortage will also impact households through disrupting the ability to commute to work, access childcare, or necessary services. Such costs may exacerbate existing inequities in access to work and essential goods and services. For example, a 2008 report found that working poor individuals spend a substantially higher portion of income on commuting—8.4 percent of total income for the working poor who drive to work compared to only 3.8 percent for other workers.[92] This means that added fuel costs are likely to hit low-income workers particularly hard. These fuel shortages will also complicate the ability for individuals to evacuate, add to prices at grocery stores, and constrain leisure travel.

[92] Puentes, R., and Roberto, E. (2008). *Commuting to Opportunity: The Working Poor and Commuting in the United States.* Available at: https://www.brookings.edu/research/commuting-to-opportunity-the-working-poor-and-commuting-in-the-united-states/

2-12 Summary of Costs

The costs of fuel releases from the CEI Hub are from a variety of sources including both direct physical impacts, fuel market impacts, cleanup, and losses in economic value. Not all costs are able to be monetized due to lack of data, uncertainty, confounding variables caused by the earthquake, and/or difficulty valuing the resource. The costs are based upon a multitude of assumptions and scenarios about the type and magnitude of fuel releases, emergency response actions and timelines, and natural phenomenon like air, water, and fire dispersion. Table 25 summarizes the range of values for each category of costs. In addition to these values there could be other costs associated with rebuilding and repairing of fossil fuel infrastructure at the CEI Hub, if that occurs, such as environmental impact studies, infrastructure recertification, infrastructure abandonment, and other operational costs.

The minimum costs to society of potential fuel releases at the CEI Hub range from **$359 million to $2.6 billion.** Because not all costs were monetized, this range of costs represents only a portion of the total costs likely to be imposed on society from fuel releases from the CEI Hub. The social costs do not include fines, penalties, lost revenue, or equipment replacement costs borne by the CEI Hub operators. Prior large oil spills demonstrate the large costs to both society as well as the operating companies imposed by oil spill events. For example, Deepwater Horizon resulted in a total cost to BP of $61.6 billion for all penalties, claims, and liabilities.[93] Although the fuel releases at CEI Hub would be occurring under very different circumstances than Deepwater Horizon, the similar volume of releases suggests that there could be similar large costs to CEI Hub operators. The subsequent chapter discusses if and how costs to society would be reimbursed through the existing claims processes.

Table 25. Summary of Costs of Fuel Releases from the CEI Hub due to a Cascadia Earthquake

Category of Costs	Summary of Costs	Range of Monetized Costs for the Modelled Scenario
Direct Impacts to People	Assuming an explosion occurs, between 0 to 7 people could be killed and 2 to 80 people could be injured. The range of costs for mortality and morbidity are between $49,000 to $74.1 million, with an average cost of $37.1 million.	$49,000 to $74.1 million
Impacts to Property	Assuming fuels in the water travel downstream to the Longview Bridge, the potential impact on residential properties values is up to $35.4 million. There is $2.5 billion in total riverfront property value in the downstream area.	$11.8 million to $35.4 million
Impacts to Navigation	A one-week closure of the shipping channel between the I-405 bridge and Longview Bridge would result in additional operating costs for commercial vessels of between $11.8 million and $17.8 million.	$11.8 million and $17.8 million

[93] NOAA, *Deepwater Horizon oil spill settlements: Where the money went*, Available at: https://www.noaa.gov/explainers/deepwater-horizon-oil-spill-settlements-where-money-went

Category of Costs	Summary of Costs	Range of Monetized Costs for the Modelled Scenario
Impacts to Fisheries	To the extent that fuel releases reduce reproduction or cause direct mortality to aquatic species there will be a reduction in income to the fishing industry, impacting owners, employees, and suppliers who rely on these funds. Increases in hatchery production would likely be needed, which would result in additional costs.	Not Monetized – Potential for significant mortality to commercial fisheries species and loss to commercial fishing entities
Impacts to Recreation	Average per-trip values of recreation for participants (i.e., consumer surplus) are between $68 to $130 per person per day. Recreationalists contribute spending to local economies at an average value of between $98 to $478 per trip. Cancelled recreational trips due to fuel releases would reduce both value for the participant and economic activity for the businesses that rely on the recreational spending. A one-month closure of the Lower Columbia River and Lower Willamette River for salmonid fishing would result in a loss of consumer surplus of $3.4 million and a loss of $3.2 million in direct trip spending.	Not Monetized – Damage to recreational resources that cannot be easily rebuilt, such as fire damage to Forest Park, will result in long-term losses to recreation.
Impacts to Human Health	The health costs of exposure to toxins for nearby people and response workers is $121 million to $249 million for both acute and chronic conditions. The primary health costs are increased risk of heart attack, decreases in productivity, and lost workdays. Additional costs would be borne from evacuations and strains on emergency response services.	$121 million to $249 million – with potential for additional costs to mental health and non-documented physical health costs.
Impacts to Habitats and Species	Habitats and species would be harmed from fuel releases. The costs of habitat restoration as compensation for habitat injury would require between 175 and 418 acres of wetland to be restored. An additional 39 to 1,219 acres of constructed wetland could be needed to compensate for injuries to bird populations. There is also the potential for compensation needed for aquatic and mammal species that are injured by the event. The expected total costs for habitat restoration are $39.7 million in the summer and $304.3 million in the winter. Total damages from injury to habitats and natural resources and required compensation are expected to range between $87 million in the summer to $669 million in the winter.	$87 million to $669 million
Cleanup Costs	Cleanup costs are projected to be between $109 million to $1.4 billion.	$109 million to $1.4 billion
Impacts to Cultural Values	Fuel releases in the Willamette River and Columbia River would harm cultural resources that are of particular importance to Tribal populations for subsistence, transportation, commerce, and ceremonial purposes. Impacts to this area would perpetuate historical inequities to a water resource already contaminated as part of the Portland Harbor Superfund.	Not Monetized – Impacts to waterways and aquatic species like salmon would result in large cultural losses.
Impacts to Fuel Prices	Releases of fuel from the CEI Hub would reduce the supply of fuels needed for transportation and	$18.8 million to $120.8 million – with additional

Category of Costs	Summary of Costs	Range of Monetized Costs for the Modelled Scenario
	commercial activity in Oregon. The effects of the earthquake on transportation infrastructure will alter the demand for fuels. A lack of fuel could constrain emergency response activities. The total economic cost to consumers of the higher fuel prices and reduction is between $18.8 million and $120.8 million. The lost value of consumption from fuel scarcity would be $11.7 million for a three-day period.	costs from loss of consumption and delays in recovery efforts
Total Monetized Costs		**$359 million to $2.6 billion**

Chapter 3: Financial Responsibility for Damages Resulting from a Spill at the CEI Hub

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Prepared for:

Multnomah County Office of Sustainability

and City of Portland Bureau of Emergency Management

Prepared by:

Enduring Econometrics

ECONorthwest
ECONOMICS · FINANCE · PLANNING

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3-1 Introduction

Each of the categories of damages that result from a spill at the CEI Hub occur directly to individuals and businesses.[1] The existing legal frameworks at the state and federal levels are designed to transfer the financial responsibility of those damages to liable parties. While the ultimate determination of liability and potential misconduct that will contribute to the spill at the CEI Hub during a CSZ event is a legal question, the initial incidence of economic harm is relatively unambiguous. Workers who are killed, residents who must evacuate, and citizens nationwide that value the ecological resources of the Lower Columbia River all bear the initial costs of a failure to prevent or contain a spill at the CEI Hub. The ability for those harmed to recover those damages will be laid at the hands of a legal process that will undoubtedly take many years to resolve and may compensate individuals inequitably.

This chapter of the report details the incidence for each category of economic damages, describes some of the legal mechanisms to transfer damages to liable parties, and discusses some of the potential transaction costs and sources of inefficiency that may occur as a result of the spill.

As described in Chapter 2 for calculating damages, the values of damages described herein are expected values net of the greater harms that would be caused by the CSZ earthquake. In other words, the damages and associated liabilities represent those that are attributable to the CEI Hub and could be preventable if actions are taken to reduce the risk of fuel releases.

3-2 Legal Mechanisms to Transfer Damages

Response to fuel releases in navigable waters of the United States are managed by a designated Federal On-Scene Coordinator and governed by Lower Columbia River response plans developed under the Oil Pollution Act of 1990. State and local governments would also participate in the response, while residents in the are would endure economic harm from evacuation, air pollution, and reduction in property values.

3-2.1 Oil Pollution Act

The Oil Pollution Act of 1990 (OPA), passed by Congress and signed into law in the wake of the Exxon Valdez oil spill, sets a framework for preventing oil spills along with a liability structure to recover damages.[2] The law carries with itself a pre-defined nomenclature, with companies who were transporting oil that spilled called "Responsible Parties" (RPs), any oil or hazardous substance designed to be burned to produce heat or power is called "fuel," and any discharge

[1] This economic analysis is based in an anthropocentric calculation of total economic value. Accordingly, damages incurred by individuals and businesses include economic harm as a result of injury to natural and cultural resources.

[2] 33 CRF 138.

or substantial threat of discharge into navigable waters or adjoining shoreline is called an "incident."[3]

OPA is primarily designed to prevent oil spills. Under this law, all areas of the U.S. (including the Columbia River) have oil spill contingency plans. Individual tank vessels and certain facilities (including those in the CEI Hub) have response plans that detail how to deal with a worst-case discharge or substantial threat of such a discharge. Additionally, OPA requires the staging of oil spill response and removal equipment.

Aside from aiming to prevent oil spills in the first place, OPA holds RPs liable for certain damages and clean-up costs from a spill. Specific categories of damages include:

- **Natural Resource Damages** – "injury to, destruction of, loss of, loss of use of, natural resources, including the reasonable costs of assessing the damages" is recoverable by federal, state, tribal, and foreign natural resource trustees.[4] Natural Resource Damage Assessment (NRDA) is the legal process that agencies use to evaluate the impacts of oil spills on public natural resources.
- **Real or Personal Property** – "injury to, or economic losses resulting from destruction of, real or personal property" is claimable by anyone who owns or leases affected property.[5]
- **Loss of Subsistence Use** – "loss of subsistence use of natural resources" is claimable by anyone who "uses natural resources which have been injured, destroyed, or lost."[6]
- **Lost Profits and Earning Capacity** – "loss of profits or impairment of earning capacity" is claimable by anyone with loss of profits or income.[7]
- **Loss of Government Revenues** – "net loss of taxes, royalties, rents fees, or net profit shares" are recoverable only by the federal government, states, and local governments.[8]
- **Increased Public Services** – the net cost of "increased or additional public services during or after removal activities, including protection from fire, safety, or health hazards" is claimable only by states and local governments.[9]

RPs are liable for removal costs and damages that are attributable to their release of oil. They are not responsible for damages that would have occurred regardless of the fuel releases. This distinction between what is attributable to the fuel releases and what is not is determined by establishing the baseline scenario and calculating damages that are in addition to that baseline. The baseline scenario is what would have occurred but for the CEI Hub fuel releases. In the case

[3] 33 CFR 138.20.

[4] 33 USC 2702(B2a).

[5] 33 USC 2702(B2b).

[6] 33 USC 2702(B2c).

[7] 33 USC 2702(B2e).

[8] 33 USC 2702(B2d).

[9] 33 USC 2702(B2f).

of CEI Hub fuel releases due to a CSZ earthquake, all damages caused by the earthquake are included in the baseline scenario, and therefore not the responsibility of the RPs. Establishing the specifics of the baseline scenario will be part of the legal process and likely subject to debate between injured and liable parties. The concept of baseline is critical importance in determining claims in the CSZ event and is likely to complicate the ability to determine the independent harms of the spill.

The baseline scenario will also determine what is covered by existing legal mechanisms and influence who is eligible to receive compensation. OPA is designed to cover only impacts that are net of the baseline scenario. For example, if impacts to navigation are part of the baseline scenario (i.e., they would have occurred regardless of the CEI Hub fuel releases due to other barriers in the rivers caused by the earthquakes) then the navigation operators might not be eligible to pursue claims under OPA. For these reasons the baseline scenario is critical for determining attribution of damages and what parties are eligible to use legal mechanism under OPA to recover damages.

OPA establishes liability limits for damages that vary by the type of facility. RPs at onshore facilities were originally liable for up to $350 million per spill in 1990. Liability limits are updated annually using the CPI-U, and currently, onshore facilities have liability limits of $672,514,900 per spill.[10, 11] While vessels are required to carry certificates of financial responsibility, onshore facilities are not. These liability limits can be waived if the discharge results from gross negligence or willful misconduct.[12]

Occasionally, oil spills cause damages that exceed the statutory liability limits established under OPA. For these situations, OPA established the Oil Spill Liability Trust Fund (OSLTF) managed by the U.S. Coast Guard's National Pollution Fund Center (NPFC). The OSLTF is primarily financed through a 9-cent per-barrel tax levied on refineries and importers/exporters of crude oil.[13] As of 2020, the OSLTF carries a balance of approximately $7.3 billion.[14] The OSLTF makes up to $50 million available per year to Federal On-Scene Coordinators to respond to spills and initiate NRDAs.[15] The remaining balance of the OSLTF is available to any person or entity that incurs removal costs or damages due to a spill.

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[10] 33 CFR 138.230.

[11] The liability limit applies to the responsible party of the onshore facility, which is defined as "any person owning or operating the facility" in 33 USC 2701 (32).

[12] 33 USC 2704(c).

[13] National Pollution Fund Center. About the OSLTF. https://www.uscg.mil/Mariners/National-Pollution-Funds-Center/about_npfc/osltf/. Accessed December 7, 2021.

[14] Department of Homeland Security (2020). Agency Financial Report for FY 2020. https://www.dhs.gov/sites/default/files/publications/dhs_agency_financial_report_fy2020_vol2.pdf. Accessed December 7, 2021.

[15] Department of Homeland Security (2006). Oil Spill Liability Trust Fund Funding for Oil Spills. https://www.uscg.mil/Portals/0/NPFC/docs/PDFs/OSLTF_Funding_for_Oil_Spills.pdf. Accessed December 7, 2021.

Any claims not paid by an RP can be submitted directly to the NPFC for payment from the OSLTF after 90 days. RPs are also able to recover certain costs incurred in their defense of claims. Specifically, this refers to costs associated with an "affirmation defense," where the RP is not the cause of the spill due to either an "act of God", "act of war", or a third party, or a "limit of liability defense," where the RP asserts that they have exceed their liability limits and they are recoverable from the OSLTF.[16]

Under OPA, the term "act of God" is defined as "an unanticipated grave natural disaster or other natural phenomenon of an exceptional, inevitable, and irresistible character the effects of which could not have been prevented or avoided by the exercise of due care or foresight".[17] If an earthquake is determined to be an "act of God" then the RPs would not have legal liability under OPA (claims would instead be paid from the OSLTF). However, there is precedence for natural disasters not to be considered an "act of God". Hurricane Ida was not defined as an "act of God" because a hurricane of that magnitude in that area was to be expected with some regularity.[18] A similar argument could be made for a CSZ earthquake, but the determination would be made through the legal process.

Additional punitive measures are also included in OPA, with civil penalties totaling either $32,500 per day or $1,100 per barrel spilled. Incidents that are a result of gross negligence or willful misconduct incurs penalties of up to $4,300 per barrel of oil discharged.[19] These penalties are generally deposited back into the OSLTF. There is no strict definition of when gross negligence occurs,[20] and this determination would likely be litigated to see if it applies to the RPs for fuel releases from the CEI Hub.

3-2.2 Oregon DEQ Oil Spill Preparedness Program

States are also permitted under OPA to establish funds to pay for costs or damages arising out of, or directly resulting from, oil pollution or the substantial threat of oil pollution.[21] ORS 468B.405 establishes fees on "covered vessels and offshore and onshore facilities to recover the costs of reviewing the plans and conducting the inspections, exercises, training activities" required for facility spill contingency plans. These fees total $15,000 to $20,000 per year for pipelines (depending on size), $20,000 per year for onshore facilities, and other fees for vessels

[16] National Pollution Fund Center. Oil Spill Claims. https://www.uscg.mil/Mariners/National-Pollution-Funds-Center/claims/. Accessed December 7, 2021.

[17] 33 USC 210(1)

[18] Henry, E.M., and Holden, R. (2021). Hurricane Ida and OPA's Acts of God. *The National Law Review.* September 16.

[19] U.S. Department of Justice, Environment and Natural Resource Division. Water. https://www.justice.gov/enrd/water. Accessed December 7, 2021.

[20] *Water Quality Insurance Syndicate v. United States of America*, Civil Action No. 15-789 (BAH), December 22, 2016.

[21] 33 USC 2718(b)

per trip. These fees go into the State Oil Spill Prevention Fund, which generates annual revenue of approximately $1 million per year.[22]

ORS 468B.455 established an Oil Spill Control Fund, which is financed through penalties recovered for violations related to the willful or negligent discharge of oil. The Oil Spill Control Fund can be used to cover costs incurred for cleanup activities, as well as reviewing contingency plans, conducting training, and restoration activities. While an important and necessary resource that supplements the OSLTF, the Oregon Oil Spill Control Fund operates on a much smaller level, with a balance of slightly under $30,000 at the end of 2020.[23]

3-2.3 Oregon State NRDA Statute

The State of Oregon has its own NRDA statute that gives the Oregon Department of Fish and Wildlife (ODFW) the authority to seek damages for the value of fish and wildlife injured or killed due to pollution.[24] This law is designed to supplement the federal Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and provide additional State power to resolve claims. Regulations enacted pursuant to the NRDA statute provide specific detail on how ODFW will "investigate, document and assess the value of natural resource losses."[25] The Oregon State NRDA statue is designed to enable the State to pursue smaller claims that might not be covered under existing federal statutes like CERCLA and OPA. Because fuel releases from the CEI Hub would be claimable under OPA, the State of Oregon would likely become a trustee and would settle through OPA – not the state NRDA process. The State of Oregon needs only to participate in one process to resolve claims.

The regulations are explicit in the methodology to calculate fish kills, fish life history, and survival rates. In addition to guidance on measuring biological harm, the regulations dictate the use of per-fish monetary values to calculate damages along with the replacement costs for fish and wildlife species.[26] The net economic value of lost or affected species must consider the "commercial, recreational, nonuse and other values associated with the resource."[27]

3-2.4 Civil Claims

Many regulatory and common-law frameworks allow individuals who endure harm to pursue compensation for damages directly. Of all the categories of costs and damages resulting from a spill at the CEI Hub, personal injury claims are the only category not explicitly covered in OPA.

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[22] Oil Spill Contingency Planning Annual Report. (2020). Oregon Department of Environmental Quality. Available at https://www.oregon.gov/deq/Hazards-and-Cleanup/Documents/erOilSpillPlan2020.pdf.

[23] Ibid.

[24] ORS 468B.060.

[25] OAR 635-410-0000.

[26] Ibid.

[27] OAR 635-410-0030.

Any claims that directly impact people or human health would need to be brought in the local or state court system and would be subject to Oregon rules and precedent on claims for personal injury and wrongful death.

3-3 Transaction Costs and Inefficiencies

Even a well-designed and efficient legal structure to transfer damages to liable parties will incur additional costs that may ultimately be borne in some manner by the liable/responsible party, the injured party, or society in general. These costs come in the form of transaction costs and the inefficiency of claims.

3-3.1 Claims Process

There are two types of claims that are covered under OPA – claims for removal costs and claims for damages. Removal costs are the costs that are associated with removal of the oil. Anyone may file a claim to the RPs for removal costs, including private parties, a State, and Tribal nations. Removal costs are recoverable as long as they were performed in accordance with the National Contingency Plan.[28] Claims are generally first presented to the RPs, then if not paid within 90 days, there is a court action or the claim is submitted directly to the OSLFT.

Claims for damages can be brought by both private and public entities, depending on the category of damages. Some damages are recoverable only by the federal government, Tribes, state governments, or other political subdivisions of states. These categories of damages include natural resource damages, loss of public revenue, and increased public services. The other categories of damages are recoverable by any person affected by the oil spill (see Section 3-2.1 for a summary of all damage types). Private claims can be combined into a class, which must be certified for members of the class to be included. Lawyers will often reach out directly to potential class members to seek their participation to enlarge the size of the class and amount of recoverable funds.

The CSZ earthquake complicates the assessment of harms attributable to fuel releases from the CEI Hub. For example, there will be fuel shortages due to both fuel releases at the CEI Hub as well as damage to transportation infrastructure that will limit the availability of replacement fuel. Similarly, costs to navigation could be incurred by vessel operators if the rivers are blocked from bridge failure(s) or debris upstream or downstream of the CEI Hub – regardless of fuel releases from the CEI Hub. If navigation is impacted from exogenous events other than CEI Hub fuel releases, then that will change the baseline scenario from which damages are calculated, affecting the value of damages attributable to the CEI Hub.

[28] 33 USC 2702(b)

3-3.2 Transaction Costs

Transaction costs in the legal system accrue from hiring attorneys, consultants, and experts to develop claims and navigate the adjudication process. These costs can also transfer to the liable parties for many categories of damages. For instance, OPA allows natural resource trustees to recover all reasonable assessment costs, defined as "costs, legal costs, and other costs necessary to carry out this part; monitoring and oversight costs; costs associated with public participation; and indirect costs that are necessary to carry out this part."[29] Courts may also sometimes award attorney's fees. In both cases, the transaction costs are borne by the liable parties and are in addition to the costs the liable parties spend on their own defense. However, there may be other instances where plaintiffs hire attorneys with a contingency fee, in which they retain a share of the total damages awarded. In these cases, the plaintiffs bear the transaction costs.

3-3.3 Inefficiencies

Inefficiencies in the legal system primarily arise through the value of time and uncertainty. Even if damages are calculated as a sum certain value, litigation, appeals, and collection of an award can take years or decades. For instance, in 1990, the S/T American Trader oil tanker ran over its anchor off Huntington Beach, California, and spilled nearly 417,000 gallons of oil. The NRDA claims ended up going to trial, and it wasn't until 1997 that the trial was completed, and a jury awarded government agencies $18.1 million for lost recreational use. The RP appealed, was successful in reducing the award to $15.4 million, and ultimately settled with state and local governments for $16 million in 1999.[30] This prolonged process introduces a cost and substantial risks inherent in litigation. Damages awarded by a court or jury might not fully capture the total damages claimed. Appeals of verdicts may also further reduce compensation.

3-3.4 Equitable Recovery

Due to transaction costs and inefficiencies, settlements of claims for civil damages – including those for natural resource damages – often are discounted. Following the Deepwater Horizon oil spill, a federal study estimated total economic value lost to natural resources to be at least $17.2 billion.[31] However, in 2016 (six years after the spill), federal and state natural resource trustees settled natural resource damage claims for $8.1 billion.[32] A substantial portion of that award has yet to be spent on restoration.[33] Despite making up only 47 percent of the estimated damages, the settlement was widely lauded and upheld by federal courts following an

[29] 15 CFR 990.30.

[30] Chapman, D. J., & Hagemann, W. M. (2001). Environmental damages in court: the American Trader case. *The law and economics of the environment*, 319.

[31] Bishop, R. C., Boyle, K. J., Carson, R. T., Chapman, D., Hanemann, W. M., Kanninen, B., ... & Scherer, N. (2017). Putting a value on injuries to natural assets: The BP oil spill. *Science*, *356*(6335), 253-254.

[32] U.S. Department of Justice. (2016). *Deepwater Horizon*. Available at: https://www.justice.gov/enrd/deepwater-horizon. Accessed December 7, 2021.

[33] NOAA, *Gulf Spill Restoration*, available at: https://www.gulfspillrestoration.noaa.gov/.

extensive public comment period.[34] This suggests that not all damages to parties will be recovered under OPA and some parties will have uncompensated costs resulting from fuel releases at the CEI Hub.

Uncompensated damages are most likely to occur for claimants with damages that are more difficult to prove. For businesses, the quality of their records will be critical to proving lost profits and/or earning capacity. For private individuals, the claims for recovery of damage to personal property and due to medical expenses could be difficult to prove that they are objectively attributable to CEI Hub fuel releases. In the Deepwater Horizon spill, health costs were claimable by coastal residents, first responders, and cleanup workers. Even if they are included in the claim, people with health symptoms are often not fully compensated for all costs they incurred. In the Deepwater Horizon spill, many claimants elected for lump sum payouts of $900 to $1,300 – which in some cases is less than the amount of their health care costs due to exposure to petrochemicals.[35]

The compensation process itself can also erode social capital in the communities that experience fuel releases. Interviews with Gulf Coast residents after Deepwater Horizon found that residents perceived "uncertainty, randomness, and unevenness in the compensation process which led to negative social comparisons and competition among community members".[36] Fuel releases can also damage human capital by making a place a less attractive location to live and work, as evidenced by the impact to property values.

3-4 Incidence of Damages by Category

Each of the categories of damages described in the previous sections of this report are detailed below, along with the individuals or organizations to whom they accrue. Where applicable, a potential legal framework and payment mechanism to transfer damages to liable parties is identified.

3-4.1 Direct Impacts to People

Assuming an explosion occurs, between 0 to 7 people could be killed and 2 to 80 people could be injured. No amount of money can restore the individual lives that would be lost if mortality occurs. The value of a statical life framework provides a potential monetary basis for the economic damages that could be recoverable under civil claims for personal injury and death.

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[34] NOAA, *Deepwater Horizon Settlements: Where the money went*, available at: https://www.noaa.gov/explainers/deepwater-horizon-oil-spill-settlements-where-money-went.

[35] *Plaisance, et al. v. BP Exploration & Production Inc., et al*, No. 12-968, U.S. District Court Eastern District of Louisiana Granting Final Approval of the Medical Benefits Class Action Settlement, January 11, 2013.

[36] Mayer, B., Running, K., & Bergstrand, K. (2015). Compensation and community corrosion: perceived inequalities, social comparisons, and competition following the Deepwater Horizon oil spill. In Sociological Forum (Vol. 30, No. 2, pp. 369-390). June.

The range of costs for mortality and morbidity are between $49,000 to $74.1 million, with an expected value of $37.1 million. Initially, these damages accrue directly to workers injured and killed onsite or their families. Civil claims for personal injury or wrongful death can be filed through the court system, with all or a portion of damages potentially recoverable from liable parties. Compensation would occur via direct payment and may be reduced because of settlement (to account for litigation risk) and attorney's fees (if not awarded to the plaintiffs). The liable parties would incur their own litigation defense costs. Depending on the degree of injury, not all potential claimants might seek recovery of damages due to the transaction costs and risks of doing so.

3-4.2 Property

Assuming fuels in the water travel downstream to the Longview Bridge, the potential short-term impact on residential properties values is up to $35.4 million. The initial damages accrue to all owners and renters of affected property. The market value reduction is an indication of the loss of economic value, so these damages accrue regardless of whether a property is sold or not. Property value claims can be filed under OPA and can be paid either by the RPs or the NPFC. Compensation would occur via direct payment and may be reduced because of settlement (to account for litigation risk) and attorney's fees. Depending on the degree of injury, not all potential claimants might seek recovery of damages due to the transaction costs. RPs would incur their own defense costs.

3-4.3 Navigation

A one-week closure of the shipping channel between the I-405 bridge and Longview Bridge would result in additional operating costs for commercial vessels of between $11.8 million and $17.8 million. The initial damages accrue to shipping companies, businesses relying on shipping, downstream consumers, and residents relying on earthquake response efforts. These losses are recoverable under OPA and can be paid either by the RPs or the NPFC. However, it may prove difficult to calculate losses for individuals or businesses not directly impacted by the navigation closure. For many consumers, these losses may be small, and transaction costs associated with filing a claim may preclude them from doing so. Any damages that are awarded may be reduced because of settlement (to account for litigation risk) and attorney's fees. RPs would incur their own defense costs.

3-4.4 Fisheries

To the extent that fuel releases reduce reproduction or cause direct mortality to aquatic species, there will be a reduction in income to the fishing industry, impacting owners, employees, and suppliers who rely on these funds. Initial damages accrue to the commercial fishing sector, with downstream effects impacting consumers if the losses result in price changes. Compensation would occur via direct payment, and these losses are recoverable under OPA and can be paid either by the RPs or the NPFC. Downstream consumer effects may be small (on a per-consumer

basis), and transaction costs may preclude the filing of claims. Any damages awarded may be reduced because of settlement (to account for litigation risk) and attorney's fees. RPs would incur their own defense costs.

3-4.5 Recreation – Consumer Surplus Values

Average per-trip values of recreation for participants (i.e., consumer surplus) are between $68 to $130 per person per day. These values are claimable by natural resource trustees as part of an NRDA claim under OPA. Compensation would occur via restoration projects designed to benefit recreational use in a manner that has a nexus to those activities that were affected. In this manner, lost recreational use is compensated; however, the actual individual recreators that had to change their behavior might not be. The total amount spent on restoration may be reduced because of settlement (to account for litigation risk), but all damages and reasonable assessment costs are claimable under OPA and would be paid either by the RPs or NPFC. RPs would incur their own assessment and defense costs.

3-4.6 Recreation – Consumer Spending

Outdoor recreation contributes spending to local economies at an average value of between $98 to $478 per trip. These losses initially accrue to local businesses that support recreation and are claimable under OPA. However, losses to businesses that do not exclusively serve recreators (i.e., gas stations) may be small or difficult to quantify on a per-business basis. Thus, some of these businesses may not file claims due to the associated transaction costs of doing so. Any damages awarded and paid by either the RPs or NPFC may be reduced because of settlement (to account for litigation risk) and attorney's fees. RPs would incur their own assessment and defense costs.

3-4.7 Human Health

The health costs to the population affected by exposure to airborne petrochemicals are approximately $121 million to $248 million. The primary health costs are increased risk of heart attack, decreases in productivity, and lost workdays. Initially, these costs accrue to individuals living or working near or downstream from the CEI Hub during the spill. These damages are not recoverable under OPA and would likely be pursued through civil claims for personal injury. Minor effects or those that may be confounded by time or comorbid conditions may be difficult to attribute to the spill and might not be claimed. Compensation would occur via direct payment and may be reduced because of settlement (to account for litigation risk) and attorney's fees (if not awarded to the plaintiffs). The liable parties would incur their own litigation defense costs. Depending on how potential litigation is structured, some injured parties could be left out of receiving settlement funds (see Section 3-3.4 for more information on potential inequities associated with the damage recovery process).

3-4.8 Habitats and Resources

Total damages from injury to habitats and natural resources and required compensation are expected to range between $87 million in the summer to $669 million in the winter. These values are claimable by natural resource trustees as part of an NRDA claim under OPA. Initial losses accrue to any citizens nationwide that hold value for the ecological resources and would be pursued on their behalf by natural resource trustees. Compensation would occur via restoration projects designed to replace or restore the ecological services lost because of the spill. Damages and all reasonable assessment costs would be paid for by the RPs or NPFC but may be reduced because of settlement (to account for litigation risk). RPs would incur their own assessment and defense costs.

3-4.9 Clean-up Costs

Total costs to clean up to oil spilled from the CEI Hub may range between $109 million to $1.4 billion. These costs are fully recoverable under OPA and would be paid for by the RPs. Should the RPs become financially insolvent following the spill, the remaining costs would be paid for by the NPFC.[37]

3-4.10 Cultural Values

Fuel releases in the Willamette River and Columbia River would harm cultural resources that are of particular importance to Tribal populations for subsistence, transportation, commerce, and ceremonial purposes. These losses accrue to regional Tribes and are claimable under OPA for federally recognized Tribes. Compensation would occur through restoration designed to replace or enhance these cultural services. Past NRDA settlements have included cultural exchange and apprenticeship programs. For example, the St. Lawrence NRDA settlement included over $8.3 million in cultural restoration projects, in addition to the nearly $7.3 million made available for ecological restoration.[38] Restoration costs and all reasonable assessment costs would be paid for by the RPs or NPFC but may be reduced because of settlement (to account for litigation risk). RPs would incur their own assessment and defense costs.

3-4.11 Fuel Prices

The total economic cost to consumers of the higher fuel prices and reduction is between $18.8 million and $120.8 million. The lost value of consumption from fuel scarcity would be $11.7

[37] Clean-up costs are not subject to liability limits under OPA.

[38] St. Lawrence River Environment Natural Resource Damage Assessment: Restoration and Compensation Determination Plan and Environmental Assessment. (2013). https://www.fws.gov/northeast/nyfo/ec/files/stlawrence/RCDP_Full_Final%20Revised%20May_2013.pdf. Accessed December 13, 2021.

million for a three-day period.[39] These costs would accrue to consumers throughout the state. While these costs may conceptually be pursued under OPA (as lost profits or income) or as a set of civil claims, they are unlikely to be. Price increases are an efficient response to scarcity, and the transaction costs associated with pursuing a large number of relatively small individual claims complicate the ability to quantify and recover these damages. Furthermore, past incidents that led to price shocks (e.g., the 1973 Arab oil embargo, the 1991 Persian Gulf war, and the 2020 Colonial Pipeline shutoff) have not resulted in substantial awarded damages. These economic costs are likely to be ultimately borne by consumers in the state.

3-5 Ultimate Financial Responsibility

The total damages of a spill at the CEI Hub will ultimately be borne by a large swath of the Oregon economy. Legal mechanisms will place a large portion of these damages at the responsibility of the firms operating CEI Hub facilities, should they be found liable. They should expect to ultimately shoulder a large portion of the damages, assessment costs, and civil penalties in addition to funds expended in their own defense.

The expected damages from a spill at the CEI Hub covered on the OPA are $435 million, but this value could be as high as $803 million and does not include impacts to commercial fisheries, cultural losses, impacts to fuel prices, and RP expenditures on legal defenses.[40] Expected cleanup costs total $701 million but could be as large as $1.4 billion. Expected civil penalties under OPA total $1.6 billion but could be as high as $8.4 billion if it is determined that the spill is the result of gross negligence or willful misconduct. The expected value of civil claims from personal injury/wrongful death is $46 million.[41]

Even though legal frameworks are designed to allow full compensation of damages, transaction costs and inefficiencies in the claims process mean that there is a likelihood that individuals, businesses, and Tribal governments may remain partially uncompensated. Uncompensated damages may be distributed inequitably across injured parties due to existing structural inequities in the legal system (see Section 3-3.4 for more information on potential inequities associated with the damage recovery process).

[39] Fuel scarcity in Oregon following the CSZ earthquake would likely extend for much longer than three days – however, the three-day estimate is what is likely attributable to CEI Hub fuel releases alone and not due to other effects of damage to transportation and pipeline infrastructure due to the earthquake.

[40] Attorney fees of claimants can be awarded under OPA. Non-monetary transaction costs to file and monitor claims cannot be awarded.

[41] The $46 million value is the sum of the expected value of direct impacts to people ($37.1 million) and human health impacts ($8.9 million).

3-6 Legal Mechanisms to Increase Financial Responsibilities

All categories of damages outlined in this report – apart from personal injury/wrongful death – are potentially recoverable under OPA.[42] Any damages incurred to individuals through personal injury/wrongful death would be potentially recoverable under separate civil action. RPs could end up not paying the full amount of their damage liability under three circumstances:[43]

- They exceed their liability limits;
- They are not the cause of the spill; or
- They become insolvent.

Under these scenarios, damages and costs claimable under OPA may be paid by the OSLTF. The expected damages claimable under OPA do not exceed the liability limits imposed by OPA for all potential RPs at the CEI Hub. Should any of the operators at the CEI Hub become financially insolvent following the CSZ event, all OPA damages and cleanup costs can potentially be paid by the OSLTF. Ignoring transaction costs and inefficiencies, the only category of damages at risk of incomplete coverage due to financial insolvency are personal injury/wrongful death claims.

While the vast majority of damages and costs associated with a spill at the CEI Hub are recoverable through the OSLTF, the availability of external funds may still serve as an economic externality. The availability of the OSLTF, while beneficial in paying damages and costs, may be a source of unaddressed moral hazard. Moral hazard arises when parties face a lack of incentives to fully guard against risk. While common in insurance markets, moral hazard is minimized through the implementation of co-payments or deductibles that align an individual's incentives with that of the insurer. Liability limits, while beneficial in providing certainty for business operating decisions, can be a source of moral hazard.[44] While the CSZ event presents a relatively uncertain risk, there may be decisions that a CEI Hub facility operator can make to minimize the likelihood of catastrophic harm. Older tanks or those closer to the water can be retrofitted, reinforced, or retired.

Economic efficiency dictates that operators at the CEI Hub should fully internalize the probability of a spill and its potential costs into operations. Local policy mechanisms could be

[42] Personal injury/wrongful death claims would be submitted through the civil claims process, not OPA.

[43] Note that damage liability is the value that is established through the claims process. Damage liability will likely be lower than total economic damages because of transaction costs, inefficiencies, and inherent inequities in the legal and claims process, as described in Section 3.

[44] Biais, B., Mariotti, T., Rochet, J. C., & Villeneuve, S. (2010). Large risks, limited liability, and dynamic moral hazard. *Econometrica*, *78*(1), 73-118.

designed that bypass a reliance on liability limits or bankruptcy proceedings. In this manner, operators may face incentives to minimize the chance of a spill by retrofitting tanks or reinforcing spill containment structures.

Certain vessels operating in U.S. waters are required under OPA to carry certificates of financial responsibility that operate similarly to a proof of insurance.[45] Onshore facilities are not required to provide certificates of financial responsibility. A market-based mechanism available to encourage operators at the CEI Hub to internalize the probability of a spill and its potential costs is to require operators to provide similar certificates of financial responsibility up to the expected value of all damages, cleanup costs, and penalties, allocated to operators by volume. The total expected value of OPA damages, civil penalties under OPA, cleanup costs, and civil claims from fuel releases at the CEI Hub is $2.8 billion. Certificates of financial responsibility would provide evidence of a firm's ability to pay their share of this value, should a spill occur. These certificates of financial responsibility can be provided through self-insurance or an insurance market, which would actuarily price the risk of a spill and potentially provide discounts for efforts to minimize its likelihood or impacts.

The State of Oregon could also increase the fee-structure for onshore facilities collected under ORS 468B.405 to cover the annualized expected value of all damages and cleanup costs of a catastrophic spill from the CEI Hub.[46] This pricing mechanism would increase the costs of operating facilities at the CEI Hub, while also potentially incentivizing operators to reduce the reliance on older or outdated infrastructure.

Economic tools provide incentives to optimize behavior. While regulatory inspections are a critical component of spill preparedness planning, they work best when complemented with financial structures that align both public and private incentives. These tools are ultimately not necessary for the recovery of most costs and damages (due to the liability structure provided under OPA), but they can provide mechanisms to minimize the likelihood of a spill, which would be the preferred scenario for all parties.

[45] The form to apply for a certificate of financial responsibility, demonstrating the information that the certificate requires to determine financial responsibility, is available at: https://www.uscg.mil/Mariners/National-Pollution-Funds-Center/Forms/

[46] See Section 3-2.2 for more information on ORS 468B.405.

3-7 Opportunities for Future Research

The purpose of this analysis is to describe the likely effects of a CSZ earthquake on the fuel stored at the CEI Hub. This research provides qualitative and quantitative descriptions of the potential amount of fuel releases, the costs that those releases could impose on society, and descriptions of if and how those costs will be reimbursed through current legal structures. This research demonstrated that there is sufficient information to determine that fuel releases are likely to occur and would impose large costs to society and the CEI Hub operators. However, there are opportunities to refine the information that was available for the analysis to provide more certainty and additional detail. The opportunities for additional research in the future fall into three categories: **refinement of the analysis, analysis of prevention actions, and expanded analysis beyond the CEI Hub facilities and CSZ earthquake scenario**.

There are numerous ways that additional research could refine the analysis in this report to provide additional information about releases and more specific damage estimates. However, all damage estimates rest on the assumptions about the amount and type of fuel that would be released. Because the likelihood of releases and materials that could be released is the basis of the research, having more accurate and complete information about the storage tanks is the first step for a more refined analysis. This research uncovered the paucity of information about the storage facilities at the CEI Hub. Some properties did not have tank storage capacity or contents information available through any government source, including the State Fire Marshal. This analysis did not conduct onsite assessments of the seismic integrity of the tanks or the soils through soil sampling or any other on the ground data collection method. Additional research working directly with the CEI Hub operators would allow for more precise information about individual tanks, their contents, and their seismic risks, all of which would lead to better estimates of what would potentially be released due to a CSZ earthquake. This information would also better prepare government agencies to respond to fuel releases or other emergency events like fires.

Once more information is available and there are more refined estimates of fuel releases from the CEI Hub, follow up studies could refine the analysis of the effects of fuel releases. These analyses could include refinement of impacts by:

- Evaluating the likelihood of fuel ignition and potential extent of fire spread under various scenarios. Having this analysis would allow for understanding of properties and public resources that are at risk of fire, such as Forest Park, businesses, and residences.
- Modeling human health impacts under ignition and non-ignition scenarios. This research would provide the information to identify the scale of needed evacuations.
- Evaluating the impacts of fuel releases on aquatic species under various response timeline and seasonality scenarios. This research would correct for the scarcity of information about impacts of fuels on aquatic species present in the Pacific Northwest, such as salmon, and could be used to model impacts to commercial and recreational fisheries.

- Studying the impact that fuel releases would have on the area's ability to attract and retain talent and investments. In other words, evaluate if and how fuel releases would affect the brand of the Portland metro region and the area's attractiveness as a place to live and work.
- Modeling and planning for how replacement fuel could be supplied to replace fuel released at the CEI Hub and to account for disruptions in supply chains due to earthquake damage.
- Assessing if and how fuel releases and any associated fires or other activities requiring emergency response would detract from other emergency response operations in the aftermath of the CSZ earthquake and what those costs would be.
- Conducting further legal analysis to gain clarity of CEI Hub operator responsibility under OPA, particularly with regard to the "Act of God" provision.

Many types of analyses could be conducted to inform policy responses aimed at preventing or reducing the risk of fuel releases. Studies could be conducted to better understand the costs of taking any prevention actions, such as making seismic retrofits, replacing tank infrastructure, decommissioning tanks, and other actions. A broader study could then compare the costs and benefits of taking any actions to prevent fuel releases. This type of study should also evaluate the distributions of benefits and costs to understand who would incur costs and who would experience benefits compared to current conditions. Policy responses to prevent fuel releases would likely also require additional legal analyses or planning. For example, although there is a fuel response plan for the Lower Columbia River, that plan does not include contingencies for how to perform the response after a major earthquake.

CEI Hub tanks is not the only location that is at risk during a CSZ earthquake or other event. The network of pipelines and rail infrastructure also pose risks of fuel releases. In addition, there are other fuel and hazardous material storage in Oregon and Southwest Washington that pose threats to natural resources and human health in Oregon in the event of a CSZ earthquake. Additional research could be conducted to better understand the cumulative effects from fuels and hazardous materials in the region. This analysis could be performed for a CSZ earthquake, as well as other events such as a Portland Hills earthquake or smaller spill event.

Exhibit List 697

Summary of Available Data and Report of Expected Earthquake Risk

Oregon Critical Energy Infrastructure Hub

Portland, Oregon

Prepared for
Multnomah County

February 2, 2022
Job No. 0202424-000 (154-035-019)

SALUS RESILIENCE

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Prepared by
Salus Resilience

Allison Pyrch, PE
Senior Associate

Della Graham, RG
Senior Project, Geologist

6420 S Macadam Avenue, Suite 100
Portland, OR 97239
503.620.7284

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APPENDIX A (PROVIDED ELECTRONICALLY ONLY FOR CONFIDENTIALITY)

City of Portland CEI Hub Tank Infrastructure Data
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Summary of Available Data and Report of Expected Earthquake Risk

Oregon Critical Energy Infrastructure Hub

Portland, Oregon

1.0 INTRODUCTION AND PROJECT UNDERSTANDING

The Cascadia Subduction Zone (CSZ) reaches from Vancouver, Canada to Cape Mendocino, California and has the capacity to produce earthquakes with a magnitude of 8.0 or higher. Geologists previously believed that these large earthquakes from the CSZ have a recurrence interval of 400 to 600 years; however, research done by a team of scientists at Oregon State University proved the recurrence interval is closer to 350 years. The most recent major earthquake was on January 26, 1700, a little over 300 years ago, with an estimated magnitude of 9.0 on the CSZ. Research by Oregon State University indicates that Oregon has a 37 percent chance of a large earthquake (> M8) from the CSZ within the next 50 years. Based on our understanding of these earthquakes and a recent study by the Oregon Department of Geology and Mineral Industries (DOGAMI), such an earthquake will cause significant damage to infrastructure throughout Oregon, the Portland Metro Region, and Multnomah County.

Part of Oregon's critical infrastructure includes the Oregon Critical Energy Infrastructure (CEI) Hub, which is located on a 6-mile stretch of the west shore of the lower Willamette River, as shown on Figure 1.1. The CEI Hub houses approximately 90 percent of the liquid fuel needed to support the state of Oregon and all of the jet fuel used by the Portland International Airport, as well as other hazardous materials (DOGAMI 2012). New technology, data, and mapping have greatly expanded our understanding of the effects of seismic hazards in our region, including the effects of earthquakes to soft and loose fill and alluvial soils, such as those mapped at the location of the CEI Hub site. These soils are prone to seismically induced strength loss, settlement, and slope failure or lateral spread. The 2017 DOGAMI data indicate that significant displacement will occur in this area during a 9.0 CSZ event. In addition to the hazards related to the soils at the site, a large portion of the existing infrastructure at the CEI Hub was constructed prior to our understanding of Oregon's seismic risk, including tanks constructed over 100 years ago that are still being used for hazardous material storage. The age of the tanks and infrastructure and the soil vulnerabilities result in significant risk to the CEI Hub infrastructure and the materials that are stored there.

The purpose of this study is to evaluate the geotechnical effects of an anticipated seismic event for the region on the CEI Hub and its infrastructure in order to support an evaluation of the economic ramifications for Multnomah County (County). Based on the scenarios developed by DOGAMI for emergency planning, the goals for this project, and our understanding of the geology in the area, the 9.0 CSZ earthquake scenario will be used for this evaluation. This earthquake scenario is the most likely to occur in the next 50 years and will be the most difficult for emergency response and long-term recovery because it will affect the entire Pacific Northwest.

This report summarizes the first phase in our evaluation and includes a bibliography of the data and reports used in our evaluation as well as a detailed summary of the earthquake scenario and geotechnical risk evaluation for the project. The impacts of the earthquake scenario outlined herein on

the CEI Hub are not addressed in this report; however, this information will be used in the next phase of the project to evaluate the CEI Hub impacts.

The geotechnical analysis contained herein is generally based on publicly available data, though includes site-specific information where available. The collected data were used to develop generalized subsurface geologic models representative of each area evaluated, and which do not account for ground stabilization work which may have been completed by individual property owners.

1.1 Geologic Setting of the CEI Hub

The CEI Hub is within the city of Portland, Oregon and lies within the Portland Basin, one of several basins that form the Puget-Willamette forearc trough of the Cascadia subduction system (Evarts et al 2009). This trough extends from the Washington-Canada border to approximately Eugene, Oregon, includes the Puget Sound and Willamette River Valley, a distance of nearly 350 miles. Contractional tectonic stresses from the convergent CSZ also create a series of north- to northwest-trending folds that extend from the Pacific coast east to the Cascade Mountains. These folds form the valleys, hills, and mountains characteristic of northwest Oregon and the Pacific Northwest in general. The Portland Basin has also been receiving sediments from the continental-scale Columbia River system for over 20 million years (Evarts et al 2009), of which the Willamette River is a tributary and the source of the near surface sediments at the CEI Hub.

The oldest deposits in the basin form the uplands that surround the valley and are composed of 30- to 40-million-year old volcanic and marine rocks and 15- to 16-million-year old basalt flows of the Columbia River Basalt Group. These rocks were folded and uplifted along faults at the southwest and northeast margins of the Portland Basin, which include the adjacent Portland Hills. The basin itself began to form approximately 20 million years ago and is filled with a thick accumulation of river sediments, including the Troutdale Formation, a gravel to cobble conglomerate found widely throughout the Portland Basin (Evarts et al 2009).

Near the end of the last ice age, a series of cataclysmic floods flowing down the Columba River Gorge repeatedly inundated the Portland Basin up to 400 feet above sea level (Evarts et al 2009). These floods originated from the repeated failing of a glacial ice dam in northwestern Montana between 16,000 and 12,000 years ago and are collectively called the Missoula Floods. While massive gravel bars were formed in the eastern Portland Basin closest to the river, these floodwaters slowed and ponded behind the narrower Columbia River valley downstream, dropping slack water deposits of sand and silt across the entire Willamette River valley. Since the end of the last ice age 13,000 years ago, sea levels have risen over 370 feet, causing the Columbia and Willamette rivers to rapidly deposit sediments across the basin, typically through overbank deposition during yearly snowmelt floods (Evarts et al 2009). These loose sand and silt deposits have been overlain by fill in places where floodplains and wetlands were developed along the banks of the Willamette and Columbia rivers.

1.2 Seismic Setting of the CSZ

Oregon sits near the contact between two large crustal tectonic plates. The Juan de Fuca Plate forms the floor of the Pacific Ocean off the coast of the northwestern United States and moves northeastward from its

spreading ridge boundary with the Pacific Plate at an average rate of approximately 1.5 inches per year. As it converges with continental North America, the Juan de Fuca Plate dips below (or "subducts") beneath the North American Plate, forming a shallow, eastward-dipping contact interface. This boundary is known as the CSZ and is responsible for the seismicity in the Pacific Northwest, producing earthquakes associated with three types of source zones: subduction interface, subduction intraslab, and shallow crustal.

Based on geologic and historical evidence, CSZ interface earthquakes occur an average of every 350 years in the form of magnitude 8 to 9.2 earthquakes. Interface earthquakes (such as the 2011 magnitude M9.0 Tohoku earthquake in northeastern Japan) are some of the largest magnitude earthquakes on record. Characteristics of this type of earthquake may include very large ground accelerations, shaking durations in excess of 3 minutes, and strong long-period ground motions that may particularly affect tall or long-period structures and deep soft soils.

Shallow crustal faults are caused by cracking of the continental crust resulting from the stress that builds as the subduction zone plates remain locked together. The Portland Hills, Oatfield, and East Bank faults run approximately in a northwest-southeast direction through downtown Portland and are generally believed to be capable of producing earthquake events in the study area. However, earthquake events on these crustal faults are less likely than the 9.0 CSZ earthquake.

Based on our discussions with the County and the project team, the scenario that will be used for this project is a M9.0 on the CSZ. This event has been widely used for evaluation and emergency planning in the Portland Metro area and Oregon because of the higher probability of its occurrence and greater area that will experience damage. Damage to the entire Pacific Northwest is expected during this scenario resulting in a much larger challenge for emergency response and recovery. DOGAMI has completed a comprehensive damage estimate based on shaking data for a 9.0 CSZ event. Based on their mapping, the CEI Hub is expected to experience very strong to severe shaking from aggregated earthquake sources, with severe shaking and moderate to heavy damage potential during a magnitude 9.0 CSZ earthquake as shown on Figure 1.2.

The anticipated ground shaking will also cause weaknesses within the subsurface soils. Liquefaction is a phenomenon where ground shaking in saturated granular (sand or silt) soils creates a rapid increase in pore water pressure that results in the sudden loss of shear strength in the soil. Sand boils and flows observed at the ground surface after an earthquake are the result of excess pore pressures dissipating upwards, carrying soil particles with the draining water. Liquefaction can result in settlement and strength loss, which can impact foundations. DOGAMI has mapped generalized liquefaction hazard at the site as moderate to high as shown on Figure 1.3. Additionally, liquefaction can cause global instability and may result in lateral spread towards water bodies and other low areas. DOGAMI has mapped the potential permanent ground deformation due to lateral spreading at the site as being between 39 and 173 inches, as shown on Figure 1.4.

1.3 History of the Oregon CEI Hub

The CEI Hub development began in the early 1900s, with the first tanks constructed in approximately 1907 at the Phillips 66 property. Since the beginning of development, the CEI Hub has expanded to

five distinct areas, with 11 owners and 31 properties as indicated in Table 1.1 below. For the purposes of our evaluation, we have separated the CEI Hub into five distinct geographic areas for geotechnical evaluation. The property ownership and designated areas are shown on Figure 1.5. Closer views of each area are show in Figure 1.6 through Figure 1.10. We reviewed data collected from the State Fire Marshall, City of Portland, Portland State University (PSU), and historical aerial and satellite imagery to aid in the evaluation.

Table 1.1 - CEI Hub Areas

Area 1 - Kinder Morgan North					
Property Name	**Address**	**City**	**State**	**Zip**	**Property ID**
Kinder Morgan - North	11400 NW ST HELENS RD	PORTLAND	OR	97231	R323828
Area 2 - Linnton					
Property Name	**Address**	**City**	**State**	**Zip**	**Property ID**
BP West Coast	9930 WI/ NW ST HELENS RD	PORTLAND	OR	97231	R323779
BP West Coast	9930 NW ST HELENS RD	PORTLAND	OR	97231	R498331
BP West Coast	9900 WI/ NW ST HELENS RD	PORTLAND	OR	97231	R323771
BP West Coast	9930 WI/ NW ST HELENS RD	PORTLAND	OR	97231	R323758
Shore Terminals / Nustar	9420 WI/ NW ST HELENS RD	PORTLAND	OR	97231	R518296
Shore Terminals / Nustar	9420 WI/ NW ST HELENS RD	PORTLAND	OR	97231	R491070
Shore Terminals / Nustar	9400 S/ NW ST HELENS RD	PORTLAND	OR	97231	R324088
Shore Terminals / Nustar	9420 NW ST HELENS RD	PORTLAND	OR	97231	R518295
Shore Terminals / Nustar	9420 WI/ NW ST HELENS RD	PORTLAND	OR	97231	R518294
Area 3 - NW Natural					
Property Name	**Address**	**City**	**State**	**Zip**	**Property ID**
Pacific Terminal Services	7900 NW ST HELENS RD	PORTLAND	OR	97210	R324159
NW Natural	7900 WI/ NW ST HELENS RD	PORTLAND	OR	97210	R324171
NW Natural	7900 WI/ NW ST HELENS RD	PORTLAND	OR	97210	R324170
NW Natural	7598 NW ST HELENS RD	PORTLAND	OR	97210	R324113
NW Natural	7900 WI/ NW ST HELENS RD	PORTLAND	OR	97210	R324172
NW Natural	7441 SW/ NW ST HELENS RD	PORTLAND	OR	97210	R324165
NW Natural	7441 NW ST HELENS RD	PORTLAND	OR	97210	R324160
NW Natural	7540 NW ST HELENS RD	PORTLAND	OR	97210	R502592
NW Natural	7540 WI/ NW ST HELENS RD	PORTLAND	OR	97210	R324213
Area 4 - Willbridge					
Property Name	**Address**	**City**	**State**	**Zip**	**Property ID**
Kinder Morgan - South	5800 WI/ NW ST HELENS RD	PORTLAND	OR	97210	R324222
Kinder Morgan - South	5800 NW ST HELENS RD	PORTLAND	OR	97210	R121076
Kinder Morgan - South	6080 WI/ NW FRONT AVE	PORTLAND	OR	97210	R315782
Chevron	5533 NW DOANE AVE	PORTLAND	OR	97210	R315798
Chevron	5533 WI/ NW DOANE AVE	PORTLAND	OR	97210	R315771
Conoco Phillips	5528 WI/ NW DOANE AVE	PORTLAND	OR	97210	R315810
Conoco Phillips	5528 NW DOANE AVE	PORTLAND	OR	97210	R315769
Zenith Energy Terminals	5501 NW FRONT AVE	PORTLAND	OR	97210	R315845
Zenith Energy Terminals	5501 NW FRONT AVE	PORTLAND	OR	97201	R315777
McCall Oil	5700 NW FRONT AVE	PORTLAND	OR	97210	R315872
McCall Oil	5480 WI/ NW FRONT AVE	PORTLAND	OR	97210	R315786
Area 5 - Equilon					
Property Name	**Address**	**City**	**State**	**Zip**	**Property ID**
Equilon	3610-3640 NW ST HELENS RD	PORTLAND	OR	97210	R315819

The earliest available aerial photographs of the study area were taken by the U.S. Army Corp of Engineers (USACOE) in 1923 with coverage limited to Area 4 and Area 5. Tanks associated with Kinder Morgan and Chevron are visible on the 1923 aerial photograph, which displays approximately 30 percent of the tanks present today.

1.3.1 Area 1 - Kinder Morgan North

Area 1 includes one property owned by Kinder Morgan and is located at 11400 NW St. Helens Road on the north end of the Linnton neighborhood and includes riverfront as shown on Figure 1.5. The earliest available photograph of Area 1 is from 1936. At that time, 12 tanks are visible on the southwest portion of the property, and the northeast portion of the property is a combination of industrial land and the Willamette River. Extensive in-river filling of the northeast portion of the property occurred through 1941 when five additional tanks were constructed on the new land. Between 1954 and 1955, three additional tanks were added to the northeast portion of the property. Additional land was added along the shoreline of the property between 1956 and 1961. Based on available data, the oldest tank remaining at this property was constructed in 1914 and is currently out of service. Of the original tanks present in 1936, three were replaced in 1944, 1958, and 2011. Two of the original tanks have been removed permanently. Based on data provided by the City of Portland (City), PSU, and satellite imagery, there are currently 33 tanks present (Cone 2020 and Dusicka 2019). Additional details are provided in *Section 4.0 Geologic Risk of the CEI Hub in a CSZ Earthquake*.

1.3.2 Area 2 - Linnton

Area 2 includes nine properties owned by BP West Coast at 9900 and 9930 NW St Helens Road and Shore Terminals/Nustar at 9400 and 9420 NW St Helens Road. All nine properties are located north of the St. Johns Bridge and include riverfront.

1.3.2.1 BP West Coast

BP West Coast includes four properties. Three located on the west side of NW St Helens Road with no tank infrastructure and one property with tanks located on the east side of NW St Helens Road along the Willamette River. The earliest available photograph of the BP West Coast property is a 1940 aerial photograph that shows eight tanks present on the southern portion of the property, and two on the northern portion of the property. Between 1948 and 1957, the shoreline of BP West Coast was filled to add approximately 30 feet of land between the existing tanks and the Willamette River. By 1962, the additional tanks present today were constructed on the northern portion of the property. Based on data provided by the City, PSU, and satellite imagery, there are currently 30 tanks present (Cone 2020 and Dusicka 2019).

1.3.2.2 Shore Terminals/Nustar

Shore Terminals/Nustar includes five properties. Two properties on the west side of NW St. Helens Road include vacant land, small office buildings, and four small tanks that appear to have been installed between 1968 and 1977. Two properties located on the east side of NW St Helens Road include extensive tank infrastructure along the Willamette River. The earliest available photograph of the Shore Terminals/Nustar property is a 1939 aerial photograph that shows that the majority of the tank infrastructure is located on the northern portion of the northern property. That photograph also

shows the southern portion of the property as well as the adjoining southern property are partially vegetated with filling activity visible. Additional filling continued on both properties through 1962, and the number of tanks approximately doubled. A large expansion of tanks on the southern property occurred between 1977 and 1984 and included additional shoreline filling. Two additional tanks were constructed on the southern portion of the southern property in 2007. The third property located on the east side of NW St Helens Road is a small, vacant piece of land on the northwest corner of the main Shore Terminals/Nustar property. Based on data provided by the City, PSU, and satellite imagery, there are currently 39 tanks present (Cone 2020 and Dusicka 2019).

1.3.3 Area 3 - NW Natural

Area 3 includes nine properties owned by Pacific Terminal Services and NW Natural at 7900, 7598, 7441, and 7540 NW St Helens Road. All nine properties are located between the St. Johns Bridge and the Burlington Northern Santa Fe railroad bridge, and include riverfront. The earliest available aerial photograph of this property is from 1936, and much of the southern portion of the property is wetland and an inlet of the Willamette River. Over 30 tanks are present on the northern portion and western property. Two large tanks are present on what appears to be a filled area of land adjacent to the Willamette River forming a partial island for the tanks. Additional filling occurred through 1944 on the southern portion of the property, and additional infrastructure was constructed, including tanks. By the late 1990s and into the 2000s, significant infrastructure was removed from the property. Based on data provided by the City, PSU, and satellite imagery, there are currently eight tanks present (Cone 2020 and Dusicka 2019).

1.3.4 Area 4 - Willbridge

Area 4 includes 11 properties owned by Kinder Morgan (5800 and 6080 NW St Helens Road), Chevron (5533 NW Doane Avenue), Conoco Phillips (5528 Doane Avenue), Zenith Energy Terminals (5501 NW Front Avenue), and McCall Oil (5700 and 5480 NW Front Avenue). All 11 properties are located south of the Burlington Northern Santa Fe railroad bridge and includes some riverfront properties.

1.3.4.1 Kinder Morgan South

Kinder Morgan South includes three properties. One property is located on the east side of NW St Helens Road, along the Willamette River with no tank infrastructure. The other two properties with tanks are located on the west side of NW St Helens Road and do not include riverfront. The earliest aerial photograph from 1923 depicts limited tank infrastructure constructed on the southern property. By 1936 the northern property remained vacant, undeveloped land and the southern property has been developed with approximately 15 tanks. Additional tanks were added to the southern property by 1944, and additional roads were constructed around the northern and southern properties. By 1956, approximately 20 tanks had been constructed on the northern property. Infrastructure continued to be added or removed over the next 50 years. Based on data provided by the City, PSU, and satellite imagery, there are currently 134 tanks present (Cone 2020 and Dusicka 2019).

1.3.4.2 Chevron

Chevron includes two properties. One property is located on the east side of NW St Helens Road along the Willamette River and appears to have one tank which was installed between 1944 and 1956. The larger property with the majority of the tank infrastructure is located on the west side of NW St Helens Road and does not include riverfront. Minor development of the property was visible in the earliest available aerial photograph from 1923. Major development of this property continued through 1936, when 12 tanks were visible on the property. Significant development of the property continued through the early 1960s, with larger tanks constructed on the eastern portion of the property and smaller volume tanks constructed on the west portion of the property. Based on data provided by the City, PSU, and satellite imagery, there are currently 146 tanks present (Cone 2020 and Dusicka 2019).

1.3.4.3 Conoco Phillips

Conoco Phillips includes two properties. One property is located on the east side of NW St Helens Road along the Willamette River and does not have any tank infrastructure based on satellite imagery. The larger property located on the west side of NW St. Helens Road was first developed prior to 1936. Approximately 20 tanks are visible on the westernmost portion of the property in 1936. The remaining property appears undeveloped, with a small water body noted east of the existing tanks. By 1944, the water body and been filled, and new tank infrastructure was installed to the east and south. By 1970, the majority of the tank infrastructure had been constructed on the site. Based on available records, the tanks all appear to be the original structures. Based on data provided by the City, PSU, and satellite imagery, there are currently 93 tanks present (Cone 2020 and Dusicka 2019). Zenith Energy Terminals.

Zenith Energy Terminals (formerly Arc Logistics) includes two properties. Both properties are located on the west side of NW Front Avenue and share a property line with Conoco Phillips. The smaller of the two properties, which is approximately 3 acres, was undeveloped until at least 1944 when buildings were constructed on the property. By 1964, one tank was constructed on the western portion of the property. A second tank was constructed by 1980, and all preexisting buildings had been removed. The larger property was first developed as housing in the early 1940s. Limited tank infrastructure development was present by 1948, on the northwest corner of the property, adjacent to the housing. By 1959, the housing had been removed, and additional tanks were constructed. Between 1964 and 1968, the former housing area had been filled and graded for additional tank infrastructure, which continued to expand through the mid-1980s. Based on data provided by the City, PSU, and satellite imagery, there are currently 97 tanks present (Cone 2020 and Dusicka 2019).

1.3.4.4 McCall Oil

McCall Oil includes two properties, both located on the east side of NW St. Helens Road, along the shore of the Willamette River. Both properties were part of the Willamette River prior to 1968. Significant filling of the site and surrounding properties continued through the 1980s. The earliest available aerial photograph of the area shows the present-day tank infrastructure had been constructed by 1986. Based on data provided by the City, PSU, and satellite imagery, there are currently 26 tanks present (Cone 2020 and Dusicka 2019).

1.3.4.5 Zenith Energy

Zenith Energy includes two properties, both located on the west side of NW St Helens Road and are not located on the riverfront. Development of the larger property to the south was noted in the 1956 aerial photograph, and one of the two tanks on the smaller property to the north was noted in the 1964 aerial photograph. By 1990, all tanks currently present were visible on the aerial photographs. Tank decommissioning's appeared as early as the 1998 aerial photograph. Based on data provided by satellite imagery and Portland Fire & Rescue (PF&R 2021), there are currently 86 tanks present.

1.3.5 Area 5 - Equilon

Area 5 includes one property owned by Equilon. The property is located on the west side of NW St Helens Road. The earliest available aerial photograph indicates that tank infrastructure was present prior to 1936 on the southeast portion of the property. Three additional tanks were constructed on the northwest portion of the property between 1944 and 1956, and a fourth tank was added in the 1990s. Based on data provided by satellite imagery, there are currently 14 tanks present.

2.0 DATA REVIEW

As part of this evaluation, we reviewed multiple technical documents, including construction reports, geotechnical reports, previous studies of the CEI Hub, and previous studies of the CSZ expected earthquake. Our document review included both publicly available data and confidential data necessary for the completion of this evaluation. Publicly available data included updated data from DOGAMI, the City, Oregon Solutions, PSU, and private contractors who have completed work at the CEI Hub. Confidential data were provided by the Oregon Office of State Fire Marshal (OSFM) in the form of a data table (Appendix A). Confidential data will be removed from the report prior to publishing. Detailed review included review of boring logs, permit applications, aerial photographs, and detailed infrastructure data provided by both OSFM and the City.

A detailed bibliography of the resource documents reviewed is provided in Table 2.1 (attached). Specific properties for which documents were reviewed as part of the geologic risk evaluation in *Section 4.0 Geologic Risk of the CEI Hub in a CSZ Earthquake* are highlighted on Figure 1.5 through Figure 1.9.

Using the technical documents provided by the City and other sources, a detailed analysis of the geologic risk to the CEI Hub in a CSZ earthquake was conducted. This included the use of local boring logs as well as the updated DOGAMI data to evaluate the ground shaking, liquefaction, and lateral displacement expected at the CEI Hub during a CSZ earthquake. Details of this evaluation are provided in Section 4.0 Geologic Risk of the CEI Hub in a CSZ Earthquake.

No site visits, subsurface explorations, or individual tank evaluations were included in the scope of work for the project.

2.1 Tank Data Collection and Review

During the initial data gathering process, it became clear that the data available from the OSFM would likely not include all data necessary to construct a complete inventory of tanks and supporting

infrastructure at the CEI Hub. A critical part of this evaluation was to include an inventory of the tanks and supporting infrastructure at the CEI Hub, which would later be used to evaluate the impacts of a CSZ earthquake on the CEI Hub. Data necessary to do this would include exact location of tanks and supporting infrastructure and the age of the tanks and supporting infrastructure. During a phone call with Mark Johnston, Assistant Chief Deputy at OSFM, (Johnston 2020), Mr. Johnston indicated that tank owners are not required to report the exact location of the tanks, rather, only the quadrant of the property in which the stored material is located is required. Additionally, OSFM does not keep records of supporting infrastructure, and tank owners are not required to report the age of the tanks. Mr. Johnston indicated that the information on tank age would likely need to be requested directly from the property owners; however, he expects doing so would involve a lengthy legal process. Publicly available data collected regarding the infrastructure at the CEI Hub are provided in *Section 3.0 Tanks and Infrastructure of the CEI Hub*.

Another key aspect of the data collection was to include the contents of each tank at the CEI. As discussed with Mr. Johnston, property owners are only required to report the amount of hazardous substances on their property once a year, and that report only needs to include the maximum daily amount at any given point during the year. Therefore, the OSFM data were supplemented with data compiled by the City and PSU (see discussion below). Data collected regarding the contents of the tanks at CEI hub are provided in *Section 3.0 Tanks and Infrastructure of the CEI Hub*.

3.0 TANKS AND INFRASTRUCTURE OF THE CEI HUB

Salus received two main datasets regarding the tanks present at the CEI Hub, both of which were incomplete. The first dataset was provided by the City in the form of a web map (Cone 2020) and feature layer (Appendix A). The web map and feature layer were created from data collected during the PSU study of the CEI Hub (Dusicka 2019). This feature layer was compared to available satellite photographs of the CEI Hub to obtain an inventory of the number of tanks present in each area and each property. Approximately 122 tanks observed during a review of satellite imagery were not included in the web map; therefore, we had no information on tanks or their contents. The majority of these 122 tanks observed in satellite imagery coincide to tanks located at Zenith Energy and Equilon, which are not listed in the COP dataset feature layer. Table 3.1 (attached) provides an abridged summary of the data provided in the feature layer and the additional tanks at Zenith Energy (107 tanks),Equilon (14 tanks), and NW Natural (1 tank)identified from satellite photographs.

The second dataset was a confidential data table provided from the OSFM's office (Appendix A). This dataset was obtained through a Freedom of Information Act (FOIA) request submitted by John Wasiutynski from the City on behalf of Salus. The data received from the OSFM are data collected by the OSFM as part of the Community Right to Know (CR2K) program. The OSFM maintains the records associated with the Oregon Community Right to Know and Protection Act of 1985 (ORS 453.307-414), which requires Oregon employers to report their hazardous substances to OSFM, including where they are stored and the hazards associated with them (OSP 2021). Employers reporting hazardous substances are required to follow specific survey instructions but are only required to report substances once per calendar year, or if a substantive change occurs (OSFM 2020).

Following receipt of the OSFM data, Salus compared the dataset to that previously received from the City. Limited redundancies were noted that allowed for merging of the data. In a follow-up conversation with OSFM, it was noted that employers are only required to report the maximum daily amount of any substance present at their entire property and the general quadrant of their property it is stored at (Johnston 2020). For example, a property may have four above ground storage tanks (ASTs) that each hold 25 gallons of gasoline, four ASTs that each hold 20 gallons of diesel, and four ASTs that each hold 10 gallons of oil. This property will report 100 gallons of gasoline, 80 gallons of diesel, and 40 gallons of oil during their yearly submittal to OSFM. Due to the amalgamation of substances in the OSFM records, this dataset is not useful for identification of contents of individual tanks. The confidential dataset is provided in Appendix A.

Additional information was collected from City (Portland Fire & Rescue) resources and permit applications to cover the Zenith, Equilon, and NW Natural properties. This information was compared with the above data sets and incorporated into our tank database.

In addition to the inventory of tanks present at the CEI Hub, Salus made efforts to create an inventory of supporting infrastructure present at the CEI Hub. No existing datasets were found inventorying supporting infrastructure; therefore, Salus relied on satellite imagery, the City web map, and Portland Maps to identify buildings present at the CEI Hub (Portland Maps 2020). A summary of this inventory is provided in Table 3.2 (attached).

4.0 GEOLOGIC RISK OF THE CEI HUB IN A CSZ EARTHQUAKE

This section presents estimates of site and soil behavior of the CEI Hub areas during a magnitude 9.0 CSZ earthquake. Estimates for the level of ground motion shaking were evaluated, the soil at each of the areas was characterized based on the existing data provided by the City, and estimates of liquefaction settlement and lateral spread were developed for each location.

4.1 CSZ Earthquake Ground Motion Shaking Intensity

Since the publication of the 2017 DOGAMI report, several additional resources have been published that can estimate the intensity of the ground motion shaking in the project areas. The resources are in the form of ground motion models published as a part of the Next Generation Attenuation-Subduction (NGA-Subduction) (Bozorgnia and Stewart 2020) research effort and simulations published in Frankel et al. (2018). The ground motion models are developed from recordings and simulations of subduction zone events around the world and developed for compatibility with probabilistic assessments of ground motion shaking, such as those used in building design and, as such, include model features to address uncertainty. The simulations represent the synthetic modeled ground surface response of 30 magnitude 9.0 events occurring in the CSZ using a large-scale numerical model of the Pacific Northwest.

The shaking of a site at the ground surface is influenced by the stiffness of the surface soil. Softer soil will typically amplify ground motion shaking more than stiff soils. While the DOGAMI report includes these soil effects and the NGA-Subduction ground motion models (GMMs) can account for these effects, the Frankel et al. (2018) simulation dataset does not. For a more direct comparison, the two

new data sources (the NGA-Subduction and Frankel et al. 2018 simulations) are evaluated in the following sections for a hard soil or rock-like site condition so a consistent basis of comparison between the models can be used. Where ground motion intensity values in this study are evaluated at the ground surface, the site classes and factors commonly used in the National Earthquake Hazards Reduction Program (NEHRP) are used to adjust the earthquake intensity hard-soil and rock condition to a surface condition in order to reflect the soft site soils. The NEHRP site factors are a simplified intensity-dependent ratio of ground motion intensity between stiff and soft sites, and they are widely adopted in design standards, such as the Oregon Structural Specialty Code, International Building Code, and American Association of State and Highway and Transportation Officials seismic design standards.

4.1.1 NGA-Subduction Ground Motion Models

The NGA-Subduction project is one of a series of research projects created to facilitate the development of ground motion models for use in seismic hazard assessments. Previous NGA projects were done for shallow crustal earthquakes (NGA-West1 and NGA-West2) and for stable continental regions (NGA-East) and the resulting models are widely used in the International Building Code (IBC) and in other design and research applications. The NGA-Subduction project is focused on the development of ground motion models for subduction zones and results from this project are in the process of being published.

Two ground motion models have been produced from the NGA-Subduction project, the Kuehn et al. (2020) model (KBCG20), and the Parker et al. (2020) model (PSHAB20). These models use information about a specified earthquake scenario to estimate the intensity of ground shaking at a site. Typical inputs for these models include the earthquake magnitude, rupture distance from the site to the epicenter, site soil stiffness, and depth to the rupture. Because of the variability and uncertainty of the ground motion shaking for a specified earthquake scenario, the models are used to develop percentiles of the ground motion intensity response. For example, for a given earthquake scenario, the ground motion models are commonly used to estimate a median, 50th percentile ground motion intensity response, in which half of the modeled ground motions values are greater than and half less than the median response. Instead of only evaluating the median (50th percentile) ground motion, it is standard practice to also consider the 84th percentile intensity response, which represents the median response plus a standard deviation (or “sigma”) of the response values.

Ground motion models, such as the KBCG20 and PSHAB20, which consider the effects of uncertainty on the level of ground motion shaking are commonly adapted for use in seismic hazard assessments that depend on the likelihood of a certain level of ground motion shaking occurring, such as in the seismic design of new buildings.

4.1.2 Frankel et al. (2019) Simulations

A series of simulations of ruptures of the CSZ interface were conducted and published in Frankel et al. (2019). Thirty ruptures of magnitude 9.0 and greater of the CSZ were modeled for a variety of rupture parameters and locations along the CSZ interface zone. One of the products of these simulations are synthetic ground motion recordings at locations throughout the Pacific Northwest. The synthetic

seismograms are representative of individual earthquake events and are not comprehensive or representative of the full range of uncertainty of ground motions due to a CSZ interface event.

For this study, the ground motions were selected for the model grid point nearest 45.57 degrees N, -122.76 degrees E, the closest model grid point to the project study area. The synthetic ground motions are two-component (north-south and east-west) synthetic acceleration time histories for a stiff soil condition. The soil condition used at the ground surface in the Frankel et al. (2019) model is a site with time averaged shear wave velocity in the top 100 feet (30 meters) of approximately 2,000 feet per second (600 meters per second). Figure 4.1 below shows the response spectrum for the 60 acceleration time series selected from the Frankel et al. (2019) model in blue with the median in red.

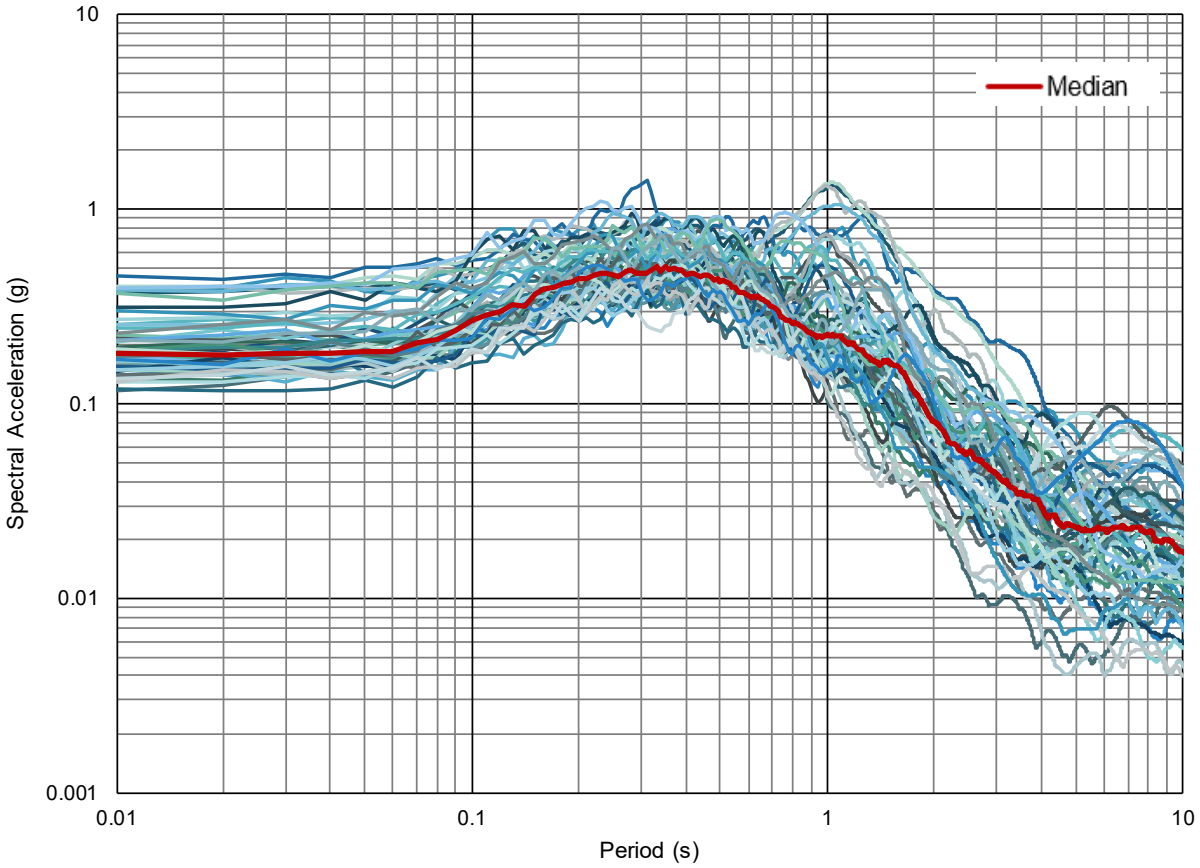


Figure 4.1 CSZ Ground Motion Components (Frankel et al. 2019)

4.1.3 Ground Motion Intensity Comparison

This study evaluates the level of shaking at the project sites of interest for a magnitude 9.0 rupture of the CSZ. This is commonly referred to as a "deterministic" event; the computed level of ground motion shaking is computed for a specific event and the likelihood of that event occurring is not considered. In analyses where the likelihood of a seismic event occurring is considered, the seismic assessment is referred to as "probabilistic." Structures designed using the IBC are typically designed considering the

lesser of an 84th percentile deterministic event and a probabilistic hazard assessment for a probability of exceedance of 2 percent in 50 years.

In engineering design, the ground motions due to seismic shaking are commonly transformed to a spectral acceleration response spectrum that can be used to model how an earthquake is experienced by a building/structure, Spectral acceleration values for the available calculation methods are shown on Figure 4.2 below for a stiff soil or rock-like Site Class B/C condition. The black line represents a probabilistic geometric mean spectrum from the 2014 USGS hazard maps commonly used in IBC design for new construction. This probabilistic curve includes the effects of both subduction events and shallow crustal events, represents the hazard of a 2 percent probability of exceedance in 50 years (equivalent to a 2,475-year return period), and is shown for comparison only. The red and blue lines are computed from the PSHAB20 and KBCG20 GMMs, respectively, with the solid lines representing the median and dashed lines representing the 84th-percentile ground motion (median plus one standard deviation, sigma). The PSHAB20 and KBCG20 GMMs were computed using the earthquake characteristics shown in Table 4.1 below. The green line is the median of the Frankel et al. (2019) simulations. The gray points are the surface intensity values from the DOGAMI (2018) report decreased by a factor of 1.2 to remove the effects of soft soil amplification and approximate a stiff soil or rock-like condition similar to the condition used for the other lines plotted on the figure. The 1.2 factor is consistent with the NEHRP amplification ratio between the site class used in the DOGAMI (2018) map near the project site (Class D, representative of the surface soil condition) and the site class used in this study for the Frankel et al. (2018) simulations and NGA-Sub GMMs (Class C, representative of a stiff soil or soft rock condition).

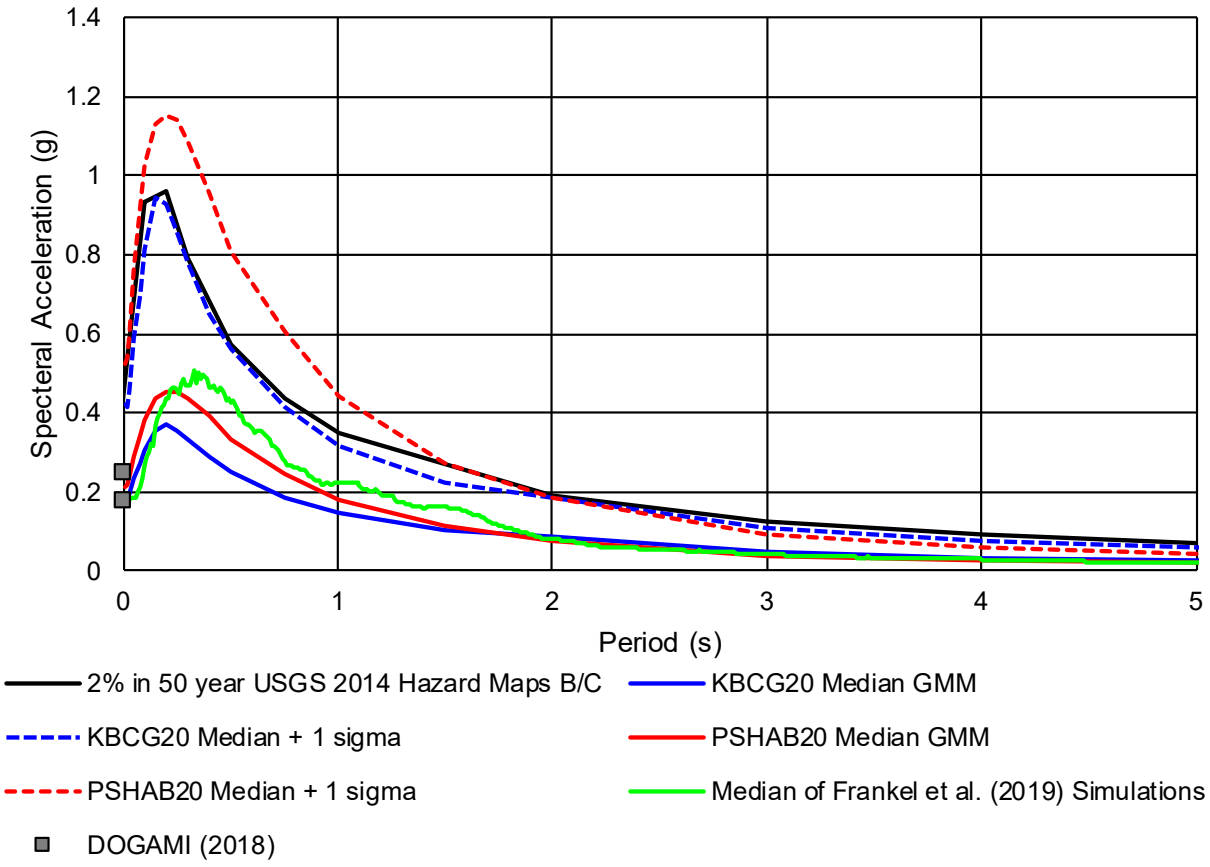


Figure 4.2 CSZ Spectral Response

Table 4.1 - KBCG20 and PSHAB20 Earthquake Parameters

Parameter	Value
Region and Type	Cascadia Interface
Moment Magnitude	9.0
V_{S30}	760 meters per second
Rupture Distance	72 kilometers
Rupture Depth	10 kilometers

Figure 4.2 indicates that the level of ground motion shaking shown in the DOGAMI hazard maps is similar to the intensity estimated from the most recent ground motion models for a CSZ rupture. However, the uncertainty range of the GMMs indicates that an 84th percentile event represents a significantly higher level of ground motion shaking than the median earthquake event; specifically, the peak ground acceleration (equivalent to the spectral response at a period of zero seconds) is approximately 100 percent higher for the 84th percentile event than the median event.

The median of the Frankel et al. (2019) simulations have a similar PGA as both the DOGAMI hazard maps and the KBCG20 and PSHAB20 ground motion models. The PGA values of the simulated ground motions range from 0.12 to 0.45. The simulations represent a range of rupture scenarios for the CSZ, not just a worst-case scenario. The similarity of the simulations to the other estimates of ground motion

shaking indicate that the site is susceptible to strong shaking from interface CSZ events anywhere along the fault.

The scope of the liquefaction and lateral spread analyses presented later in this section only considered the median event at the ground surface and not also the 84th percentile event (sigma event).

4.2 Representative Soil Information and Liquefaction Analysis

Available geotechnical subsurface soil information was collected for the areas of interest of this study. This section presents the generalized subsurface conditions of the soil at each of the locations. The characterization of the soil at these sites is representative only and not intended to replace a more detailed geotechnical design study at each location, and the values provided in this report are not intended for use in geotechnical design. The references for the geotechnical reports and other subsurface information cited in this section can be found in the attached Table 2.1.

Key information from the geotechnical reports used to characterize subsurface conditions at the sites primarily included logs of mechanically drilled borings and cone penetration test (CPT) soundings. From the borings, we evaluated standard penetration test (SPT) blow count (N_{SPT}) data, which is a standardized soil sampling method used throughout the geotechnical industry. The CPT soundings include advancing a steel probe equipped with electronic instrumentation to measure resistance, friction, and other soil parameters. Equivalent N_{SPT} values can be obtained from CPT soundings to help compare data to the drilled borings.

The soil at each area was generalized into stratigraphic units that were evaluated for their potential for immediate liquefaction settlement, an approximate upper and lower bound of N_{SPT} values and a representative fines content in the soil layer. The upper and lower bound N_{SPT} values are used to provide a range of anticipated liquefaction settlement at each site, lower N_{SPT} values indicate larger amounts of potential surface settlement during an earthquake. For the lateral spread analyses, only the lower-bound N_{SPT} profile was used.

The subsurface soil information in this section considers fine-grained soils as generally "non-liquefiable" as the focus of this study is on immediate ground surface settlements that will occur following an earthquake event. While fine-grained soils, such as silt and clay, may experience strength loss during an earthquake that results in failure of foundations and structures at the ground surface, these soils generally contribute less to ground surface settlement than coarse-grained sand and gravel. A detailed design study for each of the project areas, including further review of soil laboratory testing data may be required to characterize the likelihood of strength loss in the fine-grained soil deposits.

4.2.1 Area 1 - Kinder Morgan North

Geotechnical soil information for Area 1 is documented in a report by GeoEngineers (2011). The soil at the site generally consists of a dense layer of gravel and coarse-grained fill over layers of layers of silt and clay that appear to be generally non-liquefiable. Approximately 38 to 40 feet below the ground surface (bgs) is a unit of potentially liquefiable coarse-grained sandy silt and silt with sand that may

have beds of fine-grained clayey silt and silty clay. The groundwater table appears to be approximately 4 feet bgs. The representative stratigraphy of the area is shown in Table 4.2 (below).

The range of N_{SPT} values for the stratigraphic units are equivalent corrected blow counts from CPT soundings in the area as provided in the GeoEngineers (2011) report.

Table 4.2 - Kinder Morgan North Area Soil Stratigraphy

Stratigraphic Unit	Potentially Liquefiable	Upper Bound N_{SPT} (blows/foot)	Lower Bound N_{SPT} (blows/foot)	Fines Content (percent)	Thickness (feet)
Gravel and Silty Sand Fill	Yes	50	50	10	4
Clayey Silt to Silty Clay	No	11-22	5	60	34
Silty Sand	Yes	27	16	50	6
Clayey Silt to Silty Clay	No	50	13	60	2
Sand with Silt	Yes	35	21	40	4
Basalt	Top of bedrock encountered at approximately 50 feet below ground surface				

4.2.2 Area 2 - Linnton

The Linnton Area has the most available subsurface information of the areas reviewed in this study. Therefore, there was enough information for Area 2 information to characterize the northern and southern parcels separately.

4.2.2.1 North Area 2 - Linnton

Geotechnical soil information for the north region of Area 2 is documented in a series of reports from URS Corporation (2006, 2007a, 2007b), Professional Service Industries, Inc. (PSI) (2015) and Hart Crowser (1992). The stratigraphy generally consists of liquefiable coarse-grained fill and stream deposits overlying a layer of non-liquefiable fine-grained deposits, which overlies a deeper layer of liquefiable coarse-grained alluvial deposits. The ordinary high-water elevation was considered the top of the groundwater table at this site and is approximately 14 feet bgs. The representative stratigraphy of the area is shown in Table 4.3.

Table 4.3 - Linnton Northern Area Soil Stratigraphy

Stratigraphic Unit	Potentially Liquefiable	Upper Bound N_{SPT}	Lower Bound N_{SPT}	Fines Content (percent)	Thickness (feet)
Sandy Fill with Silt	Yes	22	8	10	20
Coarse-Grained Stream Deposits	Yes	N/A	10	10	0-10
Fine-Grained Alluvial Deposits	No	20	12	70	10-20
Sandy Alluvial Deposits	Yes	22	14	10	30
Basalt	Top of bedrock encountered at approximately 70 feet below ground surface				

In the series of URS reports the average N_{SPT} values for each of the stratigraphic units is reported and plotted with all available N_{SPT} measurements. The upper- and lower-bound N_{SPT} values were selected to represent reasonable upper and lower bounds of the available N_{SPT} data. These values are generally consistent with the noted subsurface information in the PSI and Hart Crowser reports.

The liquefiable coarse-grained stream deposits do not appear to be present throughout the site. However, because these soils represent a significant contribution to the potential for liquefaction settlement and lateral spread in the area of the site, they were considered to be 10 feet thick in the analysis of the lower-bound N_{SPT} values only and not in the upper-bound N_{SPT} value analysis.

4.2.2.2 South Area 2 - Linnton

Geotechnical soil information for the southern region of Area 2 is documented in a series of reports and technical memoranda by CH2MHILL (2006a, b, c, and d) and a report by Dames and Moore (1981). The soil generally consists of coarse-grained liquefiable gravel fill and silty sand overlying non-liquefiable fine-grained silt and clay. The groundwater table is indicated to be at approximately 18 feet bgs.

In the CH2MHILL reports, N_{SPT} values of the stratigraphic units are reported as a range. The upper and lower N_{SPT} values are taken as the middle of the range plus and minus 25 percent of the range.

Table 4.4 - Linnton Southern Area Soil Stratigraphy

Stratigraphic Unit	Potentially Liquefiable	Upper Bound N_{SPT}	Lower Bound N_{SPT}	Fines Content (percent)	Thickness (feet)
Gravel Fill	Yes	17	7	5	10
Silty Sand	Yes	9	5	45	20
Silt and Clay	No	20	9	75	35
Basalt	Top of bedrock encountered at approximately 65 feet below ground surface				

4.2.3 Area 3 - NW Natural

The subsurface soil information of Area 3 is characterized in a series of geotechnical reports by GeoEngineers (2005, 2012, 2015, 2016. 2018). Soil in this area generally consists of a unit of liquefiable coarse-grained sandy silt and fill over a thicker layer of non-liquefiable fine-grained alluvial silt. The groundwater table appears to be approximately 10 feet bgs from soil borings at the site. Soil stratigraphy information is provided in Table 4.5.

The N_{SPT} values for each of the stratigraphic units were approximated as the average of N_{SPT} values from the stratigraphic units as measured in four soil borings at the site plus and minus one half of the standard deviation.

Table 4.5 - NW Natural Northern Area Soil Stratigraphy

Stratigraphic Unit	Potentially Liquefiable	Upper Bound N_{SPT}	Lower Bound N_{SPT}	Fines Content (percent)	Thickness (feet)
Sandy Silt and Poorly Graded Sand Fill	Yes	17	7	10	20
Fine-Grained Alluvial Silt	No	8	5	80	55
Basalt	Top of bedrock encountered at approximately 80 feet below ground surface				

4.2.4 Area 4 - Willbridge

The subsurface soil information of Area 4 is characterized in reports by GeoEngineers (1998, 2000a, 2000b), PSI (2015), AMEC Earth and Environmental (2004), URS Corporation (2001) and the City of Portland (1968). However, much of the soil information in these reports only extends to depths of 20 to 40 feet bgs and does not extend to the top of the basalt bedrock. The GeoEngineers (1998) and PSI (2015) reports were the reports most significantly used to develop the generalized stratigraphy profile in Table 4.6 for Area 4.

The stratigraphy in Area 4 generally consists of liquefiable sandy fill and loose sand overlying a layer of fine-grained non-liquefiable stiff silt. Below the silt is a layer of liquefiable loose sand deposits. The groundwater table appears to be approximately 10 feet bgs.

Upper and lower bounds for the N_{SPT} values were computed from soil borings in the GeoEngineers (1998) and PSI (2015) reports that extended to the basalt. The N_{SPT} values were approximated as the average of N_{SPT} values from the stratigraphic units as measured in three soil borings at the site plus and minus one half of the standard deviation. The N_{SPT} values from this subset of the soil information available for the site are generally representative of the soil conditions documented in the other subsurface information reports.

Table 4.6 - Willbridge Area Soil Stratigraphy

Stratigraphic Unit	Potentially Liquefiable	Upper Bound N_{SPT}	Lower Bound N_{SPT}	Fines Content (percent)	Thickness (feet)
Sandy Fill and Loose Sand	Yes	19	9	5	25
Stiff Silt	No	9	9	75	15
Loose Sand	Yes	8	8	5	10
Basalt	Top of bedrock encountered at approximately 50 feet below ground surface				

4.2.5 Area 5 - Equilon

The subsurface soil information of Area 5 is characterized in reports by GeoDesign Inc. (2006), Rittenhouse-Zeman and Associates, Inc. (1990) and Shannon and Wilson, Inc. (1965). The soil at the site generally consists of a layer of liquefiable loose sand and sandy fill over a layer of stiff silt overlying a layer of liquefiable loose sand. The groundwater table appears to be at a depth of approximately 10 feet bgs. The stratigraphy information for Area 5 is shown in Table 4.7 (below).

Area 5 has generally lower N_{SPT} values for similar stratigraphic units than the other areas. The deep layer of loose sand did not have any N_{SPT} values at this location and so the N_{SPT} values of Area 4 were assumed. The Upper and Lower bound N_{SPT} Values in table 4.7 represent the range of N_{SPT} values measured in each stratigraphic layer. However, because there is so little variability in these values relative to the mean, the standard deviation of N_{SPT} was not considered for this site as it was for Areas 3 and 4.

Table 4.7 - Equilon Area Soil Stratigraphy

Stratigraphic Unit	Potentially Liquefiable	Upper Bound N_{SPT}	Lower Bound N_{SPT}	Fines Content (percent)	Thickness (feet)
Sandy Fill and Loose Sand	Yes	7	4	5	25
Stiff Silt	No	6	4	75	20
Loose Sand	Yes	8	8	10	10
Basalt	Top of bedrock encountered at approximately 50 feet below ground surface				

4.3 Surface Settlement Due to Liquefaction of Coarse-Grained Soil

Each of the characteristic soil profiles in the five areas were evaluated for estimated surface settlement due to liquefaction. The simplified Idriss and Boulanger (2008) procedure for estimating liquefaction effects during an earthquake was used. This calculation method uses the soil information provided in Tables 4.2 through 4.7 above and parameters for a characteristic earthquake. The earthquake used in this analysis was a magnitude 9.0 earthquake with a ground surface PGA of 0.3 g, which is approximately equal to the median surface response of a deterministic event as discussed in *Section 4.1 CSZ Earthquake Ground Motion Shaking Intensity*. The estimated surface settlement at each area is shown in Table 4.8.

Table 4.8 - Estimated Surface Settlement due to Liquefaction

Area	Estimated Settlement (inches)	
	Upper Bound N_{SPT} Profile	Lower Bound N_{SPT} Profile
Area 1 - Kinder Morgan North	0	2
Area 2 - Linnton North	8	19
Area 2 - Linnton South	7	8
Area 3 - NW Natural	3	9
Area 4 - Willbridge	9	14
Area 5 - Equilon	15	17

Additional estimates of surface settlement are included for some of the areas in the geotechnical reports reviewed in this study. These surface estimates are generally not evaluated for a deterministic CSZ event and use a probabilistic earthquake hazard level. A summary of the available estimates of surface settlement from these reports is in Table 4.9 below. The estimates in Area 2 North and Area 4 are based on shallow exploration data and do not consider settlement of the soil from the ground surface to the bedrock, including the deep liquefiable sand layer observed in some of the areas. The more detailed estimate of surface settlement for Area 2 South in the CH2MHILL (2006) report computed with the Ishihara and Yoshimine (1992) simplified method generally agrees with the estimate from this study in Table 4.8.

Table 4.9 - Reported Surface Settlement in Reviewed Historical Reports

Area	Reported Surface Settlement	Report	Method
Area 2 - Linnton North	1.5 to 1.75 inches	PSI (2015)	CPT
Area 2 - Linnton South	6 to 9 inches	CH2MHILL (2006)	Ishihara and Yoshimine (1992)
Area 4 - Willbridge	3 to 4.25 inches	GeoEngineers (1998)	CPT

4.4 Lateral Spread Potential

The estimated lateral spread at each site was evaluated for the five areas using the Youd, Hansen, and Bartlett (2002) simplified procedure. The Youd, Hansen, and Bartlett (2002) procedure estimates the amount of horizontal movement at a location on a slope or some distance away from a free-standing soil face due to earthquake-induced liquefaction of coarse-grained soil.

The inputs to the Youd, Hansen, and Bartlett (2002) simplified procedure include earthquake magnitude and distance, the cumulative thickness of liquefiable soil units at the site, the average mean grain size of the granular layers (D_{50}), the average fines content of the granular layers, and information about the geometry of the slope. The Youd, Hansen, and Bartlett (2002) procedure is limited to earthquake magnitudes 6 to 8, and a magnitude 8 earthquake was considered for this study. If the procedure is extrapolated to a magnitude 9 earthquake, the estimated lateral spread increases by a factor of 7. The earthquake distance used was 70 kilometers and is consistent with the deterministic seismic hazard analyses discussed in *Section 4.1 CSZ Earthquake Ground Motion Shaking Intensity*. The thickness of the liquefiable soil layers and fines content of the soil layers used in this analysis is consistent with the stratigraphy profiles given in *Section 4.2 Representative Soil*

Information. A single representative D_{50} of 0.25 millimeters for all granular soil was estimated from the laboratory testing results provided in the historical subsurface information documents discussed in *Section 4.2 Representative Soil Information*. The range of the D_{50} for both the shallow and deep granular materials was fairly consistent and ranged from 0.1 to 0.7 millimeters.

The Youd, Hansen, and Bartlett (2002) correlations depend on the geometry of the site investigated and consider either a sloping ground condition or a free-face condition. For this study, we evaluated the surface profile at each area on the cross-section lines shown on Figures 1.5 to 1.9 using LiDAR data (DOGAMI 2014) for upland topography and bathymetry data (2005) for offshore slopes. Generally, the areas at each of the sites where tanks are located are flat and has little to no slope. However, along the Willamette River, there is a consistent elevation change from the ground surface down to the edge of the river. Under the surface of the river, the slope of this elevation change generally becomes more gradual and the submerged slope ends at approximately the same elevation as the basalt encountered in the reviewed borings. In this preliminary study, we considered the elevation change from the upland ground surface to the approximate bottom of the submerged slope as a free-face soil condition that ranged from 50 to 70 feet tall for most locations. For Area 3, we considered the height of the free face only to include the surficial liquefiable sand as the free face condition that has a height of 20 feet. Horizontal lateral spread displacement estimates are provided in Table 4.10 below as a function of distance from the soil free-face.

Table 4.10 - Estimated Lateral Spread at Each Area Varied by Distance to Free Face

Area	Estimated Lateral Spread (feet)				
	Distance to Free Face of Soil				
	50 Feet	100 Feet	250 Feet	500 Feet	1000 Feet
Area 1 - Kinder Morgan North	8	5	3	2	1
Area 2 - Linnton North	20	13	8	5	3
Area 2 - Linnton South	13	9	5	3	2
Area 3 - NW Natural	6	4	2	2	1
Area 4 - Willbridge	14	9	5	4	2
Area 5 - Equilon	15	10	6	4	2

Geotechnical reports for locations in some of the areas reviewed for this study included estimates of lateral spread as shown in Table 4.11. As with the liquefaction settlement analyses discussed in Section 4.3, these reports evaluate the lateral spread potential for a probabilistic design condition and not a deterministic condition representative of a magnitude 9 subduction event. The CPT analyses in PSI (2015) and Geoengineers (1998) do not consider surface geometry, are of limited depth, and are simplified procedures similar to the Youd, Hansen, and Bartlett (2002) analysis conducted for this study.

The CH2MHILL (2006) analysis was a 2-dimensional finite difference model run with the software FLAC for the edge slope of the soil along the Willamette River, the same slope considered a free-face in this study. The FLAC analyses were conducted with detailed soil models for a series of earthquake time histories to model the behavior of the slope during an earthquake. While there have been several advancements in numerical modeling and understanding subduction zone earthquake hazards in the

Portland area, the analyses conducted in the CH2MHILL report are generally representative of detailed, high-quality analyses and result in a similar maximum displacement as estimated with the Youd, Hansen, and Bartlett (2002) analysis above.

Table 4.11 - Reported Surface Settlement in Reviewed Historical Reports

Area	Reported Lateral Spread	Report	Method
Area 2 - Linnton North	1.3 to 1.8 feet	PSI (2015)	CPT
Area 2 - Linnton South	1.2 to 12.7 feet	CH2MHILL (2006)	2D FLAC Nonlinear Analysis
Area 4 - Willbridge	4.6 to 6.7 feet	GeoEngineers (1998)	CPT

5.0 TECHNICAL REFERENCES

References for project-specific documents reviewed are included in Table 2.1.

Bozorgnia, Yousef, and Jonathan Stewart. "Data Resources for NGA-Subduction Project." PEER Report 02/2020, Pacific Earthquake Engineering Research Center, UC Berkeley.

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Evarts, R.C., J.E. O'Connor, R.E. Wells, and I.P. Madin 2009. The Portland Basin: A (big) river runs through it. GSA Today, 19(9), pp.4-10.

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Youd T.L., C.M. Hansen, and S.F. Bartlett 2002. Revised Multilinear Regression Equations for Prediction of Lateral Spread Displacement. Journal of Geotechnical and Geoenvironmental Engineering, Vol. 128, No. 12.

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Table 2.1: Documents Reviewed
Portland, Oregon

	Author	Document	Date	Format	Summary
1	AMEC Earth & Environmental	Geotechnical Engineering Report, Chevron Asphalt Facility, Portland, Oregon	December 2004	Report	Subsurface information related to the design and construction of a new rail spur track and driveway for truck shipments.
2	AMEC Earth & Environmental	Locations of Deep Gravel, Hydrogeologic Zone Pumping Test Wells, Constructed on City of Portland Property in 2008	January 2009	Report Excerpt	Only Figure 1 and Borings EX-S-03-123, EX-S-04-125, EX-S-05-125, PM-01-018, PM-01-085, PM-01-120, PM-01-147, and PM-05-024.
3	CH2MHILL (2006a)	Geotechnical Data Report, Valero LP Portland Terminal, Tank Farm Expansion Project	June 2006	Report	Subsurface information related to the design and construction of two new 100,000-barrel gasoline/diesel storage tanks.
4	CH2MHILL (2006b)	Geotechnical Recommendations Report, Valero LP Portland Terminal, Tank Yard 5 Expansion Project	June 2006	Report	Subsurface information and interpreted soil parameters related to the design and construction of two new 100,000-barrel gasoline/diesel storage tanks.
5	CH2MHILL (2006c)	Seismic Site Hazard Report, Valero LP Portland Terminal, Tank Yard 5 Expansion Project	August 2006	Report	Subsurface information and interpreted soil parameters for a seismic hazard analysis related to the design and construction of two new 100,000-barrel gasoline/diesel storage tanks.
6	CH2MHILL (2006d)	Valero LP Portland Terminal Tank Yard 5 Expansion Project	October 6, 2006	Technical Memorandum	Interpreted soil properties for proposed jet grout ground improvements related to the design and construction of two new 100,000-barrel gasoline/diesel storage tanks.
7	City Club of Portland	Big Steps Before the Big One: How the Portland area can bounce back after a major earthquake	February 14, 2017	Report	Research report on the resiliency of the City of Portland area.
8	City of Portland, Oregon	Portland Maps	December 24, 2020	Website	Online mapping service
9	City of Portland, Oregon	CoP Application for Permit #2018-181859-000-00-CO	August 21, 2018	Permit Application	Accessed via Portland Maps website on May 7, 2021
10	City of Portland, Oregon	Geotechnical Investigation, Ramsey Lake Trunk Sewer, CSO Combination, BES Project Number 5273	December 20, 1994	Report	NOT IN PROJECT AREA
11	City of Portland, Oregon	Site plans of Equilon and Zenith Properties with tank content information.	No dates	Site plans	Mark ups provide fill and content info for some tanks on Equilon and Zenith properties. Plans were provided by CoP Bureau of Emergency Management and the Portland Fire & Resuce on May 7, 2021 via email.
12	City of Portland, Oregon	Portland Bureau of Planning and Sustainability's Fossil Fuel Terminal Zoning Amendments website	2020	Website	Provides overview of the Fossil Fuel Terminal Zoning Amendments that restrict the development of new and expansion of storage tank capacity at existing terminals.
13	City of Portland, Oregon	NW Saltzman Road, Culvert Replacement City Map	April 2002	Report Excerpt	Only Plates 1-11, Borings 1-9
14	City of Portland, Oregon	NW St. Helens Rd. NW 35th Ave. Sanitary Sewer System	June 1968	Report Excerpt	Boring Logs and Maps only
15	City of Portland, Oregon	SLRT Monitoring Demolition and Installation Project E10516	November 24, 2014	Report Excerpt	Only Logs HA-1a, HA-1b, HA-2 and HA-3.
16	Cone, Paul City of Portland	CEI Hub analysis	Updated December 4, 2020	Web Map	Web map of the CEI Hub based of data gathered during the 2019 PSU study.
17	Dames & Moore	Final Report, Extended Soils Investigation and Oil Seepage Control Scheme, Portland Terminal, Portland, Oregon	January 13, 1981	Report	Subsurface information related to the design and construction of a cement-bentonite cutoff wall.
18	Dames & Moore	Foundation Investigation, Proposed Whirly Crane, 3450 N.W. Front Street, Portland, Oregon	August 1972	Report Excerpt	Only Plate 1 and Boring 2

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	Author	Document	Date	Format	Summary
19	DOGAMI	DOGAMI Open-File Report O-18-02 Earthquake Regional Impact Analysis For Clackamas, Multnomah, and Washington Counties, Oregon	2018	Website	Provides information about potential impacts to Multnomah county from a magnitude 9 Cascadia Subduction Zone earthquake.
20	Dusicka, P. and Norton, G. Portland State University	Liquid Storage Tanks at the Critical Energy Infrastructure (CEI) Hub; Seismic Assessment of Tank Inventory	No Date	Presentation	Summary of the Seismic Assessment of Tank Inventory report completed in 2019.
21	Dusicka, P. and Norton, G. Portland State University	Liquid Storage Tanks at the Critical Energy Infrastructure (CEI) Hub; Seismic Assessment of Tank Inventory	May 2019	Report	Summary of tank failures in past earthquakes, data on CEI Hub tanks, CEI Hub tank inventory, and potentially mitigation options.
22	Fore K. and Mills, M. Oregon Solutions	Critical Energy Infrastructure Hub	March 2019	Report	Assessment to determine potential avenues for collaborative action that could increase resiliency of the CEI Hub.
23	GeoDesign Inc	Report Of Geotechnical Engineering Services, Penske Property, 4285 NW Yeon Avenue, Portland, Oregon	July 25, 2006	Report	Subsurface information related to the design and construction of a new 5,000 square foot single story building.
24	GeoEngineers	Site Specific Seismic Hazard Report, Proposed New Pre-fabricated Metal Building, Northwest Natural Gasco Facility, 7900 NW Street Helens Road, Portland, Oregon, File No. 6024-002-06	November 7, 2012	Letter Report	Subsurface information and interpreted soil parameters for a site specific seismic hazard analysis related to the design and construction of a new fabricated metal building.
25	GeoEngineers	Geotechnical Engineering Report, Gasco LNG Tank Containment Retrofit, Portland LNG Plant, Portland, Oregon	June 1, 2018	Report	Subsurface information related to the retrofit of an existing containment basin.
26	GeoEngineers	Geotechnical Engineering Report, Gasco Water Tank and Ancillary Building, Portland, Oregon	November 3, 2005	Report	Subsurface information related to the design and construction of a new water storage tank and an associated building.
27	GeoEngineers	Geotechnical Engineering Report, Proposed Communication Tower, Portland LNG Plant, Portland, Oregon	July 22, 2015	Report	Subsurface information related to the design and construction of a new 80-foot-tall steel lattice communication tower.
28	GeoEngineers	Geotechnical Engineering Report, Tank No. 51 Replacement Project, Chevron Willbridge Terminal, Portland, Oregon	November 18, 1999	Report	Subsurface information related to the design and construction of a new storage tank.
29	GeoEngineers	Geotechnical Engineering Services, Soil Liquefaction and Lateral Spreading Mitigation, Linnton Terminal Tank Replacement, Portland, Oregon	January 7, 2011	Report	Subsurface information and interpreted soil parameters for liquefaction-induced settlement and lateral spreading mitigation related to the design and construction of a new storage tank, including compaction grouting ground improvement.
30	GeoEngineers	Geotechnical Engineering Services, Willbridge Terminal Tank Replacement, Portland, Oregon	July 25, 2011	Report	Subsurface information and soil parameters related to the design and construction of three (3) new 120,000 bbl storage tanks, including liquefaction and slope stability analyses.
31	GeoEngineers	Report of Geotechnical Engineering Services, Tank No. 62 Replacement Project, Chevron Willbridge Terminal, Portland, Oregon	October 15, 1998	Report	Subsurface information related to the design and construction of a new storage tank.

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	Author	Document	Date	Format	Summary
32	GeoEngineers	Geotechnical Engineering Report, Portland LNG Plant - New Heater System, Portland, Oregon, File No. 6024-172-01	January 22, 2016	Report & Addendum Letter	Subsurface information and interpreted soil parameters related to the design and construction of a new oil heater, heat exchanger, and associated piping, including liquefaction and lateral spread analyses.
33	GeoEngineers (2000a)	Geotechnical Engineering Report, Tank No. 60 Replacement Project, Chevron Willbridge Terminal, Portland, Oregon	August 7, 2000	Report	Subsurface information related to the design and construction of a new storage tank.
34	GeoEngineers (2000b)	Geotechnical Engineering Report, Willbridge Intercompany Pipeline, Portland, Oregon	June 8, 2000	Report	Subsurface information related to the design and construction of a new pipeline and vapor recovery unit.
35	Goldfinger, Chris	Turbidite Event History - Methods and Implications for Holocene Paleoseismicit of the Cascadia Subduction Zone	2012	Professional Paper	Study of turbidites to develop of record of paleoearthquakes in the Cascadia Subduction Zone.
36	Hart Crowser	Geotechnical Engineering Design Study, Proposed Fender Pile Replacement, ARCO Products Company Bulk Terminal, Portland, Oregon	November 30, 1992	Report	Subsurface information related to new breasting and mooring dolphins.
37	Johnston, Mark, OSFM	Interview with Della Graham, Hart Crowser	December 4, 2020	Interview	Phone call with Mark Johnston, Regulatory Services Division, Oregon Office of State Fire Marshal
38	Johnston, Mark, OSFM	Interview with Della Graham, Hart Crowser	January 6, 2021	Interview	Phone call with Mark Johnston, Regulatory Services Division, Oregon Office of State Fire Marshal
39	Multnomah County	Multnomah County Services Contract Number: DCA-SVCSGEN-12459-2021	April 13, 2020	Contract	Services Contract
40	Oregon Department of Energy	2020 Biennial Energy Report	November 2020	Report	A comprehensive review of energy resources, policies, trends, and forecasts for the State of Oregon.
41	Oregon Seismic Safety Policy Advisory Commission	CEI Hub Mitigation Strategies	December 31, 2019	Report	Mitigation strategies for the CEI Hub including increasing fuel resilience to survive Cascadia.
42	Oregon State Police	Oregon State Fire Marshal Survey Information Instructions	No Date	Document	Instructions for yearly reporting of hazardous substance storage in the State of Oregon.
43	Oregon State Police	Oregon State Fire Marshal Hazardous Materials Database	Accessed December 4, 2020	Web Portal	Hazardous substance storage information and incident reports from emergency responders.
44	PacRim Geotechnical Inc.	Geotechnical Report, Proposed Replacement Of Asphalt Tanks, 5480 Front Avenue, Portland, Oregon	December 10, 1999	Report	Subsurface information related to the design and construction of four (4) new storage tanks.
45	Papaefthimiou, J. and Fore, K. Portland Bureau of Emergency Management	City of Portland & Critical Energy Infrastructure Hub	January 2019	Presentation	Summary of the Linnton community risks associated with the CEI Hub
46	Professional Service Industries, Inc.	Geotechnical Engineering Report, Proposed 90,000 Gallon Butane Tank, BP West Coast Products Company, Portland Terminal, 9930 NW St. Helens Road, Portland, Oregon	June 26, 2014 (Revised: February 13, 2015)	Report	Subsurface information and interpreted soil parameters for a site-specific hazard analysis related to the design and construction of a new 90,000-gallon butane storage tank, including drilled pier foundations.
47	Professional Service Industries, Inc.	Geotechnical Engineering Report, Proposed 90,000-Gallon Butane Tank, Chevron USA, Willbridge Terminal, 5924 NW Front Avenue, Portland, Oregon	June 5, 2015 (Revised: September 11, 2015)	Report	Subsurface information related to the design and construction of a new 90,000-gallon butane storage tank and blending facility, including drilled pier foundations.

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	Author	Document	Date	Format	Summary
48	Rittenhouse-Zeman & Associates, Inc.	Subsurface Exploration And Geotechnical Engineering Report, Texaco TRMI Distribution Center, Portland, Oregon	June 1990	Report	Subsurface information related to the design and construction of a new 113,500 bbl gasoline storage tank.
49	Shannon and Wilson, Inc.	Subsurface Investigation, Guilds Lake Interceptor Sewer & Portsmouth Tunnel, Portland, Oregon	October 20, 1965	Report	Boring Logs and Maps only
50	Steven, Thompson & Runyan, Inc.	Unit 2 Phase II Linnton Interceptor Boring Logs	November 30, 1973	Report Excerpt	Boring Logs and Maps only
51	Tetra Tech	Mitigation Action Plan	September 2016	Report	Summary of how natural hazards will affect the City of Portland and the ways the impacts can be reduced.
52	Tony Schick Oregon Public Broadcasting	How We Mapped NW Portland's 'Tank Farms'	September 29, 2015	Article	Detailed discussion of data gathering process to map the CEI Hub.
53	URS Corporation	Final Geotechnical Analyses Report, Proposed Seawall Replacement, BP Terminal 22, Linnton, Oregon	April 2007	Report	Subsurface information related to the design and construction of a new sheet pile wall (supersedes April 2006 report).
54	URS Corporation	Final Geotechnical Report, Proposed Seawall Replacement, BP Terminal 22, Linnton, Oregon	April 2006	Report	Subsurface information related to the design and construction of a new sheet pile wall (superseded by April 2007 report).
55	URS Corporation	Geotechnical Data Report, 48" Force Main, Portland NW CSO Force Main System, Portland, Oregon	April 2001	Report	Figure 1 (site plan), Borings FM48-20 through FM48-24 with associated lab test data (particle size distribution and plasticity charts)
56	URS Corporation	Geotechnical Report, Proposed Oil-Water Separator, BP - Terminal 22, Linnton, Oregon	February 2007	Report	Subsurface information related to the design and construction of a new oil-water separator.
57	Wang, Y., Bartlett, S. F., and Miles, S. DOGAMI	Earthquake Risk Study for Oregon's Critical Energy Infrastructure Hub	August 2012	Report	Earthquake risk study of the CEI Hub as part of the Oregon Energy Assurance Project with the Oregon Department of Energy.

Table 3.1 - CEI Hub Tank Inventory
Portland, Oregon

Area 1 - Kinder Morgan North				
Kinder Morgan - North - 11400 NW St Helens Road, Portland, OR 97231 - Property ID R232828				
Tank ID[1]	**Contents**	**Capacity (Gal)**	**Year**	**Type**
KML10007	Out of Service	418,278	1922	Vertical Fixed Roof
KML11017	Out of Service	469,938	1941	Internal Floating Roof
KML11019	Out of Service	469,896	1941	Internal Floating Roof
KML17018	Gasoline	735,714	1941	Internal Floating Roof
KML17020	Gasoline	742,896	1941	Internal Floating Roof
KML17027	Gasoline	739,074	1954	Internal Floating Roof
KML20011	Diesel	856,506	1932	Vertical Fixed Roof
KML2024	Out of Service	92,896	1937	Vertical Fixed Roof
KML30016	Diesel	1,253,784	1941	Vertical Fixed Roof
KML3034	Storm Water	137,046	1925	Vertical Fixed Roof
KML305	Out of Service	12,936	1926	Vertical Fixed Roof
KML306	Out of Service	12,936	1926	Vertical Fixed Roof
KML309	Out of Service	12,936	1926	Vertical Fixed Roof
KML310	Out of Service	12,936	1926	Vertical Fixed Roof
KML312	Out of Service	12,936	1926	Vertical Fixed Roof
KML313	Out of Service	12,936	1926	Vertical Fixed Roof
KML314	Out of Service	12,936	1926	Vertical Fixed Roof
KML315	Out of Service	12,936	1926	Vertical Fixed Roof
KML326	Out of Service	12,600	NA	Vertical Fixed Roof
KML330	Out of Service	12,012	1926	Vertical Fixed Roof
KML331	Out of Service	12,936	1926	Vertical Fixed Roof
KML45028	Gasoline	1,889,538	1955	Internal Floating Roof
KML532	Out of Service	29,908	1965	Vertical Fixed Roof
KML55008	Out of Service	2,288,832	1933	Vertical Fixed Roof
KML55022	Gasoline	2,309,286	1928	Vertical Fixed Roof
KML55023	Out of Service	2,312,016	1944	Internal Floating Roof
KML59029	Gasoline	2,454,060	1955	Vertical Fixed Roof
KML72021	Diesel	2,842,297	2011	Vertical Fixed Roof
KMLSalt tower	Contact Water	22,890	NA	Vertical Fixed Roof
Area 2 - Linnton				
BP West Coast - 9930 WI/NW St Helens Road, Portland, OR 97231 - Property ID R323779				
Tank ID	**Contents**	**Capacity (Gal)**	**Year**	**Type**
No known tanks present				
BP West Coast - 9930 NW St Helens Road, Portland, OR 97231 - Property ID R498331				
Tank ID	**Contents**	**Capacity (Gal)**	**Year**	**Type**
BP1	Gasoline	3,808,434	1940	Internal Floating Roof
BP10	Diesel	1,008,840	1941	Fixed Roof
BP11	Gasoline	1,354,122	1940	Internal Floating Roof
BP12	Ethanol	605,346	1961	Internal Floating Roof
BP13	Ethanol	602,994	1961	Internal Floating Roof
BP14	Diesel	1,121,736	1942	Fixed Roof
BP15	Biodiesel	804,972	1943	Fixed Roof
BP17	Diesel	3,329,340	1940	Fixed Roof
BP18	Diesel	1,104,726	1945	Fixed Roof
BP19	Oily Wastewater	198,828	1961	Internal Floating Roof
BP2	Groundwater Remediation	1,231,000	1957	Internal Floating Roof
BP21	Gasoline additive	220,080	1961	Fixed Roof
BP24	Gasoline Additive	20,286	1970	Fixed Roof
BP25	Gasoline Additive	20,241	1966	Fixed Roof
BP23b	Diesel Lubricity Additive	2,100	2005	Horizontal Tank
BP23a	Diesel additive	2,000	2005	Fixed Roof
BP3	Gasoline	1,584,366	1957	Internal Floating Roof
BP4	Gasoline	1,105,860	1957	Internal Floating Roof

BP40	Unavailable	0	1954	Fixed Roof
BP41	Out of Service	0	1954	Fixed Roof
BP42	Out of Service	0	1954	Fixed Roof
BP43	Out of Service	0	1954	Fixed Roof
BP44	Out of Service	0	1954	Fixed Roof
BP45	Unavailable	0	1954	Fixed Roof
BP46	Biodiesel	221,970	1954	Fixed Roof
BP5	Gasoline	895,314	1957	Internal Floating Roof
BP6	Gasoline	1,014,384	1957	Internal Floating Roof
BP7	Gasoline	648,018	1957	Internal Floating Roof
BP8	Gasoline	790,272	1957	Internal Floating Roof
BP9	Diesel	2,295,636	1940	Fixed Roof
BP West Coast - 9900 WI/NW St Helens Road, Portland, OR 97231 - Property ID R323771				
Tank ID	**Contents**	**Capacity (Gal)**	**Year**	**Type**
No known tanks present				
BP West Coast - 9930 WI/NW St Helens Road, Portland, OR 97231 - Property ID R323758				
Tank ID	**Contents**	**Capacity (Gal)**	**Year**	**Type**
No known tanks present				
Shore Terminals - 9420 WI/NW St Helens Road, Portland, OR 97231 - Property ID R518296				
Tank ID[1]	**Contents**	**Capacity (Gal)**	**Year**	**Type**
NU23	Gasoline/Diesel additive	10,048	NA	Cone
NU24	Biodiesel additive	NA	NA	Horizontal Tank
NU30	NA	NA	NA	NA
Shore Terminals - 9420 WI/NW St Helens Road, Portland, OR 97231 - Property ID R491070				
Tank ID[1]	**Contents**	**Capacity (Gal)**	**Year**	**Type**
NU10026	Gasoline/diesel	4,200,000	2007	Internal Floating Roof
NU10027	Gasoline/diesel	4,200,000	2007	Internal Floating Roof
NU1009	Gasoline/Diesel	392,887	1981	Internal Floating Roof
NU1010	Gasoline/Diesel	393,264	1980	Internal Floating Roof
NU1011	Ethanol/Gasoline	393,149	1980	Internal Floating Roof
NU2705	Diesel	1,158,532	1980	Internal Floating Roof
NU2706	Gasoline/Diesel	1,085,895	1980	Internal Floating Roof
NU3201	Ethanol	1,264,793	1979	Internal Floating Roof
NU3203	Gasoline/Diesel	1,265,942	1979	Internal Floating Roof
NU3204	Gasoline/Diesel	1,267,302	1979	Internal Floating Roof
NU4402	Gasoline/Diesel	1,761,801	1979	Internal Floating Roof
NU4507	Out of Service	1,849,692	1980	Internal Floating Roof
NU6408	Gasoline/Diesel	2,649,782	1981	Internal Floating Roof
NU1315	Out of service	56,124	1938	Cone
NU1316	Out of service	56,112	1938	Cone
Shore Terminals - 9400 WI/NW St Helens Road, Portland, OR 97231 - Property ID R324088				
Tank ID	**Contents**	**Capacity (Gal)**	**Year**	**Type**
No known tanks present				
Shore Terminals - 9420 WI/NW St Helens Road, Portland, OR 97231 - Property ID R518295				
Tank ID[1]	**Contents**	**Capacity (Gal)**	**Year**	**Type**
NU2020	Gasoline	821,940	1935	Internal Floating Roof
NU2021	Gasoline	832,032	1935	Internal Floating Roof
NU2022	Gasoline	832,032	1935	Internal Floating Roof
NU2113	Biodiesel	865,857	1938	Internal Floating Roof
NU2511	MFO	1,060,587	1925	Cone
NU2512	MFO	1,049,587	1925	Cone
NU3510	Ethanol	1,456,019	1937	Internal Floating Roof
NU3605	MFO	1,442,470	1938	Cone
NU3614	Gasoline/Diesel	1,398,810	1958	Internal Floating Roof
NU5618	Gasoline	2,220,204	1958	Internal Floating Roof
NU5901	Gasoline	2,414,958	1929	Internal Floating Roof
NU5902	Diesel	2,386,734	1929	Internal Floating Roof
NU5919	Diesel	2,147,688	1935	Cone
NU703	Cutter	309,498	1938	Internal Floating Roof

NU8006	Gasoline/Diesel	3,379,698	1953	Internal Floating Roof
NU8007	Gasoline	3,338,748	1953	Internal Floating Roof
NU8308	Gasoline/Diesel	3,352,746	1969	Internal Floating Roof
NU181	Gasoline/Diesel additive	7,685	NA	Cone
NU195	NA	NA	NA	NA
NU212	NA	NA	NA	NA
NU5209	Gasoline/Diesel	2,190,678	1971	Internal Floating Roof
Shore Terminals - 9420 WI/NW St Helens Road, Portland, OR 97231 - Property ID R512294				
Tank ID	**Contents**	**Capacity (Gal)**	**Year**	**Type**
No known tanks present				
Area 3 - NW Natural				
Pacific Terminal Services - 7900 NW St. Helens Road, Portland, OR 97210 - Property ID R324159				
Tank ID	**Contents**	**Capacity (Gal)**	**Year**	**Type**
PA1	Residual oil	60,000	1980	NA
PA2	Diesel oil	60,000	1980	NA
PA3	Residual oil	20,000	1980	NA
NW Natrual - 7900 WI/NW St. Helens Road, Portland, OR 97210 - Property ID R324171				
Tank ID	**Contents**	**Capacity (Gal)**	**Year**	**Type**
No known tanks present				
NW Natrual - 7900 WI/NW St. Helens Road, Portland, OR 97210 - Property ID R324170				
Tank ID	**Contents**	**Capacity (Gal)**	**Year**	**Type**
PA4	Residual oil	80,000	1940	NA
PA5	Residual oil	55,000	1940	NA
NW Natrual - 7598 NW St. Helens Road, Portland, OR 97210 - Property ID R324113				
Tank ID[1]	**Contents**	**Capacity (Gal)**	**Year**	**Type**
PA6	Diesel oil	12	1988	NA
PA7	Residual oil	475	1993	NA
NWN-Tank 001	Liquefied Natural Gas	7,100,000	NA	NA
NW Natrual - 7900 WI/NW St. Helens Road, Portland, OR 97210 - Property ID R324172				
Tank ID	**Contents**	**Capacity (Gal)**	**Year**	**Type**
No known tanks present				
NW Natrual - 7441 SW/NW St. Helens Road, Portland, OR 97210 - Property ID R324165				
Tank ID	**Contents**	**Capacity (Gal)**	**Year**	**Type**
No known tanks present				
NW Natrual - 7441 NW St. Helens Road, Portland, OR 97210 - Property ID R324160				
Tank ID	**Contents**	**Capacity (Gal)**	**Year**	**Type**
No known tanks present				
NW Natrual - 7540 NW St. Helens Road, Portland, OR 97210 - Property ID R3502592				
Tank ID	**Contents**	**Capacity (Gal)**	**Year**	**Type**
No known tanks present				
NW Natrual - 7540 WI/NW St. Helens Road, Portland, OR 97210 - Property ID R324213				
Tank ID	**Contents**	**Capacity (Gal)**	**Year**	**Type**
No known tanks present				
Area 4 - Willbridge				
Kinder Morgan - 5800 WI/NW St. Helens Road, Portland, OR 97210 - Property ID R324222				
Tank ID	**Contents**	**Capacity (Gal)**	**Year**	**Type**
KMW100	Diesel	3,381,000	1949	Vertical Fixed Roof
KMW101	Gasoline	3,381,000	1949	Internal Floating Roof
KMW102	Out of Service	306,600	1951	Vertical Fixed Roof
KMW103	Out of Service	168,000	1950	Vertical Fixed Roof
KMW104	Lubricity additive	168,000	1950	Vertical Fixed Roof
KMW105	Ethanol	168,000	1951	Internal Floating Roof
KMW106	Out of Service	302,546	1951	Vertical Fixed Roof
KMW116	Gasoline	3,385,200	1961	Internal Floating Roof
KMW117	Biodiesel	567,000	1951	Internal Floating Roof
KMW118	Gasoline	2,360,400	1951	Internal Floating Roof
KMW123	Gasoline	3,322,200	1952	Internal Floating Roof
KMW124	Gasoline	3,393,600	1952	Internal Floating Roof
KMW128	Gasoline	2,347,800	1953	Internal Floating Roof

KMW134	Gasoline	2,364,600	1955	Internal Floating Roof
KMW137	Out of Service	222,936	1956	Vertical Fixed Roof
KMW138	Avgas	571,830	1956	Internal Floating Roof
KMW139	Out of Service	572,628	1956	Vertical Fixed Roof
KMW140	Storm water	630,000	1956	Vertical Fixed Roof
KMW141	Out of Service	730,800	1956	Vertical Fixed Roof
KMW143	Out of Service	252,927	1959	Vertical Fixed Roof
KMW152	Ethanol	47,800	1964	Internal Floating Roof
KMW84	Gasoline	2,356,200	1948	Internal Floating Roof
KMW86	Out of Service	222,805	1948	Vertical Fixed Roof
KMW87	Out of Service	222,469	1948	Vertical Fixed Roof
KMW88	Out of Service	222,574	1948	Vertical Fixed Roof
KMW89	Out of Service	222,919	1948	Vertical Fixed Roof
KMW12003	Gasoline	5,040,000	2012	Internal Floating Roof
KMW85	Diesel	2,347,800	1948	Vertical Fixed Roof
Kinder Morgan - 5800 NW St. Helens Road, Portland, OR 97210 - Property ID R121076				
Tank ID[1]	**Contents**	**Capacity (Gal)**	**Year**	**Type**
KMW12001	Jet A	5,040,000	2012	Internal Floating Roof
KMW12002	Diesel	5,040,000	2012	Internal Floating Roof
KMW155	Out of Service	4,200	1965	Vertical Fixed Roof
KMW156	Out of Service	7,667	1965	Vertical Fixed Roof
KMW157	Out of Service	24,868	1969	Vertical Fixed Roof
KMW158	Out of Service	24,851	1969	Vertical Fixed Roof
KMW159	Out of Service	21,000	1969	Vertical Fixed Roof
KMW160	Out of Service	24,860	1969	Vertical Fixed Roof
KMW161	Out of Service	24,863	1969	Vertical Fixed Roof
KMW162	Out of Service	24,850	1969	Vertical Fixed Roof
KMW163	Out of Service	24,856	1969	Vertical Fixed Roof
KMW169	Out of Service	24,990	1928	Vertical Fixed Roof
KMW170	Out of Service	24,990	1928	Vertical Fixed Roof
KMW171	Out of Service	24,990	NA	Vertical Fixed Roof
KMW172	Out of Service	24,990	NA	Vertical Fixed Roof
KMW176	Out of Service	25,353	NA	Vertical Fixed Roof
KMW177	Out of Service	24,457	NA	Vertical Fixed Roof
KMW186	Out of Service	25,604	NA	Vertical Fixed Roof
KMW187	Out of Service	24,000	NA	Vertical Fixed Roof
KMW188	Out of Service	24,600	NA	Vertical Fixed Roof
KMW189	Out of Service	24,035	NA	Vertical Fixed Roof
KMW2	Jet A	3,175,200	1915	Vertical Fixed Roof
KMW3	Out of Service	553,350	1915	Vertical Fixed Roof
KMW5	Out of Service	439,605	1915	Vertical Fixed Roof
KMW52	Jet A	3,229,800	1923	Vertical Fixed Roof
KMW54	Diesel	3,435,600	1929	Vertical Fixed Roof
KMW6	Out of Service	215,166	1915	Vertical Fixed Roof
KMW61	Out of Service	25,200	1929	Vertical Fixed Roof
KMW62	Out of Service	11,676	1929	Vertical Fixed Roof
KMW63	Out of Service	24,766	1929	Vertical Fixed Roof
KMW69	Jet A	3,431,400	1937	Vertical Fixed Roof
KMW7	Out of Service	440,538	1915	Vertical Fixed Roof
KMW70	Jet A	1,461,600	1938	Vertical Fixed Roof
KMW71	Transmix	862,260	1937	Vertical Fixed Roof
KMW73	Transmix	546,714	1937	Vertical Fixed Roof
KMW74	Out of Service	305,712	1937	Vertical Fixed Roof
KMW75	Out of Service	25,000	1938	Vertical Fixed Roof
KMW76	Out of Service	25,000	1938	Vertical Fixed Roof
KMW8	Out of Service	216,804	1915	Vertical Fixed Roof
KMW10	Out of Service	22,722	1915	Vertical Fixed Roof
KMW11	Out of service	22,722	1915	Vertical Fixed Roof

KMW12	Out of service	22,722	1915	Vertical Fixed Roof
KMW125	Out of service	12,525	1946	Vertical Fixed Roof
KMW126	Out of service	24,703	1923	Vertical Fixed Roof
KMW127	Out of service	24,703	1923	Vertical Fixed Roof
KMW129	Out of service	7,728	1927	Vertical Fixed Roof
KMW13	Out of service	2,856	1915	Vertical Fixed Roof
KMW131	Out of service	4,737	1954	Vertical Fixed Roof
KMW14	Out of service	2,856	1915	Vertical Fixed Roof
KMW145	Out of service	7,980	1960	Vertical Fixed Roof
KMW146	Out of service	7,980	1960	Vertical Fixed Roof
KMW147	Out of service	7,980	1961	Vertical Fixed Roof
KMW148	Out of service	7,980	1961	Vertical Fixed Roof
KMW15	Out of service	2,856	1915	Vertical Fixed Roof
KMW153	Out of service	7,637	1965	Vertical Fixed Roof
KMW154	Out of service	7,637	1965	Vertical Fixed Roof
KMW16	Out of service	2,814	1915	Vertical Fixed Roof
KMW166	Contact Water	33,600	1970	Vertical Fixed Roof
KMW167	Contact Water	24,024	1928	Vertical Fixed Roof
KMW17	Out of service	2,814	1915	Vertical Fixed Roof
KMW173	Jet A	49,980	1972	Vertical Fixed Roof
KMW18	Out of Service	2,814	1915	Vertical Fixed Roof
KMW190	Additive	8,400	Unknown	Horizontal Tank
KMW192	Additive	8,064	Unknown	Horizontal Tank
KMW193	Additive	10,080	Unknown	Horizontal Tank
KMW194	Slop water	6,300	Unknown	Horizontal Tank
KMW22	Out of service	11,760	1915	Vertical Fixed Roof
KMW23	Out of service	11,718	1915	Vertical Fixed Roof
KMW25	Out of service	11,760	1915	Vertical Fixed Roof
KMW26	Out of service	22,806	1916	Vertical Fixed Roof
KMW30	Out of service	11,718	1915	Vertical Fixed Roof
KMW31	Out of service	11,760	1915	Vertical Fixed Roof
KMW32	Out of service	11,472	1915	Vertical Fixed Roof
KMW33	Out of service	17,472	1915	Vertical Fixed Roof
KMW34	Out of service	17,481	1915	Vertical Fixed Roof
KMW35	Out of service	4,397	1924	Vertical Fixed Roof
KMW36	Out of service	4,368	1924	Vertical Fixed Roof
KMW37	Out of service	4,368	1924	Vertical Fixed Roof
KMW38	Out of service	4,368	1924	Vertical Fixed Roof
KMW39	Out of service	4,397	1924	Vertical Fixed Roof
KMW4	Out of service	215,754	1915	Vertical Fixed Roof
KMW40	Out of service	5,544	1923	Vertical Fixed Roof
KMW41	Out of service	5,502	1923	Vertical Fixed Roof
KMW42	Out of service	5,502	1923	Vertical Fixed Roof
KMW43	Out of service	5,502	1923	Vertical Fixed Roof
KMW44	Out of service	5,515	1923	Vertical Fixed Roof
KMW45	Out of service	5,540	1923	Vertical Fixed Roof
KMW46	Out of service	11,642	1923	Vertical Fixed Roof
KMW47	Out of service	11,600	1923	Vertical Fixed Roof
KMW48	Out of service	11,642	1923	Vertical Fixed Roof
KMW49	Out of service	11,677	1923	Vertical Fixed Roof
KMW50	Out of service	11,507	1923	Vertical Fixed Roof
KMW51	Out of service	11,634	1923	Vertical Fixed Roof
KMW56	Out of service	19,867	1929	Vertical Fixed Roof
KMW57	Out of service	19,800	1929	Vertical Fixed Roof
KMW58	Out of service	19,800	1929	Vertical Fixed Roof
KMW59	Out of service	19,855	1929	Vertical Fixed Roof
KMW60	Out of service	19,824	1929	Vertical Fixed Roof
KMW65	Jet A	861,336	1930	Vertical Fixed Roof

KMW66	Out of service	856,800	1930	Vertical Fixed Roof
KMW72	Out of service	549,024	1937	Vertical Fixed Roof
KMW77	Out of service	25,741	1938	Vertical Fixed Roof
KMW82	Out of service	11,642	1923	Vertical Fixed Roof
KMW83	Out of service	19,867	1923	Vertical Fixed Roof
KMW9	Out of service	22,722	1915	Vertical Fixed Roof
KMW90	Out of service	2,982	1946	Vertical Fixed Roof
Kinder Morgan - 6080 WI/NW St. Helens Road, Portland, OR 97210 - Property ID R315782				
Tank ID	**Contents**	**Capacity (Gal)**	**Year**	**Type**
No known tanks present				
Chevron - 5533 NW Doane Avenue, Portland, OR 97210 - Property ID R315798				
Tank ID[1]	**Contents**	**Capacity (Gal)**	**Year**	**Type**
CH1	Unleaded Gasoline	3,412,315	1997	Internal Floating Roof
CH100	Gear Lube	17,624	1946	Fixed Roof
CH101	Compressor Oil	17,284	1958	Fixed Roof
CH109	Delo GL 80/90	17,624	NA	Fixed Roof
CH128	Rykon Prem 32	74,586	NA	AST
CH129	Base Oil	642,935	NA	Fixed Roof
CH130	Base Oil	255,112	NA	Fixed Roof
CH142	Base Oil	648,620	1984	Fixed Roof
CH143	Supreme 5W30	62,033	NA	Fixed Roof
CH144	Havoline 10W30	61,864	NA	Fixed Roof
CH145	Out of Service	61,864	NA	Fixed Roof
CH150	Delo 400-10	25,311	NA	Fixed Roof
CH154	Map 100	83,422	NA	Fixed Roof
CH155	Delo 400-15W40	83,422	NA	Fixed Roof
CH156	Delo 400-30	83,022	NA	Fixed Roof
CH164	Swing Tank	6,354,155	2009	AST
CH3	Unleaded Gasoline	2,392,178	1999	Fixed Roof
CH43	Base Oil	837,085	1993	Fixed Roof
CH44	Base Oil	835,393	1920	Fixed Roof
CH45	Ethanol	958,693	1999	Fixed Roof
CH47	Unleaded Gasoline	3,609,743	1929	Fixed Roof
CH48	Water/Oil Slop	396,547	1979	Fixed Roof
CH60	Unleaded Gasoline	4,999,697	2001	Fixed Roof
CH62	Unleaded Gasoline	6,812,135	2000	Fixed Roof
CH64	Diesel	844,275	1947	Fixed Roof
CH75	Jet Fuel	1,004,586	1952	Fixed Roof
CH76	Base Oil	498,258	1960	Fixed Roof
CH96	Additive	17,624	1966	Fixed Roof
CH163	Swing Tank	6,354,155	2009	AST
CH122	1000 THF	61,864	NA	Fixed Roof
CH97	Additive	17,624	1966	Fixed Roof
CH127	ATF dex 111	109,976	NA	Fixed Roof
CH118	Blend Mix/ Line Wash	17,577	1976	Fixed Roof
CH139	Blend Mix/ Line Wash	25,591	NA	Fixed Roof
CH28	Blend Mix/ Line Wash	29,071	1913	Fixed Roof
CH176	Blended Oil	2,632	NA	Fixed Roof
CH177	Blended Oil	2,632	NA	Fixed Roof
CH178	Blended Oil	2,632	NA	Fixed Roof
CH179	Blended Oil	2,632	NA	Fixed Roof
CH180	Blended Oil	4,700	1993	Fixed Roof
CH181	Blended Oil	4,700	1993	Fixed Roof
CH182	Blended Oil	11,374	1994	Fixed Roof
CH183	Blended Oil	11,374	1994	Fixed Roof
CH184	Blended Oil	11,374	1994	Fixed Roof
CH185	Blended Oil	11,374	1994	Fixed Roof
CH186	Blended Oil	11,374	1994	Fixed Roof

CH187	Blended Oil	11,374	1994	Fixed Roof
CH188	Blended Oil	11,374	1994	Fixed Roof
CH27	Chevron 7075F	29,613	1913	Fixed Roof
CH9	Chevron 7075F	169,193	1949	Fixed Roof
CH57	Citgo Brt Stock 150	152,433	1921	Fixed Roof
CH25	Clarity PM 150	8,665	1913	Fixed Roof
CH16	Clarity PM 220	29,447	1913	Fixed Roof
CH22	Clarity PM 220	13,982	1954	Fixed Roof
CH41	Clarity Saw Guide 46	17,331	1949	Fixed Roof
CH133	CVX 3105	17,577	NA	Fixed Roof
CH147	Delo 100-40	25,523	NA	Fixed Roof
CH90	Delo 400-15W40	208,848	1954	Fixed Roof
CH123	Delo 400-40	61,864	NA	Fixed Roof
CH14	Delo 6170 CFO 20W40	190,343	1950	Fixed Roof
CH106	Delo G/L 80/90	17,818	1969	Fixed Roof
CH138	Drive Train Fluid HD 10	17,378	NA	Fixed Roof
CH37	Drive Train Fluid HD 10	17,378	1949	Fixed Roof
CH105	Empty	17,624	1969	Fixed Roof
CH116	Empty	17,724	1976	Fixed Roof
CH132	Empty	18,165	NA	Fixed Roof
CH152	Empty	17,624	NA	Fixed Roof
CH160	Empty	25,447	NA	Fixed Roof
CH19	Empty	29,071	NA	Fixed Roof
CH21	Empty	29,583	1992	Fixed Roof
CH23	Empty	13,982	1997	Fixed Roof
CH24	Empty	8,859	1993	Fixed Roof
CH29	Empty	11,750	1949	Fixed Roof
CH30	Empty	11,750	1949	Fixed Roof
CH34	Empty	25,379	NA	Fixed Roof
CH40	Empty	18,018	NA	Fixed Roof
CH42	Empty	29,583	1913	Fixed Roof
CH79	Empty	17,378	1960	Fixed Roof
CH81	Empty	17,724	1951	Fixed Roof
CH84	Empty	17,184	1952	Fixed Roof
CH88	Empty	17,624	1850	Fixed Roof
CH12	ExxonMobil EM-100	586,302	1950	Fixed Roof
CH17	ExxonMobile EHC45	29,327	1913	Fixed Roof
CH35	FAMM Tara 30 DP 30	25,379	NA	Fixed Roof
CH7	Famm Taro Sepcial 70	100,594	1913	Fixed Roof
CH6	GEO HDAX L ASH 40	100,277	1913	Fixed Roof
CH56	GST ISO 100	25,379	NA	Fixed Roof
CH110	GST ISO 32	17,624	NA	Fixed Roof
CH113	Hybase C414	17,378	NA	Fixed Roof
CH131	Hybase C414	17,577	NA	Fixed Roof
CH28	Industrial EP 150	17,771	1949	Fixed Roof
CH114	Industrial EP 220	17,624	NA	Fixed Roof
CH82	Infineum M7038	17,624	1951	Fixed Roof
CH65	Lubrizol 4991	17,524	1938	Fixed Roof
CH87	Lubrizol 4991	17,430	1913	Fixed Roof
CH11	Lubrizol 4991D	211,915	1950	Fixed Roof
CH151	MAR EO 9250-40	17,724	NA	Fixed Roof
CH4	Neutral 220R	435,761	1913	Fixed Roof
CH61	Neutral 600R	400,379	1941	Fixed Roof
CH5	Neutral Oil	365,834	1913	Fixed Roof
CH89	Oil Stop	19,431	1952	Fixed Roof
CH137	Oloa 2000	60,757	NA	Fixed Roof
CH85	Oloa 44200	17,671	1952	Fixed Roof
CH18	Oloa 550006L	29,583	1913	Fixed Roof

CH112	Oloa 6073EV	17,818	NA	Fixed Roof
CH91	Oloa 9740C	17,671	1961	Fixed Roof
CH102	Out of Service	12,954	1978	Fixed Roof
CH103	Out of Service	13,006	1978	Fixed Roof
CH119	Out of Service	19,593	1977	Fixed Roof
CH120	Out of Service	19,593	1977	Fixed Roof
CH121	Out of Service		1978	Fixed Roof
CH135	Out of Service	19,379	1982	Fixed Roof
CH136	Out of Service	20,303	1982	Fixed Roof
CH140	Out of Service	83,234	NA	Fixed Roof
CH141	Out of Service	140,308	NA	Fixed Roof
CH158	Out of Service	NA	NA	Fixed Roof
CH159	Out of Service	25,379	1987	Fixed Roof
CH80	Out of Service	17,378	NA	Fixed Roof
CH92	Out of Service	17,577	1961	Fixed Roof
CH10	Paratone 8451	169,616	1950	Fixed Roof
CH78	Paratone 8451	311,722	1960	Fixed Roof
CH20	Pennzoil 75HC	29,071	1914	Fixed Roof
CH117	Raffene 2000L	17,624	1976	Fixed Roof
CH13	Raffene 750L	45,682	NA	Fixed Roof
CH46	Red Chain Bar 150	11,750	1924	Fixed Roof
CH77	RPM HDMO 15W40	128,511	1960	Fixed Roof
CH83	RPM HDMO 15W40	17,331	1951	Fixed Roof
CH149	RPM HDMO 30	26,311	NA	Fixed Roof
CH99	RPM UGL 80W90	62,033	NA	Fixed Roof
CH98	Rykon Oil 46	91,364	1968	Fixed Roof
CH94	Rykon Oil 68	67,419	NA	Fixed Roof
CH15	Rykon Prem 32	28,951	1913	Fixed Roof
CH26	Rykon Prem 32	29,447	1913	Fixed Roof
CH8	Rykon Prem MV	104,897	1913	Fixed Roof
CH72	Saw Guide 150	17,284	1959	Fixed Roof
CH36	Shell MV1 100	25,379	NA	Fixed Roof
CH31	SynFluid $, 4CST	8,712	1953	Fixed Roof
CH108	Techron Additive	208,425	1970	Fixed Roof
CH104	Texaco Havoline 5S30	17,331	NA	Fixed Roof
CH146	Transmix	25,447	NA	Fixed Roof
CH157	Turbine Oil	52,872	NA	AST
CH148	VER 800 Mar 30	33,839	NA	Fixed Roof
CH33	Viscoplex 1-604	13,997	NA	Fixed Roof
CH32	Viscoplex 7-305	13,918	1950	Fixed Roof
CH29	NA	17,724	1949	Fixed Roof
CH51	NA	NA	NA	NA
Chevron - 5533 WI/NW Doane Avenue, Portland, OR 97210 - Property ID R315771				
Tank ID[1]	**Contents**	**Capacity (Gal)**	**Year**	**Type**
No known tanks present				
Conoco Phillips - 5528 WI/NW Doane Avenue, Portland, OR 97210 - Property ID R315810				
Tank ID[1]	**Contents**	**Capacity (Gal)**	**Year**	**Type**
PH2561	Marine Fuel Oil	1,569,582	1929	Riveted Steel
PH2579	Hydraulic Tractor Oil	1,800	1929	Welded Steel
PH2669	Marine Diesel	449,694	1931	Riveted Steel
PH2713	Unax AW 46	109,000	1937	Welded Steel
PH2714	Guardol 15W/40	109,000	1937	Welded Steel
PH2783	Decant Oil	948,066	1937	Riveted Steel
PH2784	Diesel #2	1,439,130	1937	Riveted Steel
PH2915	Unleaded Gasoline	3,262,056	1938	Welded Steel
PH2916	Diesel #2	1,652,196	1938	Welded Steel
PH2917	RLOP 220 N	612,000	1938	Welded Steel
PH2982	Diesel #1	416,262	1941	Welded Steel

PH2983	RLOP 220 N	304,000	1941	Welded Steel
PH3407	Unleaded Gasoline	2,955,540	1949	Welded Steel
PH3408	Unleaded Gasoline	1,639,680	1949	Welded Steel
PH3409	Unleaded Gasoline	948,654	1949	Welded Steel
PH3410	Ethanol	278,964	1949	Welded Steel
PH3411	Unleaded Gasoline	259,350	1949	Welded Steel
PH3412	Diesel #1	279,426	1949	Welded Steel
PH3413	Unleaded Gasoline	259,560	1949	Welded Steel
PH3414	RLOP 220 N	200,000	1949	Welded Steel
PH3415	SUN 525	200,000	1949	Welded Steel
PH3416	RLOP 100N	200,000	1949	Welded Steel
PH3417	ULTRA S-4	200,000	1949	Welded Steel
PH3579	Industrial Fuel Oil	3,307,668	1950	Welded Steel
PH36	Stop Oil	20,496	1907	Riveted Steel
PH3623	HiTech 6576	18,228	1950	Welded Steel
PH3639	SUP SYN BL 5W/30	120,000	1951	Welded Steel
PH3739	SUN 150 B/S	200,000	1954	Welded Steel
PH3740	RLOP 600 N	277,000	1954	Welded Steel
PH3741	Ramar CLF 17E	17,500	1954	Welded Steel
PH3742	MP Gear Lube 80/90	17,500	1954	Welded Steel
PH3743	Utility	18,600	1954	Welded Steel
PH3744	HYNAP N100	17,500	1954	Welded Steel
PH3745	HITEC 5751	17,500	1954	Welded Steel
PH3746	Lubrizol 4998C	17,500	1954	Welded Steel
PH3747	Lubrizol 4990CH	17,500	1954	Welded Steel
PH3757	HITEC 1193	17,500	1954	Welded Steel
PH3760	Raffene 750L	17,500	1954	Welded Steel
PH3761	Diesel #2	3,240,342	1954	Welded Steel
PH4191	Lubrizol 48254	17,500	1964	Welded Steel
PH4192	Lubrizol 7075F	17,500	1964	Welded Steel
PH4223	Slop Oil	18,690	1968	Welded Steel
PH4241	UNAX AW 68	17,500	1968	Welded Steel
PH4242	UNAX AW 68	17,500	1968	Welded Steel
PH4243	HT4/10W	17,500	1968	Welded Steel
PH4244	Mohawk 450	17,500	1968	Welded Steel
PH4245	SUN 525	17,500	1968	Welded Steel
PH4252	Residual Fuel Oil	458,640	1968	Welded Steel
PH4253	Residual Fuel Oil	451,290	1968	Welded Steel
PH4254	PS 300	459,312	1968	Welded Steel
PH4255	Biodiesel	404,250	1968	Welded Steel
PH4256	Out of Service	195,408	1968	Welded Steel
PH4257	Out of Service	38,367	1968	Welded Steel
PH4258	Line Clippings	18,000	1968	Welded Steel
PH4259	Transmix	205,506	1968	Welded Steel
PH4266	Flush	17,500	1968	Welded Steel
PH4281	Versa Tran ATF	17,500	1969	Welded Steel
PH4300	Ramar CLF 17E	25,500	1969	Welded Steel
PH4302	RLOP 600N	17,500	1971	Welded Steel
PH4303	RLOP 100N	17,500	1971	Welded Steel
PH4305	Out of Service	8,900	1971	Welded Steel
PH4306	RLOP 100N	200,000	1971	Welded Steel
PH4318	Diesel #2	1,422,456	1973	Welded Steel
PH4320	Sup Syn BL 10W/30	35,000	1973	Welded Steel
PH4321	Uniguide II 100	35,000	1973	Welded Steel
PH4322	T5X HD 15W/40	35,000	1973	Welded Steel
PH4323	Super ATF	35,000	1973	Welded Steel
PH4331	Ethyl HITEC 6888E	25,500	1973	Welded Steel
PH4332	Super ATF	17,500	1973	Welded Steel

PH4333	Point Premier 10W/30	17,500	1973	Welded Steel
PH4334	Super 5W/20	17,500	1973	Welded Steel
PH4369	RLOP 220 N	17,500	1979	Welded Steel
PH4388	Utility	13,500	1984	Welded Steel
PH4389	Utility	13,500	1984	Welded Steel
PH4390	Bar & Chain 150	13,500	1985	Welded Steel
PH4391	Utility	13,500	1985	Welded Steel
PH4392	Utility	13,500	1985	Welded Steel
PH4393	Utility	13,500	1985	Welded Steel
PH4394	Utility	13,500	1985	Welded Steel
PH4395	Utility	13,500	1985	Welded Steel
PH4397	Lubrizol 9692A	13,500	1985	Welded Steel
PH4398	HITEC 1193A	13,500	1985	Welded Steel
PH4399	Firebird 15W/40	13,500	1985	Welded Steel
PH4400	Guardol 30	13,500	1985	Welded Steel
PH4403	HT4/30W	13,500	1985	Welded Steel
PH4404	Fleet Sup EC 15W/40	13,500	1985	Welded Steel
PH4405	HITEC 3472	13,500	1987	Welded Steel
PH4406	Lubrizol 9990A	13,500	1987	Welded Steel
PH4407	Ethyl HITEC 388	13,500	1987	Welded Steel
PH4408	Ethyl HITEC 5756	13,500	1987	Welded Steel
PH4441	Octel 9056	18,648	1993	Welded Steel
PH4327	Gasoline Slops	10,080	1974	Welded Steel
PH1471	Hydraulic Tractor Oil	17,300	1921	Riveted Steel
PH4401	Mohawk 150	13,500	1985	Welded Steel
PH4402	TSX HD10	13,500	1985	Welded Steel
PHF103	UTRA 58	25,500	1973	Welded Steel
PHF104	UTRA 59	17,500	1973	Welded Steel
Conoco Phillips - 5528 NW Doane Avenue, Portland, OR 97210 - Property ID R315769				
Tank ID	**Contents**	**Capacity (Gal)**	**Year**	**Type**
No known tanks present				
Zenith Energy - 5501 NW Front Avenue, Portland, OR 97210 - Property ID R315845				
Tank ID[1]	**Contents**	**Capacity (Gal)**	**Year**	**Type**
Tank 129	Asphalt	NA	NA	NA
Tank 128	Asphalt	NA	NA	NA
Tank 127	Asphalt	NA	NA	NA
Tank 70	Asphalt	NA	NA	NA
Tank 125	Asphalt	NA	NA	NA
Tank 124	Asphalt	NA	NA	NA
Tank 123	Asphalt	NA	NA	NA
Tank 122	Asphalt	NA	NA	NA
Tank 121	Asphalt	NA	NA	NA
Tank 120	Asphalt	NA	NA	NA
Tank 112	Asphalt	NA	NA	NA
Tank 110	Asphalt	NA	NA	NA
Tank 101	Asphalt	NA	NA	NA
Tank 126	Asphalt	NA	NA	NA
Tank 003	Asphalt	NA	NA	NA
Tank 71	Avgas	1,402,380	NA	Internal Floating Roof
Tank 184	Biodiesel	222,000	NA	NA
Tank 307	Caustic	NA	NA	NA
Tank 74	Charge Stock	NA	NA	NA
Tank 100	Charge Stock	NA	NA	NA
Tank 102	Charge Stock	NA	NA	NA
Tank 106	Crude Oil	5,611,788	NA	External Floating Roof
Tank 67	Crude Oil	3,234,000	NA	NA
Tank 93	Crude Oil	2,829,918	NA	NA
Tank 69	Crude Oil	NA	NA	NA

Tank 130	Crude Oil	3,200,000	NA	Internal Floating Roof
Tank 68	Crude Oil	2,900,000	NA	NA
Tank 63	Crude Oil	4,763,472	NA	Internal Floating Roof
Tank 104	Crude Oil	NA	NA	NA
Tank 105	Crude Oil	5,241,684	NA	External Floating Roof
Tank 001	Crude Oil	NA	NA	NA
Tank 308	Murol	NA	NA	NA
Tank 182	NA	NA	NA	NA
Tank 183	NA	NA	NA	NA
Tank 185	NA	NA	NA	NA
Tank 202	NA	NA	NA	NA
Tank 203	NA	NA	NA	NA
Tank 209	NA	NA	NA	NA
Tank 213	NA	NA	NA	NA
Tank 208	NA	NA	NA	NA
Tank 211	NA	NA	NA	NA
Tank 306	NA	NA	NA	NA
Tanks 95	NA	NA	NA	NA
Tank 114	NA	NA	NA	NA
Tank 302	NA	NA	NA	NA
Tank 162	NA	NA	NA	NA
Tank 166	NA	NA	NA	NA
Tank 167	NA	NA	NA	NA
Tank 168	NA	NA	NA	NA
Tank 169	NA	NA	NA	NA
Tank 170	NA	NA	NA	NA
Tank 171	NA	NA	NA	NA
Tank 172	NA	NA	NA	NA
Tank 20	NA	NA	NA	NA
Tank 173	NA	NA	NA	NA
Tank 174	NA	NA	NA	NA
Tank 180	NA	NA	NA	NA
Tank 179	NA	NA	NA	NA
Tank 206	NA	NA	NA	NA
Tank 210	NA	NA	NA	NA
Tank 177	NA	NA	NA	NA
Tank 176	NA	NA	NA	NA
Tank 178	NA	NA	NA	NA
Tank 181	NA	NA	NA	NA
Tank 200	NA	NA	NA	NA
Tank 201	NA	NA	NA	NA
N2	NA	NA	NA	NA
Tank 317	NA	NA	NA	NA
BAS #2	NA	NA	NA	NA
KO T#5	NA	NA	NA	NA
BAS #3	NA	NA	NA	NA
BAS #4	NA	NA	NA	NA
Tank 160	NA	NA	NA	NA
Tank 161	NA	NA	NA	NA
Tank 314	NA	NA	NA	NA
Tank 002	NA	NA	NA	NA
KO T#2	NA	NA	NA	NA
CAS #5	NA	NA	NA	NA
BAS #1	NA	NA	NA	NA
Tank 305	NA	NA	NA	NA
KO T#1	NA	NA	NA	NA
Tank 163	NA	NA	NA	NA
Tank 164	NA	NA	NA	NA

Tank 165	NA	NA	NA	NA
Tank 152	NA	NA	NA	NA
Tank 151	NA	NA	NA	NA
Tank 158	NA	NA	NA	NA
Tank 157	NA	NA	NA	NA
Tank 156	NA	NA	NA	NA
Tank 148	NA	NA	NA	NA
Tank 149	NA	NA	NA	NA
Tank 150	NA	NA	NA	NA
Tank 142	NA	NA	NA	NA
Tank 143	NA	NA	NA	NA
Tank 144	NA	NA	NA	NA
Tank 147	NA	NA	NA	NA
Tank 146	NA	NA	NA	NA
Tank 145	NA	NA	NA	NA
Tank 140	NA	NA	NA	NA
Tank 141	NA	NA	NA	NA
Tank 300	NA	NA	NA	NA
K-23	NA	NA	NA	NA
TW-2	NA	NA	NA	NA
Tank 207	NA	NA	NA	NA
Tank 66	Universal Low-Sulfer Diesel	3,188,598	NA	NA
Tank 111	Wastewater	NA	NA	NA
Tank 113	Wastewater	NA	NA	NA
Zenith Energy - 5501 NW Front Avenue, Portland, OR 97210 - Property ID R315777				
Tank ID[1]	**Contents**	**Capacity (Gal)**	**Year**	**Type**
No known tanks present				
McCall Oil - 5700 NW Front Avenue, Portland, OR 97210 - Property ID R315872				
Tank ID[1]	**Contents**	**Capacity (Gal)**	**Year**	**Type**
MC1	Asphalt	11,247,180	1976	Cone Roof
MC19	Asphalt	427,770	1954	Cone Roof
MC2	Asphalt	11,787,300	1973	Cone Roof
MC20	Asphalt	427,770	1954	Cone Roof
MC21	Asphalt	428,064	1954	Cone Roof
MC10	Biodiesel	469,392	1974	Internal Floating Roof
MC5	Biodiesel	27,216	1974	Cone Roof
MC6	Biodiesel	27,216	1974	Cone Roof
MC9	Biodiesel	473,004	1979	Cone Roof
MC4	Bunker	9,357,936	1976	Cone Roof
MC7	Diesel	2,658,726	1978	Internal Floating Roof
MC8	Diesel	2,680,482	1977	Internal Floating Roof
MC11	Oil and water	20,160	1974	Cone Roof
MC12	Oil and water	10,080	1974	Cone Roof
McCall Oil - 5480 NW Front Avenue, Portland, OR 97210 - Property ID R315786				
Tank ID[1]	**Contents**	**Capacity (Gal)**	**Year**	**Type**
MC18	Anti-strip	4,914	1989	Cone Roof
MC22	Asphalt	18,942	1954	Cone Roof
MC23	Asphalt	18,942	1954	Cone Roof
MC24	Asphalt	19,068	2000	Cone Roof
MC25	Asphalt	79,800	2000	Cone Roof
MC26	Asphalt	79,800	2000	Cone Roof
MC27	Asphalt	79,800	2000	Cone Roof
MC28	Boiler fuel	8,358	1954	Cone Roof
MC15	Flux	21,840	1986	Cone Roof
MC16	Flux	30,198	1989	Cone Roof
MC33	Poly phosphoric acid	5,405	2005	Cone Roof
MC29	Unichem	11,000	1974	Cone Roof
Area 5 - Equilon				

Equilon - 3610-3640 St. Helens Road, Portland, OR 97210 - Property ID R315819				
Tank ID[1]	Contents	Capacity (Gal)	Year	Type
T-13519	Diesel	560,112	NA	Cone Roof
T-13520	Diesel	558,852	NA	Cone Roof
T-13521	Diesel	559,986	NA	Cone Roof
T-13522	Diesel	558,432	NA	Cone Roof
T-13523	Out of Service	565,320	NA	Cone Roof
T-13524	Diesel	559,146	NA	Cone Roof
T-36002	Diesel	1,537,704	NA	Cone Roof
T-55000	Gasoline	1,986,264	NA	Internal Fixed Roof
T-55001	Ethanol	2,331,714	NA	Internal Fixed Roof
T-80103	Diesel	3,303,636	NA	Cone Roof
T-80104	Gasoline	3,348,912	NA	Internal Fixed Roof
T-80110	Gasoline	3,317,622	NA	Internal Fixed Roof
T-84200	Gasoline	3,528,756	NA	Internal Fixed Roof
T-7017	Water	267,456	NA	External Fixed Roof

Notes:

[1]Tanks noted in satellite images, but not listed in available GIS data, are given the designation based on property ID and count, and are *italicized* . Example: Zenithh = "ZE-*Tank 1* "

NA - Data not available

Table 3.2 - CEI Hub Supporting Infrastructure
Portland, Oregon

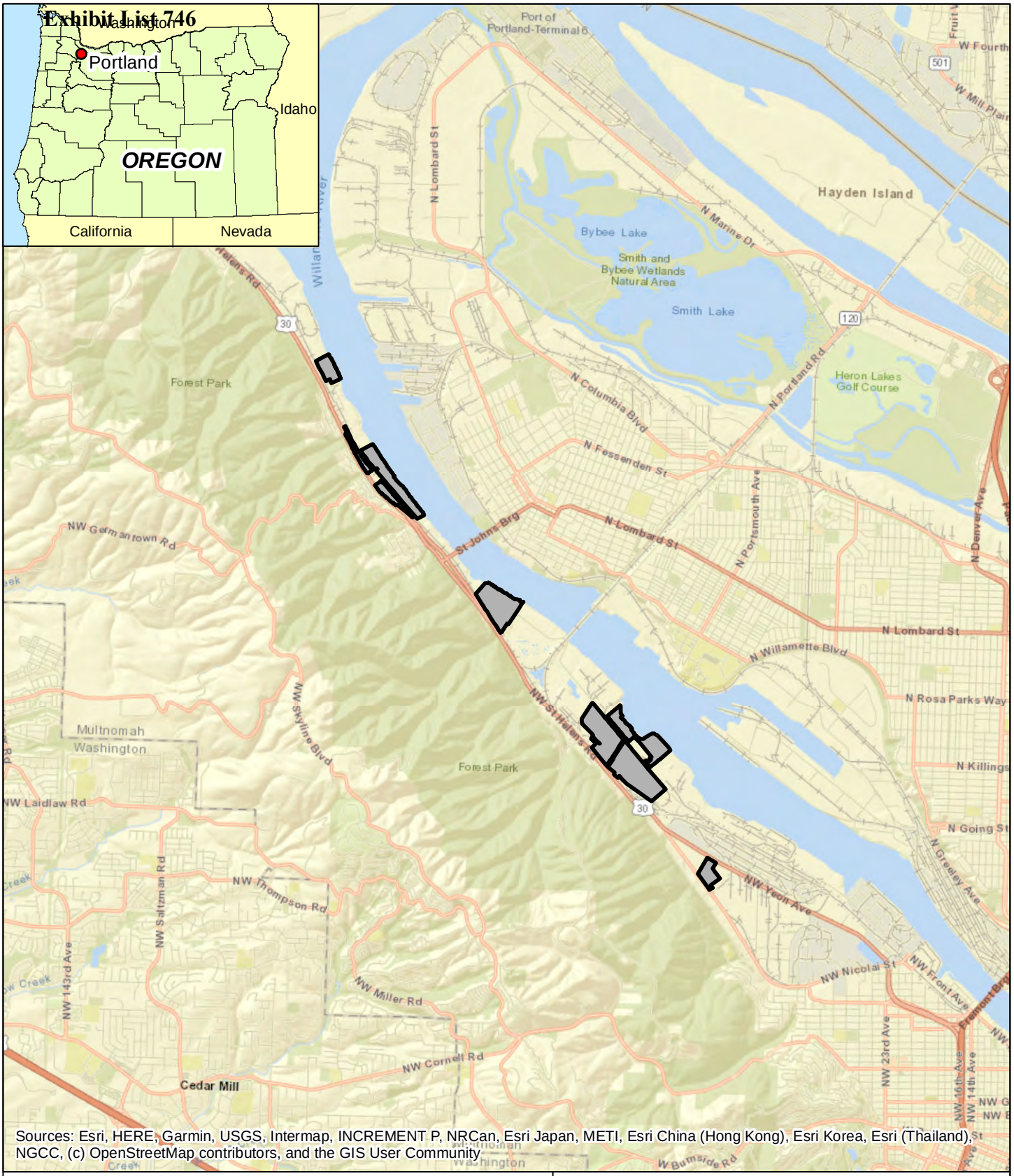
Area 1 - Kinder Morgan North	
Kinder Morgan - North - 11400 NW St Helens Road, Portland, OR 97231 - Property ID R232828	
Building	**Area (Sq Ft)**
Bldg 1	14,823
Bldg 2	6,800
Bldg 3	5,084
Bldg 4	4,640
Bldg 5	4,495
Bldg 6	3,472
Bldg 7	2,592
Bldg 8	2,232
Bldg 9	750
Bldg 10	527
Bldg 11	77
Area 2 - Linnton	
BP West Coast - 9930 WI/NW St Helens Road, Portland, OR 97231 - Property ID R323779	
Building	**Area (Sq Ft)**
No Buildings Present	
BP West Coast - 9930 NW St Helens Road, Portland, OR 97231 - Property ID R498331	
Building	**Area (Sq Ft)**
Bldg 1	27,050
Bldg 2	8,380
Bldg 3	2,860
Bldg 4	2,740
Bldg 5	930
Bldg 6	Unknown
BP West Coast - 9900 WI/NW St Helens Road, Portland, OR 97231 - Property ID R323771	
Building	**Area (Sq Ft)**
Bldg 1	6,020
Bldg 2	1,917
BP West Coast - 9930 WI/NW St Helens Road, Portland, OR 97231 - Property ID R323758	
Building	**Area (Sq Ft)**
No Buildings Present	
Shore Terminals - 9420 WI/NW St Helens Road, Portland, OR 97231 - Property ID R518296	
Building	**Area (Sq Ft)**
Bldg 1	6,150
Bldg 2	1,952
Bldg 3	440
Bldg 4	256
Bldg 5	180
Bldg 6	96
Shore Terminals - 9420 WI/NW St Helens Road, Portland, OR 97231 - Property ID R491070	
Building	**Area (Sq Ft)**
Bldg 1	5,434
Bldg 2	644
Bldg 3	25
Shore Terminals - 9400 WI/NW St Helens Road, Portland, OR 97231 - Property ID R324088	
Building	**Area (Sq Ft)**
No Buildings Present	

Shore Terminals - 9420 WI/NW St Helens Road, Portland, OR 97231 - Property ID R518295	
Building	**Area (Sq Ft)**
Bldg 1	6,520
Bldg 2	6,400
Bldg 3	4,840
Bldg 4	2,500
Bldg 5	460
Bldg 6	200
Bldg 7	180
Shore Terminals - 9420 WI/NW St Helens Road, Portland, OR 97231 - Property ID R512294	
Building	**Area (Sq Ft)**
No Buildings Present	
Area 3 - NW Natural	
Pacific Terminal Services - 7900 NW St. Helens Road, Portland, OR 97210 - Property ID R324159	
Building	**Area (Sq Ft)**
Bldg 1	2,328
Bldg 2	1,800
NW Natural - 7900 WI/NW St. Helens Road, Portland, OR 97210 - Property ID R324171	
Building	**Area (Sq Ft)**
No Buildings Present	
NW Natural - 7900 WI/NW St. Helens Road, Portland, OR 97210 - Property ID R324170	
Building	**Area (Sq Ft)**
Bldg 1	NA
Bldg 2	NA
NW Natural - 7598 NW St. Helens Road, Portland, OR 97210 - Property ID R324113	
Building	**Area (Sq Ft)**
Bldg 1	NA
Bldg 2	Removed
Bldg 3	NA
Bldg 4	NA
Bldg 5	NA
Bldg 6	NA
Bldg 7	NA
Bldg 8	NA
Bldg 9	NA
Bldg 10	NA
Bldg 11	NA
Bldg 12	NA
NW Natural - 7900 WI/NW St. Helens Road, Portland, OR 97210 - Property ID R324172	
Building	**Area (Sq Ft)**
Bldg 1	3,000
Bldg 2	NA
Bldg 3	NA
NW Natrual - 7441 SW/NW St. Helens Road, Portland, OR 97210 - Property ID R324165	
Building	**Area (Sq Ft)**
No Buildings Present	
NW Natural - 7441 NW St. Helens Road, Portland, OR 97210 - Property ID R324160	
Building	**Area (Sq Ft)**
No Buildings Present	
NW Natural - 7540 NW St. Helens Road, Portland, OR 97210 - Property ID R3502592	
Building	**Area (Sq Ft)**
Bldg 1	Removed
Bldg 2	Removed

Bldg 3	Removed
Bldg 4	Removed
NW Natural - 7540 WI/NW St. Helens Road, Portland, OR 97210 - Property ID R324213	
Building	**Area (Sq Ft)**
No Buildings Present	
Area 4 - Willbridge	
Kinder Morgan - 5800 WI/NW St. Helens Road, Portland, OR 97210 - Property ID R324222	
Building	**Area (Sq Ft)**
Bldg 1	55,734
Bldg 2	1,489
Bldg 3	1,348
Bldg 4	848
Kinder Morgan - 5800 NW St. Helens Road, Portland, OR 97210 - Property ID R121076	
Building	**Area (Sq Ft)**
Bldg 1	10,061
Bldg 2	4,792
Bldg 3	2,500
Bldg 4	1,456
Bldg 5	168
Bldg 6	160
Kinder Morgan - 6080 WI/NW St. Helens Road, Portland, OR 97210 - Property ID R315782	
Building	**Area (Sq Ft)**
Bldg 1	NA
Bldg 2	NA
Bldg 3	NA
Chevron - 5533 NW Doane Avenue, Portland, OR 97210 - Property ID R315798	
Building	**Area (Sq Ft)**
Bldg 1	128,836
Bldg 2	7,696
Bldg 3	3,912
Bldg 4	2,878
Bldg 5	2,004
Bldg 6	1,976
Bldg 7	1,836
Bldg 8	1,616
Bldg 9	NA
Bldg 10	NA
Bldg 11	NA
Bldg 12	NA
Bldg 13	NA
Bldg 14	NA
Chevron - 5533 WI/NW Doane Avenue, Portland, OR 97210 - Property ID R315771	
Building	**Area (Sq Ft)**
Bldg 1	NA
Conoco Phillips - 5528 WI/NW Doane Avenue, Portland, OR 97210 - Property ID R315810	
Building	**Area (Sq Ft)**
Bldg 1	50,400
Bldg 2	12,660
Bldg 3	2,312
Bldg 4	960
Bldg 5	525
Bldg 6	363

Bldg 7	264
Conoco Phillips - 5528 NW Doane Avenue, Portland, OR 97210 - Property ID R315769	
Building	**Area (Sq Ft)**
Bldg 1	8,000
Zenith Energy - 5501 NW Front Avenue, Portland, OR 97210 - Property ID R315845	
Building	**Area (Sq Ft)**
Bldg 1	22,895
Bldg 2	4,110
Bldg 3	3,930
Bldg 4	2,736
Bldg 5	2,652
Bldg 6	2,034
Bldg 7	1,716
Bldg 8	1,144
Bldg 9	864
Bldg 10	799
Bldg 11	380
Zenith Energy - 5501 NW Front Avenue, Portland, OR 97210 - Property ID R315777	
Building	**Area (Sq Ft)**
No Buildings Present	
McCall Oil - 5700 NW Front Avenue, Portland, OR 97210 - Property ID R315872	
Building	**Area (Sq Ft)**
Bldg 1	980
Bldg 2	850
Bldg 3	NA
Bldg 4	NA
McCall Oil - 5480 NW Front Avenue, Portland, OR 97210 - Property ID R315786	
Building	**Area (Sq Ft)**
Bldg 1	NA
Bldg 2	NA
Bldg 3	NA
Bldg 4	NA
Bldg 5	NA
Bldg 6	NA
Area 5 - Equilon	
Equilon - 3610-3640 St. Helens Road, Portland, OR 97210 - Property ID R315819	
Building	**Area (Sq Ft)**
Bldg 1	5,376
Bldg 2	4,680
Bldg 3	2,484
Bldg 4	1,350
Bldg 5	840
Bldg 6	180

Exhibit List 746



Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

Legend

Project Areas

0 0.5 1 2 Miles

Note: Feature locations are approximate.

N

Oregon Critical Energy Infrastructure Hub
Portland, Oregon

CEI Hub Location Map

154-035-019 04/21

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Figure
1.1

Document Path: F:\Notebooks\154035019_Critical_Energy_Infrastructure_Hub_Seismic_Risk_Analysis\GIS\MGIS\154035019_AA_VM.mxd Date: 2/22/2021 User Name: ericlindquist

Exhibit List 747

Kinder Morgan North Area

Linnton Area

NW Natural Area

Willbridge Area

Equilon Area

Source: DOGAMI Open File Report O-20-01.

Legend

Potential Permanent Ground Deformation

- None
- Low (0 – 10 cm; 0 – 4 inches)
- Moderate (10 – 30 cm; 4 – 12 inches)
- High (30 – 100 cm; 12 – 39 inches)
- Very High (100 – 1180 cm; 39 – 173 inches)

Project Areas

N

0 0.25 0.5 1 Miles

Note: Feature locations are approximate.

Oregon Critical Energy Infrastructure Hub
Portland, Oregon

Potential Permanent Ground Deformation Due to Lateral Spreading Cascadia Subduction Zone M9.0 Earthquake

154-035-019 04/21

HARTCROWSER A division of Haley & Aldrich

Figure **1.4**

Document Path: F:\Notebooks\154035019_Critical_Energy_Infrastructure_Hub_Seismic_Risk_Analysis\GIS\MGIS\154035019_AD_GroundMotionGroundDeformation.mxd Date: 2/22/2021 User Name: ericlindquist

Kinder Morgan North Area

Linnton Area

NW Natural Area

Willbridge Area

Equilon Area

Modified Mercalli Intensity Scale	Perceived Shaking	Damage Potential
IV	Light	None
V	Moderate	Very light
VI	Strong	Light
VII	Very Strong	Moderate
VIII	Severe	Moderate/ Heavy
IX	Violent	Heavy

Source: DOGAMI Open File Report O-20-01.

Legend

Project Areas

0 0.25 0.5 1 Miles

Note: Feature locations are approximate.

Oregon Critical Energy Infrastructure Hub
Portland, Oregon

Perceived Shaking and Damage Potential Simulated Cascadia Subduction Zone Magnitude 9.0 Earthquake

154-035-019 04/21

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Figure
1.2

Document Path: F:\Notebooks\154035019_Critical_Energy_Infrastructure_Hub_Seismic_Risk_Analysis\GIS\MGIS\154035019_AD_GroundMotionGroundDeformation.mxd Date: 2/22/2021 User Name: ericlindquist

Source: Aerial photograph provided by Hexagon Imagery Program Data.

Legend

DOGAMI Liquefaction Susceptibility

- None
- Very Low
- Low
- Moderate
- High
- Very High
- Project Areas

0 1,000 2,000 4,000 Feet

Note: Feature locations are approximate.

Oregon Critical Energy Infrastructure Hub
Portland, Oregon

Liquefaction Hazard Mapping

154-035-019 04/21

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Figure
1.3

Document Path: F:\Notebooks\154035019_Critical_Energy_Infrastructure_Hub_Seismic_Risk_Analysis\GIS\MGIS\154035019_AE_SP.mxd Date: 2/22/2021 User Name: ericlindquist

Exhibit List 750

Willamette River

Kinder Morgan North Area
Area 1

Linnton Area
Area 2

NW Natural Area
Area 3

Willbridge Area
Area 4

Equilon Area
Area 5

Source: Aerial photograph provided by Hexagon Imagery Program Data.

Legend

- Project Areas

Kinder Morgan North Area Owners
- Kinder Morgan

Linnton Area Owners
- BP West Coast
- Shore Terminals / Nustar

NW Natural Area Owners
- NW Natural
- Pacific Terminal Services

Equilon Area Owners
- Equilon

Willbridge Area Owners
- Chevron
- Conoco Phillips
- Kinder Morgan
- McCall Oil
- Zenith Energy Terminals

N

0 900 1,800 3,600 Feet

Note: Feature locations are approximate.

Oregon Critical Energy Infrastructure Hub
Portland, Oregon

CEI Hub Map

154-035-019 04/21

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Figure **1.5**

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Willamette River

Kinder Morgan
Tax ID: R323828
11400 NW ST HELENS RD

NW 112TH AVE
NW 111TH AVE
NW 110TH AVE
NW 109TH AVE
NW 108TH AVE
NW FRONT AVE
NW ST HELENS RD
NW 1ST ST
NW 2ND ST
NW 2ND CT
NW 3RD ST

Source: Aerial photograph provided by Hexagon Imagery Program Data.

Legend

- Project Area
- Property with Geotechnical Information Used in Analysis
- Approximate Location of Geotechnical Analysis Section

N

0 125 250 500 Feet

Note: Feature locations are approximate.

Critical Energy Infrastructure Hub Seismic Risk Analysis
Portland, Oregon

CEI Area 1 – Kinder Morgan North

154-035-019 04/21

HARTCROWSER A division of Haley & Aldrich

Figure **1.6**

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Exhibit List 752

Willamette River

Shore Terminals / Nustar
Tax ID: R491070
9420 WI/ NW ST HELENS RD

Shore Terminals / Nustar
Tax ID: R518294/R518295
9420 NW ST HELENS RD

Shore Terminals / Nustar
Tax ID: R324088
9400 S/ NW ST HELENS RD

BP West Coast
Tax ID: R498331
9930 NW ST HELENS RD

Shore Terminals / Nustar
Tax ID: R518296
9420 WI/ NW ST HELENS RD

BP West Coast
Tax ID: R323758
9930 WI/ NW ST HELENS RD

BP West Coast
Tax ID: R323771
9900 WI/ NW ST HELENS RD

BP West Coast
Tax ID: R323779
9930 WI/ NW ST HELENS RD

NW BRIDGE AVE
NW GERMANTOWN RD
NW HARDY AVE
NW HARBOR BLVD
NW ST HELENS RD
NW ROSEWAY AVE
NW ROSARIA AVE
NW ELVA AVE
NW HOGE AVE
NW WILARK AVE
NW MACKAY AVE
NW MEARS BLVD
NW 105TH AVE
NW 2ND ST
NW 3RD ST
NW 4TH ST
NW FIRELANE 9 RD
NW LILAC AVE

Source: Aerial photograph provided by Hexagon Imagery Program Data.

Legend

- Project Area
- Tax Lot Boundary
- Property with Geotechnical Information Used in Analysis
- Approximate Location of Geotechnical Analysis Section

N

0 200 400 800
Feet

Note: Feature locations are approximate.

Critical Energy Infrastructure Hub Seismic Risk Analysis
Portland, Oregon

CEI Area 2 – Linnton

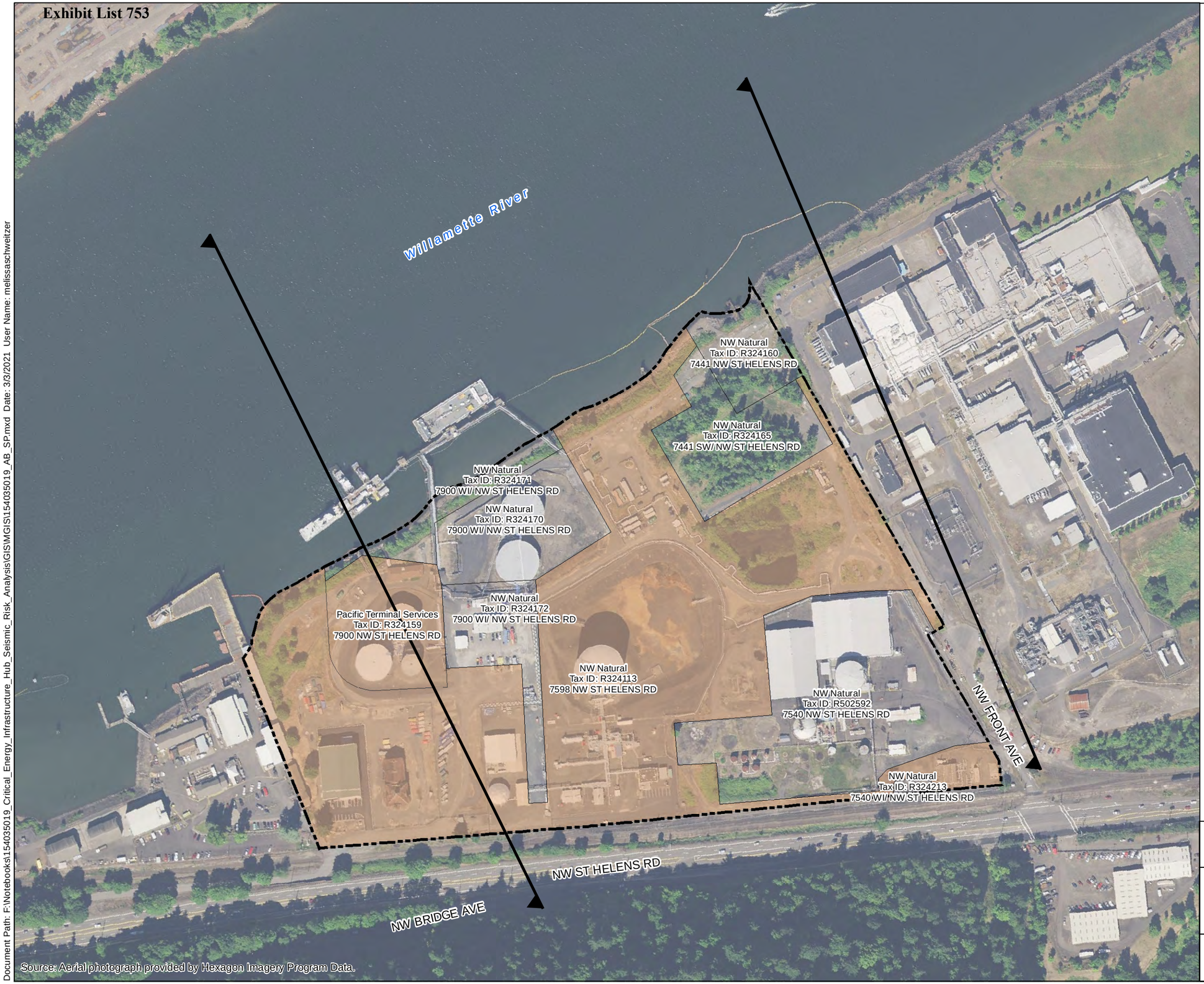
154-035-019 04/21

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Figure
1.7

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Exhibit List 753



Source: Aerial photograph provided by Hexagon Imagery Program Data.

Legend

- Project Area
- Tax Lot Boundary
- Property with Geotechnical Information Used in Analysis
- Approximate Location of Geotechnical Analysis Section

N

0 125 250 500 Feet

Note: Feature locations are approximate.

Critical Energy Infrastructure Hub Seismic Risk Analysis
Portland, Oregon

CEI Area 3 – NW Natural

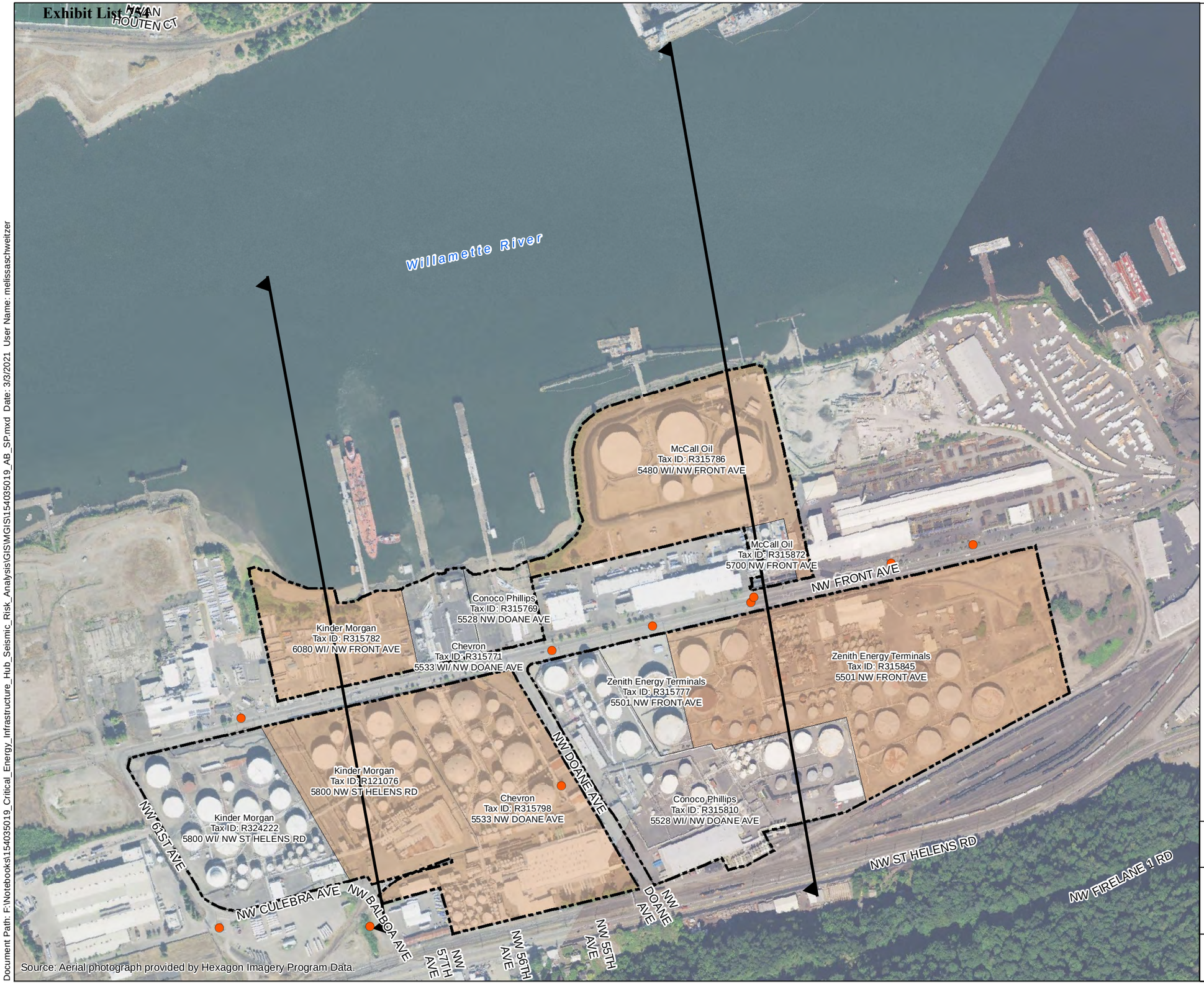
154-035-019 04/21

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Figure
1.8

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Exhibit List 154



Source: Aerial photograph provided by Hexagon Imagery Program Data.

Legend

- Project Area
- Tax Lot Boundary
- Property with Geotechnical Information Used in Analysis
- BES Borings used in Geotechnical Analysis
- Approximate Location of Geotechnical Analysis Section

N

0 225 450 900 Feet

Note: Feature locations are approximate.

Critical Energy Infrastructure Hub Seismic Risk Analysis
Portland, Oregon

CEI Area 4 – Willbridge

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Figure **1.9**

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Exhibit List 755



Legend

- Project Area
- Property with Geotechnical Information Used in Analysis
- BES Borings used in Geotechnical Analysis

N

0 90 180 360 Feet

Note: Feature locations are approximate.

Critical Energy Infrastructure Hub Seismic Risk Analysis
Portland, Oregon

CEI Area 5 – Equilon

154-035-019 04/21

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Figure **1.10**

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APPENDIX A
City of Portland CEI Hub Tank Infrastructure Data
Oregon State Fire Marshal CEI Hub Tank Data (Confidential)

APPENDIX A

REDACTED

Exhibit List 758

Report of Cascadia Subduction Zone Earthquake Impacts

Oregon Critical Energy Infrastructure Hub

Portland, Oregon

Prepared for
ECONorthwest and Multnomah County

February 2, 2022
Job No. 0202424-000 (154-035-019)





SALUS RESILIENCE

SALUS RESILIENCE

Report of Cascadia Subduction Zone Earthquake Impacts

Oregon Critical Energy Infrastructure Hub

Portland, Oregon

Prepared for
ECONorthwest and Multnomah County

February 2, 2022
Job No. 0202424-000 (154-035-019)

Prepared by
Salus Resilience

Allison Pyrch, PE
Senior Associate

Della Graham, RG
Senior Project, Geologist

6420 S Macadam Avenue, Suite 100
Portland, OR 97239
503.620.7284

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Report of Cascadia Subduction Zone Earthquake Impacts

Oregon Critical Energy Infrastructure Hub

Portland, Oregon

1.0 INTRODUCTION

This report summarizes our evaluation of the infrastructure impacts of a Cascadia Subduction Zone (CSZ) Earthquake on the Critical Energy Infrastructure (CEI) Hub in Northwest Portland, Oregon. The impacts to infrastructure were developed based on the geotechnical evaluation presented in our *Summary of Available Data and Report of Expected Earthquake Risk* dated February 2, 2022, (Salus 2022), the previous work completed at the site by others as referenced in Salus (2022), and the standards and references included in this document. No on-site evaluation was completed for this scope of work.

The geotechnical evaluation summarized in Salus (2022) developed estimates of earthquake-induced ground deformation due to liquefaction settlement and lateral spreading (movement toward the river) due to a CSZ event. This report discusses the potential effects of those estimated ground movements on the seismic performance of numerous aboveground storage tanks (ASTs) at the CEI Hub. This performance evaluation is broadly based on the assumed design/construction standards for the tanks based on their age and does not account for subsequent seismic upgrades which may have been undertaken by individual property owners. Information about the tanks, such as age, capacity, and contents, is provided in Salus (2022). The data, along with the results of the tank evaluations, are also presented in Appendix A to this report.

2.0 TANK DAMAGE ASSESSMENT METHODOLOGY

As discussed in Salus (2022), tank data were collected from the Office of Oregon State Fire Marshal (OSFM) and the City of Portland (City), the latter of which was developed from the Portland State University (PSU) 2019 study of the CEI Hub (Dusicka and Norton 2019). After a review of the available data, it was determined that the City dataset was more complete than the OSFM dataset and would be used as the main source for the tank inventory, with additional tank counts coming from a review of aerial photographs.

The evaluation of the tank inventory indicated that 630 tanks are present at the CEI Hub:

- 512 of the 630 tanks were listed in the City database in Area 1 through Area 4. One hundred and seventeen (117) of the 630 tanks were identified through figures provided by Portland Fire and Rescue (PF&R 2021) in Area 1 through 5. One additional tank was identified through City of Portland maps (Portlandmaps.com 2021) Of these 630 tanks:
    - 390 of the 630 tanks have a material assigned to the tank.
    - 240 of the 630 tanks do not have known contents, and therefore, were not evaluated.
        - 143 are listed as Out of Service.

  - 72 are listed as Unknown and do not have any information on status (in service or out of service), year built, latitude and longitude, contents, or capacity. All of these tanks are located at the Zenith property.
  - 18 are listed as Empty.
  - 7 are listed as Unavailable and do not have any information on status (in service or out of service), contents, or capacity.
- 193 of the 630 tanks do not have a known tank age, and therefore, were assumed to be constructed prior to 1993.

This results in 390 tanks that have enough information to be evaluated for release potential and are addressed in Sections 3.1 through 3.3. The locations of these tanks were based on either the specific location provided in the City database (latitude/longitude) or the property where it was located when a latitude/longitude was not provided. For tanks that were only located by property, the damage zones were decided based on visual inspection of the aerial photographs. Two hundred and nineteen (219) of the 390 tanks had specific locations identified. The remaining 171 of the 390 tanks had property information only. Further assumptions made for our evaluation include:

- Tank contents have not changed since the PSU study (Dusicka and Norton 2019) from which the City data are based.
- Tank capacity was provided for 516 tanks, and average fill was provided for 314 tanks from the collected data. We calculated the percent fill of the 314 tanks that had both capacity and average fill volumes by dividing the average fill volume by the tank capacity volume. The percent fill of these 314 tanks was found to be 67 percent. We then assumed that all tanks would have this same percent fill, We then applied the calculated percent fill to all tanks across the CEI Hub that had a known capacity (516 of the 630 tanks). The result was the "Expected Fill," which is the known tank capacity multiplied by 67 percent.
- Zenith property, which has no data in the City tank data, was evaluated based on figures provided by Portland Fire & Rescue (PF&R 2021) and the volumes provided for 10 tanks on that figure are assumed to be Expected Fill. Therefore, we did not apply the average percent fill of 67 percent these 10 tanks.
- Equilon, which has no data in the City tank data or the OSFM, was evaluated based on the figure provided by Portland Fire & Rescue (PF&R 2021). Tank capacity was listed as barrels (BBLs) on the provided figure. The data was converted to gallons using the assumption that there are 42 gallons in a barrel. The average percent fill of 67 percent was then applied to the tank capacity to obtain the average expected fill.
- NW Natural has no information on materials present in the City tank data or the OSFM, however capacity for the 7.1-million-gallon Liquefied Natural Gas (LNG) tank was obtained from City of Portland permit records. We have labeled this tank *NWN-Tank 001* for evaluation purposes.

2.1 Tank Damage Assumptions

Tank damage assumptions were developed using information provided on building codes within the DOGAMI report (Wang 2012), specifically a memorandum by the Oregon Building Codes Division (OBCD) summarizing changing seismic design requirements in Oregon (OBCD 2012), and tank design standards provided by the American Petroleum Institute (API), American Concrete Institute (ACI), and the American Society of Civil Engineers (ASCE). These references are listed in our reference section.

No structural engineering evaluation was completed for this study. As described below, the expected performance of tanks was broadly grouped based on tank age and the building code requirements at the time of tank construction. No tank- or site-specific information regarding detailed site characterization or historical seismic upgrade work was made available to use for this study. Geotechnical assessments were based on publicly available (and limited confidential) data and information as described in Salus (2022).

Tank damage was generally based either on the tank age and/or anticipated ground deformations, as described below.

2.1.1 Tank Age

The age of tanks was used to determine the likely standards that were followed during the design of the tanks. For our evaluation we assumed that seismic design of the tanks at the CEI Hub location followed city/state building codes, and therefore, age-appropriate UBC-/IBC-/ASCE-based seismic requirements were used for the tanks. We have not accounted for any subsequent seismic upgrade work which may have been completed by individual property owners.

Based on our review and OBCD information (OBCD 2012) UBC/IBC/ASCE design standards, and state and city building codes were adopted in Oregon in 1974 and included seismic design parameters for a Seismic Zone of 2. It was not until 1993 that Oregon was designated a Seismic Zone 3 and the seismic design requirements were significantly increased (by 50%) to better reflect the local seismic risk. (OBCD 2012).. Further, based on information provided by the City of Portland Bureau of Development Services to DOGAMI (Wang 2012), the City of Portland first required geotechnical reports to evaluate liquefaction potential and soil strength loss in 1996. However, it was not until 2004 that silty soils such as those located at the CEI Hub were considered liquefiable. Prior to 2004 these soils were widely considered non-liquefiable.

Based on this information, we have made the following broad assumptions about tank design and performance based on the tank age.

- Tanks constructed prior to 1993 were not designed to resist levels of seismic loading required by current seismic standards and thus we have assumed that they will experience significant damage that has the potential to result in a release of materials during the CSZ event. There are 402 tanks that have been identified as being constructed prior to 1993. There are an additional 193 tanks with no tank age data that are assumed to have been constructed prior to 1993. In total, 595

tanks at the CEI Hub are assumed to be construction prior to 1993 and therefore not designed to resist current levels of seismic loading and will release material during the CSZ event.

- Tanks constructed in 1993 through 2004 are assumed to be designed for greater levels of seismic shaking than older tanks, but are assumed to be potentially susceptible to damage due to liquefaction settlement and lateral spread in sandy and silty soils. There are 23 tanks that have been identified as being constructed between 1993 and 2004.

- Tanks constructed after 2004 are assumed to have been designed to withstand earthquake shaking and associated ground deformation levels associated with current seismic design standards, and thus are unlikely to release material during the CSZ event. There are 12 tanks that have been identified as being constructed after 2004. (This does not include any older tanks which may have seismically upgraded by individual tank owners.)

Due to their age and the lack of modern-era seismic design standards, we anticipate the 402 tanks known to have been constructed before 1993 and the 193 with no age (assumed to be constructed before 1993) will likely be damaged and release material during a CSZ earthquake event.

We recognize that even tanks designed and constructed after 2004 will not necessarily have been designed to resist seismic shaking equal to the intensities that are anticipated to be associated with the CSZ. Therefore, even some of these more modern tanks are likely to experience damage; however, for purposes of this scenario evaluation that has not been quantified.

2.1.2 Ground Deformation

In Salus (2022), the potential for ground deformation due to liquefaction-induced ground settlement, lateral spreading, and slope failure was estimated. If significant enough, ground deformation can cause damage to tanks. Based on our review of tank standards and information assembled by Akhavan-Zanjani (2009), steel tanks can undergo settlement on the order of 1 to 3 feet depending on tank diameter without suffering significant distress. Allowable tilt is on the order of 0.5 to 1 foot depending on tank height. Allowable settlements are expected to be less for concrete tanks.

Tanks built during 1993 and before 2004 were evaluated based on the anticipated settlement, lateral spread, and expected slope failure due to site geometry (retaining walls, slope etc.). If settlement and lateral spread or slope failure is expected to exceed allowable amounts, the tanks were assumed to be damaged enough to release material. However, based on our evaluation, the 23 tanks built between 1993 and 2004 were not located in areas expected to exceed the allowable deformations noted above, and therefore, were not considered to release material.

2.1.3 Tank Material Release

As noted above, we anticipate the 402 tanks constructed before 1993, and the 193 assumed to be constructed before 1993, will likely be damaged during a CSZ event. The consequence of tank damage is a release of materials. We have assumed that tank damage will result in between 50 to 100 percent of the contents being released to the ground or in the water.

The 23 tanks built between 1993 and 2004 and the 12 tanks built after 2004 are expected to remain relatively intact after a CSZ event; however, we have assumed releases due to connection failures and other incidental damage may result in up to 10 percent release.

2.1.4 Tank Characterization

Tanks were grouped by content and age as outlined above. Further, we categorized the materials as flammable and hazardous based on the material identified as contents. We referenced the Safety Data Sheets (SDS) for each material to categorize the tanks as outlined below. SDS sheets were generally accessed through an online software database (CSS 2021). Tank characterizations as outlined below were incorporated into GIS and are shown on figures in Appendix C of Salus 2021.

- Tank Groups
  - Group 1 - No information on contents/amount of material present (79 of 630 tanks)
  - Group 2 - Out of Service/Empty (161 of 630 tanks)
  - Group 3 - Content and amount of material present available
    - Group 3A - Built before 1993 (357 of 630 tanks)
    - Group 3B - Built 1993-2004 (21 of 630 tanks)
    - Group 3C - Built after 2004 (12 of 630 tanks)

- Tank Material Impact Categories
  - Flammability
    - Category 1 - Liquids with flashpoints below 73.4°F (23°C) and boiling points at or below 95°F (35°C) [106 of 630 tanks]
    - Category 2 - Liquids with flashpoints below 73.4°F (23°C) and boiling points at or above 95°F (35°C) [28 of 630 tanks]
    - Category 3 - Liquids with flashpoints at or above 73.4°F (23°C) and at or below 140°F (60°C) [66 of 630 tanks]
    - Category 4 - Liquids having flashpoints above 140°F (60°C) and at or below 199.4°F (93°C) [0 tanks]
    - None (Out of Service/Empty) [161 of 630 tanks]
    - Not Flammable (14 of 630 tanks)
    - Unknown (255 of 630 tanks)

- Hazardous
  - Yes - Hazardous (All flammable materials are considered hazardous) [337 of 630 tanks]
  - No - Non-Hazardous (7 of 630 tanks)
  - None (Out of Service/Empty) [161 of 630 tanks]
  - Unknown (125 of 630 tanks)

2.1.5 Damage Zone Characterization

Damage zones were developed to indicate where materials released from failed tanks are anticipated to be located and were categorized into three categories, including released material remains on the ground, released material flows into the Willamette River, and released material has the potential to spread or be spread by water or rain to the Willamette River. These zones were estimated based on proximity to water, expected settlement and lateral spread estimates as determined in Salus (2022) our geotechnical evaluation, and topography (retaining walls and existing slopes).

We understand that containment berms, walls and other structures are present at the various CEI Hub properties. We do not have any information on these structures, no site visits were conducted, and no structural engineering evaluations were completed. However, concrete and berm structures are generally susceptible to settlement and lateral spread and have been assumed to fail, and therefore, release material where more than 1 foot of lateral movement is expected. Further, based on Environmental Protection Agency (EPA) guidance for preparation of spill prevention and control plans, these standards generally require that tank spill containment be designed to contain between 100 and 110 percent of the capacity of the largest tank within the containment area. Based on aerial photography, these containment areas generally contain several tanks that may be damaged and release their contents, therefore, the containment structures are not assumed to prevent spills during a seismic event where more than one tank is likely to be damaged and significant ground movement is anticipated.

Based on our evaluation, the damage zones were defined as shown in Table 2.1 and in Appendix C of the main report (Salus 2021).

Table 2.1 - Damage Zone Summary

	Damage Zone (distance from slope crest/wall (feet))		
	Material In Water	Material Potentially in Water	Material On Land
Area 1 - Kinder Morgan N	0-500	500-750	750+
Area 2 - Linnton N	0-500	500-750	750+
Area 2 - Linnton S	0-500	500-750	750+
Area 3 - NW Natural	0-250	250-500	500+
Area 4 - Willbridge	0-250	250-500	500+
Area 5 - Equilon	n/a	n/a	All

These damage zones were incorporated into GIS and compared to the City dataset. A discussion of the tank damage assessment results for the 630 tanks evaluated is provided in Section 3.

3.0 MATERIAL RELEASE ESTIMATES AT THE CEI HUB

In Section 2, we evaluated the potential for tanks to be damaged in a seismic event based on age and ground deformation. In this section, we estimate the potential volume of materials that might be released from susceptible tanks. The loss of materials is grouped in material type and proximity to the Willamette River.

3.1 Estimate of Hazardous Materials Spilled to Willamette River

Of the 630 tanks present, 114 tanks were estimated to have the potential to release the contents to the Willamette River based on tank age and location. However, 30 of these tanks were categorized as Out of Service or Unavailable, and therefore not included in this summary. A detailed table of the tanks is provided in Appendix B.

3.1.1 Full Spill - 50 to 100 Percent of Contents

We estimate that 78 of the 84 tanks, which are all built before 1993, have the potential to release between 50 to 100 percent of their contents to the Willamette River. These tanks were sorted by content and minimum and maximum expected volume lost. A total of 20 unique substances are included in these releases as summarized below in Table 3.1.

Table 3.1 - Materials with Potential to Release to the Willamette River by Area - Full Spill

Area	Property	Contents	Volume Lost Minimum (gallons)	Volume Lost Maximum (gallons)
1	Kinder Morgan North	Contact Water	7,668	15,336
		Diesel	509,615	1,019,231
		Gasoline	2,497,509	4,995,019
		Storm Water	45,910	91,821
2	BP	Biodiesel	344,026	688,051
		Diesel	2,968,193	5,936,386
		Ethanol	404,794	809,588
		Gasoline	3,752,258	7,504,516
		Gasoline Additive	87,303	174,607
		Groundwater Remediation	412,385	824,770
		Oily Wastewater	66,607	133,215
	Shore Terminals	Biodiesel	290,062	580,124
		Biodiesel Additive[7]	NA	NA
		Cutter	103,682	207,364
		Diesel	1,907,140	3,814,279
		Ethanol	911,472	1,822,944
		Ethanol/Gasoline[2]	131,705	263,410
		Gasoline	3,504,071	7,008,142
		Gasoline/Diesel Additive[4]	5,941	11,881
		Gasoline/Diesel[3]	6,411,500	12,822,999
		Marine Fuel Oil	1,190,136	2,380,271
3	Pacific Terminal Services	Diesel Oil	20,104	40,208
		Residual Oil[6]	65,325	130,650
4	McCall Oil	Asphalt	3,767,805	7,535,611
		Biodiesel	333,937	667,875
		Bunker	3,134,909	6,269,817
		Diesel	1,788,635	3,577,269
		Oil and water	10,130	20,261

3.1.2 Minor Releases - Up to 10 Percent of Contents

We estimate that 6 of the 86 tanks (built during or after 1993) have the potential to release up to 10 percent of their contents into the Willamette River. These six tanks were sorted by content and minimum and maximum expected volume lost. A total of five unique substances are included in these releases as summarized in Table 3.2.

Table 3.2 - Materials with Potential to Release to the Willamette River by Area - Minor Release

Area	Property	Contents	Volume Lost Maximum (gallons)
1	Kinder Morgan North	Diesel	190,434
2	BP	Diesel Additive	134
		Diesel Lubricity Additive	141
	Shore Terminals	Gasoline/Diesel[3]	562,800
3	Pacific Terminal Services	Residual Oil[6]	32

3.2 of Hazardous Materials Potentially Spilled to Willamette River

Our evaluation indicates that 18 tanks are expected to release the following percentage of contents in areas that could potentially be released into to the Willamette River via overland flow or carried by water runoff. A detailed table of these tanks is provided in Appendix C.

3.2.1 Full Spill - 50 to 100 Percent of Contents

We estimate that 12 of the 18 tanks (built prior to 1993) have the potential to release between 50 and 100 percent of their contents onto the ground surface and potentially into the Willamette River. Seven unique substances are included in these releases as summarized in Table 3.3.

Table 3.3 - Materials with Potential to Release and Flow to the Willamette River by Area - Full Spill

Area	Property	Contents	Volume Lost Minimum (gallons)	Volume Lost Maximum (gallons)
3	Pacific Terminal Services	Residual Oil[6]	6,700	13,400
4	Conoco Phillips	Unleaded Gasoline	990,106	1,980,212
	McCall Oil	Anti-strip	1,646	3,292
		Asphalt	4,385,098	8,770,197
		Boiler Fuel	2,800	5,600
		Flux	17,433	34,865
		Unichem	3,685	7,370

3.2.2 Minor Releases - 10 Percent of Contents

We estimate that 6 of the 18 tanks (built after 1993) have the potential to release up to 10 percent of the tank contents in areas that could potentially reach the Willamette River due to connection failures. The tanks are located in Area 4 as summarized in Table 3.4.

Table 3.4 - Materials with Potential to Release and Flow to the Willamette River - Minor Release

Area	Property	Contents	Volume Lost Maximum (gallons)
4	Chevron	Unleaded Gasoline	228,625
	McCall Oil	Asphalt	17,317
		Polyphosphoric Acid	362

3.3 Estimate of Hazardous Materials Spilled to Ground Surface

Of the tanks with known locations, 498 have the potential to release contents onto to the ground. However, 209 of these tanks are categorized as Out of Service, Empty, NA, or Unavailable. A detailed table of the remaining 289 tanks is provided in Appendix D.

3.3.1 Full Spill - 50 to 100 Percent of Contents

We estimate that 268 tanks have the potential to release 50 to 100 percent of their tank contents onto the ground. These tanks were sorted by content and minimum and maximum expected volume lost. A total of 149 unique substances have the potential to be released to the ground surface as summarized in Table 3.5.

Table 3.5 - Materials with Potential to Release to the Ground Surface - Full Spill

Area	Property	Contents	Volume Lost Minimum (gallons)	Volume Lost Maximum (gallons)
4	Chevron	1000 THF	20,724	41,449
		Additive	11,808	23,616
		ATF dex 111	36,842	73,684
		Base Oil	964,907	1,929,813
		Blend Mix/ Line Wash	24,200	48,400
		Blended Oil	3,527	7,054
		Chevron 7075F	66,600	133,200
		Citgo Brt Stock 150	51,065	102,130
		Clarity PM 150	2,903	5,806
		Clarity PM 220	14,549	29,097
		Clarity Saw Guide 46	5,806	11,612
		Compressor Oil	5,790	11,580
		CVX 3105	5,888	11,777
		Delo 100-40	8,550	17,100
		Delo 400-10	8,479	16,958
		Delo 400-15W40	97,910	195,821
		Delo 400-30	27,812	55,625
		Delo 400-40	20,724	41,449
		Delo 6170 CFO 20W40	63,765	127,530
		Delo G/L 80/90	5,969	11,938
		Delo GL 80/90	5,904	11,808
		Diesel	282,832	565,664
		Drive Train Fluid HD 10	11,643	23,287
		ExxonMobil EM-100	196,411	392,822
		ExxonMobile EHC45	9,825	19,649
		FAMM Tara 30 DP 30	8,502	17,004
		Famm Taro Sepcial 70	33,699	67,398
		Gear Lube	5,904	11,808
		GEO HDAX L ASH 40	33,593	67,186
		GST ISO 100	8,502	17,004

Area	Property	Contents	Volume Lost Minimum (gallons)	Volume Lost Maximum (gallons)
		GST ISO 32	5,904	11,808
		Havoline 10W30	20,724	41,449
		Hybase C414	11,710	23,420
		Industrial EP 150	5,953	11,907
		Industrial EP 220	5,904	11,808
		Infineum M7038	5,904	11,808
		Jet Fuel	336,536	673,073
		Lubrizol 4991	11,710	23,419
		Lubrizol 4991D	70,992	141,983
		Map 100	27,946	55,893
		MAR EO 9250-40	5,938	11,875
		Neutral 220R	145,980	291,960
		Neutral 600R	134,127	268,254
		Neutral Oil	122,554	245,109
		Oil Stop	6,509	13,019
		Oloa 2000	20,354	40,707
		Oloa 44200	5,920	11,840
		Oloa 550006L	9,910	19,821
		Oloa 6073EV	5,969	11,938
		Oloa 9740C	5,920	11,840
		Paratone 8451	161,248	322,496
		Pennzoil 75HC	9,739	19,478
		Raffene 2000L	5,904	11,808
		Raffene 750L	15,303	30,607
		Red Chain Bar 150	3,936	7,873
		RPM HDMO 15W40	48,857	97,714
		RPM HDMO 30	8,814	17,628
		RPM UGL 80W90	20,781	41,562
		Rykon Oil 46	30,607	61,214
		Rykon Oil 68	22,585	45,171
		Rykon Prem 32	44,550	89,099
		Rykon Prem MV	35,140	70,281
		Saw Guide 150	5,790	11,580
		Shell MV1 100	8,502	17,004
		Supreme 5W30	20,781	41,562
		SynFluid $, 4CST	2,919	5,837
		Techron Additive	69,822	139,645
		Texaco Havoline 5S30	5,806	11,612
		Transmix	8,525	17,049
		Turbine Oil	17,712	35,424
		Undefined Petroleum	5,938	11,875
		Unleaded Gasoline	1,209,264	2,418,528
		VER 800 Mar 30	11,336	22,672
		Viscoplex 1-604	4,689	9,378

Area	Property	Contents	Volume Lost Minimum (gallons)	Volume Lost Maximum (gallons)
		Viscoplex 7-305	4,663	9,325
		Water/Oil Slop	132,843	265,686
	Conoco Phillips	Bar & Chain 150	4,523	9,045
		Biodiesel	135,424	270,848
		Decant Oil	317,602	635,204
		Diesel #1	233,055	466,111
		Diesel #2	2,597,632	5,195,263
		Ethanol	93,453	186,906
		Ethyl HITEC 388	4,523	9,045
		Ethyl HITEC 5756	4,523	9,045
		Ethyl HITEC 6888E	8,543	17,085
		Firebird 15W/40	4,523	9,045
		Fleet Sup EC 15W/40	4,523	9,045
		Flush	5,863	11,725
		Gasoline Slops[5]	3,377	6,754
		Guardol 15W/40	36,515	73,030
		Guardol 30	4,523	9,045
		HITEC 1193	5,863	11,725
		HITEC 1193A	4,523	9,045
		HITEC 3472	4,523	9,045
		HITEC 5751	5,863	11,725
		HiTech 6576	6,106	12,213
		HT4/10W	5,863	11,725
		HT4/30W	4,523	9,045
		Hydraulic Tractor Oil	6,399	12,797
		HYNAP N100	5,863	11,725
		Industrial Fuel Oil	1,108,069	2,216,138
		Line Clippings	6,030	12,060
		Lubrizol 48254	5,863	11,725
		Lubrizol 4990CH	5,863	11,725
		Lubrizol 4998C	5,863	11,725
		Lubrizol 7075F	5,863	11,725
		Lubrizol 9692A	4,523	9,045
		Lubrizol 9990A	4,523	9,045
		Marine Diesel	150,647	301,295
		Marine Fuel Oil	525,810	1,051,620
		Mohawk 150	4,523	9,045
		Mohawk 450	5,863	11,725
		MP Gear Lube 80/90	5,863	11,725
		Point Premier 10W/30	5,863	11,725
		PS 300	153,870	307,739
		Raffene 750L	5,863	11,725
		Ramar CLF 17E	14,405	28,810

Area	Property	Contents	Volume Lost Minimum (gallons)	Volume Lost Maximum (gallons)
		Residual Fuel Oil[6]	304,827	609,653
		RLOP 100N	139,863	279,725
		RLOP 220 N	379,723	759,445
		RLOP 600N	98,658	197,315
		Stop Oil	13,127	26,255
		SUN 150 B/S	67,000	134,000
		SUN 525	72,863	145,725
		Sup Syn BL 10W/30	11,725	23,450
		SUP SYN BL 5W/30	40,200	80,400
		Super 5W/20	5,863	11,725
		Super ATF	17,588	35,175
		T5X HD 15W/40	11,725	23,450
		Transmix	68,845	137,689
		TSX HD10	4,523	9,045
		ULTRA S-4	67,000	134,000
		Unax AW 46	36,515	73,030
		UNAX AW 68	5,863	11,725
		UNAX AW 68	5,863	11,725
		Uniguide II 100	11,725	23,450
		Unleaded Gasoline	2,133,716	4,267,431
		Utility	37,889	75,777
		UTRA 58	8,543	17,085
		UTRA 59	5,863	11,725
		Versa Tran ATF	5,863	11,725
	Kinder Morgan South	Additive	8,892	17,784
		Avgas	191,563	383,126
		Biodiesel	189,945	379,890
		Contact Water	19,304	38,608
		Diesel	3,070,074	6,140,148
		Ethanol	72,293	144,586
		Gasoline	7,675,185	15,350,370
		Jet A	4,090,121	8,180,242
		Lubricity Additive	56,280	112,560
		Slop Water	2,111	4,221
		Storm Water	211,050	422,100
		Transmix	472,006	944,013
	McCall Oil	Asphalt	6,346	12,691
	Zenith Energy	Asphalt	NA	NA
		Avgas	701,190	1,402,380
		Biodiesel	111,000	222,000
		Caustic	NA	NA
		Charge Stock	NA	NA
		Crude Oil	13,890,431	27,780,862
		Murol	NA	NA

Area	Property	Contents	Volume Lost Minimum (gallons)	Volume Lost Maximum (gallons)
		Universal Low-Sulfer Diesel	1,594,299	3,188,598
		Wastewater	NA	NA
5	Equilon	Diesel	2,558,686	5,117,372
		Ethanol	781,124	1,562,248
		Gasoline	4,080,821	8,161,641
		Water	89,598	179,196

3.3.2 Minor Releases - 10 Percent of Contents

We estimate that 21 tanks have the potential to release up to 10 percent of their contents onto the ground. The 21 tanks were sorted by content and minimum and maximum expected volume lost. Eight unique substances have the potential to be released onto the ground surface as summarized in Table 3.6. All of these tanks are located in Area 4.

Table 3.6 - Materials with Potential to Release to the Ground Surface - Minor Release

Area	Property	Contents	Volume Lost Maximum (gallons)
3	Northwest Natural Gas	Liquefied Natural Gas	475,700
4	Conoco Phillips	Octel 9056	1,249
	Chevron	Base Oil	56,085
		Blended Oil	5,964
		Ethanol	64,232
		Swing Tank	851,457
		Unleaded Gasoline	951,669
	Kinder Morgan South	Diesel	337,680
		Gasoline	337,680
		Jet A	337,680

3.4 Estimate of Hazardous Materials Expected to Burn

During the development of the tank inventory, the materials present in the tanks were reviewed for flammability based on the flammability categories outlined on the standard MSDSs. The 390 tanks evaluated were divided based on the flammability categories defined in Section 2 (Step 2). The number of tanks in each flammability category are as follow:

- Category 1 - 106 Tanks
- Category 2 - 28 Tanks
- Category 3 - 66 Tanks
- Category 4 - 0 Tanks
- Not Flammable - 14 Tanks
- Unknown (Contents Known, Flammability Category Not Found) - 176 Tanks

Of the 390 tanks with known contents at the CEI Hub, 200 (approximately 51 percent) have materials that are known to be flammable. The estimated volume of flammable materials present at the CEI Hub

is 209,533,756 gallons. Therefore, the contents of these tanks all have the potential to burn, either on land or in the water. Because burning requires both a fuel and ignition source, it is not possible to have a specific numerical value for the estimated quantity of materials that will burn. Rather, it is only possible to estimate that 209,533,756 gallons have the *potential* to burn.

Based on the Tank Damage Assessment Methodology, we estimate that 87,246,258 to 179,996,640 gallons of flammable material will be released either to the Willamette River or on land.

3.5 Estimate of Hazardous Materials Present

In addition to the flammability of materials present at the CEI Hub, tank contents were also evaluated for their hazardous characteristics. The 390 tanks evaluated were divided based on hazardous or non-hazardous characteristics as defined in Section 2 (Step 2). The number of tanks in each hazard category are as follow:

- Hazardous - 337 Tanks
- Non-Hazardous - 7 Tanks
- Unknown (Contents Known, Hazard Category Not Found) - 46 Tanks

Of the 390 tanks with known contents at the CEI Hub, 337 (approximately 86 percent) have materials that have are known to be hazardous.

4.0 REFERENCES

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Exhibit List 778

Willamette River

Kinder Morgan North Area
Area 1

Linnton Area
Area 2

NW Natural Area
Area 3

Willbridge Area
Area 4

Equilon Area
Area 5

Source: Aerial photograph provided by Hexagon Imagery Program Data.

Legend

- Project Areas

Kinder Morgan North Area Owners
- Kinder Morgan

Linnton Area Owners
- BP West Coast
- Shore Terminals / Nustar

NW Natural Area Owners
- NW Natural
- Pacific Terminal Services

Equilon Area Owners
- Equilon

Willbridge Area Owners
- Chevron
- Conoco Phillips
- Kinder Morgan
- McCall Oil
- Zenith Energy Terminals

N

0 900 1,800 3,600 Feet

Note: Feature locations are approximate.

Oregon Critical Energy Infrastructure Hub
Portland, Oregon

CEI Hub Map

154-035-019 04/21

HARTCROWSER
A division of Haley & Aldrich

Figure 1

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Exhibit List 779



Tank Release

- Flammable and Hazardous
- Empty or Out of Service

No Tank Release

- Flammable and Hazardous
- Taxlot Boundary

Damage Zone

- Material in Water
- Potentially in Water

N

FIGURE 2A
KINDER MORGAN NORTH

FEBRUARY 2022
GIS FIGURE PROVIDED BY ECONORTHWEST

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Exhibit List 780



Tank Release

- Flammable and Hazardous
- No Data
- Empty or Out of Service
- Tank Failure, not Flammable and not Hazardous

No Tank Release

- Flammable and Hazardous
- Taxlot Boundary

Damage Zone

- Material in Water
- Potentially in Water

N

FIGURE 2B
LINNTON

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Exhibit List 781



Tank Release

- Flammable and Hazardous

No Tank Release

- Flammable and Hazardous
- Taxlot Boundary

Damage Zone

- Material in Water
- Potentially in Water

N

FIGURE 2C
NW NATURAL

FEBRUARY 2022
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Exhibit List 782



Tank Release

- Flammable and Hazardous
- Flammable (but not Hazardous)
- Hazardous (but not Flammable)
- No Data
- Empty or Out of Service
- Tank Failure, not Flammable and not Hazardous

Damage Zone

- Material in Water
- Potentially in Water

No Tank Release

- Flammable and Hazardous
- Hazardous (but not Flammable)
- No Data
- Taxlot Boundary

N

FIGURE 2D
WILLBRIDGE

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Tank Release

- Flammable and Hazardous
- Empty or Out of Service
- Tank Failure, not Flammable and not Hazardous
- Taxlot Boundary

Damage Zone

- Material in Water
- Potentially in Water

N

FIGURE 2E
EQUILON

FEBRUARY 2022
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APPENDIX A
Full Tank Data

Exhibit List 785

Appendix A: Full Tank Data

Area	Property	Tank ID[1]	Latitude	Longitude	Contents	Capacity (Gal)	Expected Fill (Gal) (67% of Capacity)[2]	Year	Type	Tank Group	Flammability Category	Hazardous Category	Damage Zone	Tank Age Failures	Percent Lost Min	Percent Lost Max	Volume Lost Min	Volume Lost Max
2	BP	BP1	-122.7806873	45.59494967	Gasoline	3,808,434	2,551,651	1940	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	1,275,825	2,551,651
2	BP	BP10	-122.7788011	45.59386607	Diesel	1,008,840	675,923	1941	Fixed Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	337,961	675,923
2	BP	BP11	-122.7800489	45.59444227	Gasoline	1,354,122	907,262	1940	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	453,631	907,262
2	BP	BP12	-122.7802194	45.59496165	Ethanol	605,346	405,582	1961	Internal Floating Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	202,791	405,582
2	BP	BP13	-122.7804499	45.59525087	Ethanol	602,994	404,006	1961	Internal Floating Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	202,003	404,006
2	BP	BP14	-122.7794397	45.59361625	Diesel	1,121,736	751,563	1942	Fixed Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	375,782	751,563
2	BP	BP15	-122.7791647	45.59373755	Biodiesel	804,972	539,331	1943	Fixed Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	269,666	539,331
2	BP	BP17	-122.7786956	45.5935232	Diesel	3,329,340	2,230,658	1940	Fixed Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	1,115,329	2,230,658
2	BP	BP18	-122.7797157	45.5935084	Diesel	1,104,726	740,166	1945	Fixed Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	370,083	740,166
2	BP	BP19	-122.7785286	45.59376099	Oily Wastewater	198,828	133,215	1961	Internal Floating Roof	Group 3A	Not Flammable	Unknown	Material in Water	Tank Failure	50%	100%	66,607	133,215
2	BP	BP2	-122.780702	45.5946449	Groundwater Remediation	1,231,000	824,770	1957	Internal Floating Roof	Group 3A	Not Flammable	Unknown	Material in Water	Tank Failure	50%	100%	412,385	824,770
2	BP	BP21	-122.7782544	45.59352925	Gasoline Additive	220,080	147,454	1961	Fixed Roof	Group 3A	Category 2	Yes	Material in Water	Tank Failure	50%	100%	73,727	147,454
2	BP	BP23a	Unknown	Unknown	Diesel Additive	2,000	1,340	2005	Fixed Roof	Group 3C	Category 3	Yes	Material in Water	No Tank Failure	0%	10%	0	134
2	BP	BP23b	Unknown	Unknown	Diesel Lubricity Additive	2,100	1,407	2005	Horizontal Tank	Group 3C	Category 3	Yes	Material in Water	No Tank Failure	0%	10%	0	141
2	BP	BP24	Unknown	Unknown	Gasoline Additive	20,286	13,592	1970	Fixed Roof	Group 3A	Category 2	Yes	Material in Water	Tank Failure	50%	100%	6,796	13,592
2	BP	BP25	Unknown	Unknown	Gasoline Additive	20,241	13,561	1966	Fixed Roof	Group 3A	Category 2	Yes	Material in Water	Tank Failure	50%	100%	6,781	13,561
2	BP	BP3	-122.7813045	45.59482967	Gasoline	1,584,366	1,061,525	1957	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	530,763	1,061,525
2	BP	BP4	-122.7810795	45.59457546	Gasoline	1,105,860	740,926	1957	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	370,463	740,926
2	BP	BP40	-122.7793826	45.59410523	Unavailable	0	0	1954	Fixed Roof	Group 1	Unknown	Unknown	Material in Water	Tank Failure	50%	100%	0	0
2	BP	BP41	-122.7792266	45.59415752	Out of Service	0	0	1954	Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
2	BP	BP42	-122.7790785	45.59420894	Out of Service	0	0	1954	Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
2	BP	BP43	-122.778926	45.59426297	Out of Service	0	0	1954	Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
2	BP	BP44	-122.7789974	45.59410785	Out of Service	0	0	1954	Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
2	BP	BP45	-122.7791499	45.59405643	Unavailable	0	0	1954	Fixed Roof	Group 1	Unknown	Unknown	Material in Water	Tank Failure	50%	100%	0	0
2	BP	BP46	-122.7793016	45.59400501	Biodiesel	221,970	148,720	1954	Fixed Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	74,360	148,720
2	BP	BP5	-122.7807976	45.59434127	Gasoline	895,314	599,860	1957	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	299,930	599,860
2	BP	BP6	-122.7804436	45.5945153	Gasoline	1,014,384	679,637	1957	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	339,819	679,637
2	BP	BP7	-122.7803002	45.59476875	Gasoline	648,018	434,172	1957	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	217,086	434,172
2	BP	BP8	-122.7803993	45.59427087	Gasoline	790,272	529,482	1957	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	264,741	529,482
2	BP	BP9	-122.7792567	45.59324486	Diesel	2,295,636	1,538,076	1940	Fixed Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	769,038	1,538,076
4	Chevron	CH1	-122.7414229	45.56525743	Unleaded Gasoline	3,412,315	2,286,251	1997	Internal Floating Roof	Group 3B	Category 1	Yes	Potentially in Water	Tank Failure	0%	10%	0	228,625
4	Chevron	CH10	Unknown	Unknown	Paratone 8451	169,616	113,643	1950	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	56,821	113,643
4	Chevron	CH100	-122.7429011	45.5642678	Gear Lube	17,624	11,808	1946	Fixed Roof	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	5,904	11,808
4	Chevron	CH101	-122.7429342	45.56422771	Compressor Oil	17,284	11,580	1958	Fixed Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	5,790	11,580
4	Chevron	CH102	Unknown	Unknown	Out of Service	12,954	8,679	1978	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH103	Unknown	Unknown	Out of Service	13,006	8,714	1978	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH104	Unknown	Unknown	Texaco Havoline 5S30	17,331	11,612	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,806	11,612
4	Chevron	CH105	Unknown	Unknown	Empty	17,624	11,808	1969	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH106	Unknown	Unknown	Delo G/L 80/90	17,818	11,938	1969	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,969	11,938
4	Chevron	CH108	Unknown	Unknown	Techron Additive	208,425	139,645	1970	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	69,822	139,645
4	Chevron	CH109	-122.7429586	45.56419459	Delo GL 80/90	17,624	11,808	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,904	11,808
4	Chevron	CH11	Unknown	Unknown	Lubrizol 4991D	211,915	141,983	1950	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	70,992	141,983
4	Chevron	CH110	Unknown	Unknown	GST ISO 32	17,624	11,808	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,904	11,808
4	Chevron	CH112	Unknown	Unknown	Oloa 6073EV	17,818	11,938	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,969	11,938
4	Chevron	CH113	Unknown	Unknown	Hybase C414	17,378	11,643	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,822	11,643
4	Chevron	CH114	Unknown	Unknown	Industrial EP 220	17,624	11,808	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,904	11,808
4	Chevron	CH116	Unknown	Unknown	Empty	17,724	11,875	1976	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH117	Unknown	Unknown	Raffene 2000L	17,624	11,808	1976	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,904	11,808
4	Chevron	CH118	Unknown	Unknown	Blend Mix/ Line Wash	17,577	11,777	1976	Fixed Roof	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	5,888	11,777
4	Chevron	CH119	Unknown	Unknown	Out of Service	19,593	13,127	1977	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH12	Unknown	Unknown	ExxonMobil EM-100	586,302	392,822	1950	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	196,411	392,822
4	Chevron	CH120	Unknown	Unknown	Out of Service	19,593	13,127	1977	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH121	Unknown	Unknown	Out of Service	NA	NA	1978	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH122	Unknown	Unknown	1000 THF	61,864	41,449	NA	Fixed Roof	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	20,724	41,449
4	Chevron	CH123	Unknown	Unknown	Delo 400-40	61,864	41,449	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	20,724	41,449
4	Chevron	CH127	Unknown	Unknown	ATF dex 111	109,976	73,684	NA	Fixed Roof	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	36,842	73,684
4	Chevron	CH128	-122.7425148	45.56345508	Rykon Prem 32	74,586	49,973	NA	AST	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	24,986	49,973
4	Chevron	CH129	-122.7425998	45.56357042	Base Oil	642,935	430,766	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	215,383	430,766
4	Chevron	CH13	Unknown	Unknown	Raffene 750L	45,682	30,607	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	15,303	30,607
4	Chevron	CH130	-122.7424451	45.56367296	Base Oil	255,112	170,925	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	85,463	170,925
4	Chevron	CH131	Unknown	Unknown	Hybase C414	17,577	11,777	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,888	11,777
4	Chevron	CH132	Unknown	Unknown	Empty	18,165	12,171	NA	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH133	Unknown	Unknown	CVX 3105	17,577	11,777	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,888	11,777
4	Chevron	CH135	Unknown	Unknown	Out of Service	19,379	12,984	1982	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH136	Unknown	Unknown	Out of Service	20,303	13,603	1982	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH137	Unknown	Unknown	Oloa 2000	60,757	40,707	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	20,354	40,707
4	Chevron	CH138	Unknown	Unknown	Drive Train Fluid HD 10	17,378	11,643	NA	Fixed Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	5,822	11,643
4	Chevron	CH139	Unknown	Unknown	Blend Mix/ Line Wash	25,591	17,146	NA	Fixed Roof	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	8,573	17,146
4	Chevron	CH14	Unknown	Unknown	Delo 6170 CFO 20W40	190,343	127,530	1950	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	63,765	127,530
4	Chevron	CH140	Unknown	Unknown	Out of Service	83,234	55,767	NA	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH141	Unknown	Unknown	Out of Service	140,308	94,006	NA	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH142	-122.7419897	45.56398912	Base Oil	648,620	434,575	1984	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	217,288	434,575
4	Chevron	CH143	-122.7423285	45.56487029	Supreme 5W30	62,033	41,562	NA	Fixed Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	20,781	41,562
4	Chevron	CH144	-122.7422762	45.56493129	Havoline 10W30	61,864	41,449	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	20,724	41,449
4	Chevron	CH145	-122.7421647	45.56504633	Out of Service	61,864	41,449	NA	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH146	Unknown	Unknown	Transmix	25,447	17,049	NA	Fixed Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	8,525	17,049
4	Chevron	CH147	Unknown	Unknown	Delo 100-40	25,523	17,100	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	8,550	17,100
4	Chevron	CH148	Unknown	Unknown	VER 800 Mar 30	33,839	22,672	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	11,336	22,672
4	Chevron	CH149	Unknown	Unknown	RPM HDMO 30	26,311	17,628	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	8,814	17,628
4	Chevron	CH15	Unknown	Unknown	Rykon Prem 32	28,951	19,397	1913	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	9,699	19,397
4	Chevron	CH150	-122.7422169	45.56498533	Delo 400-10	25,311	16,958	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	8,479	16,958
4	Chevron	CH151	Unknown	Unknown	MAR EO 9250-40	17,724	11,875	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,938	11,875
4	Chevron	CH152	Unknown	Unknown	Empty	17,624	11,808	NA	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH154	-122.7430858	45.5638464	Map 100	83,422	55,893	NA	Fixed Roof	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	27,946	55,893
4	Chevron	CH155	-122.7430004	45.56378191	Delo 400-15W40	83,422	55,893	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	27,946	55,893
4	Chevron	CH156	-122.7429184	45.56372439	Delo 400-30	83,022	55,625	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	27,812	55,625
4	Chevron	CH157	Unknown	Unknown	Turbine Oil	52,872	35,424	NA	AST	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	17,712	35,424
4	Chevron	CH158	Unknown	Unknown	Out of Service	NA	NA	NA	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH159	Unknown	Unknown	Out of Service	25,379	17,004	1987	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH16	Unknown	Unknown	Clarity PM 220	29,447	19,729	1913	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	9,865	19,729
4	Chevron	CH160	Unknown	Unknown	Empty	25,447	17,049	NA	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH163	Unknown	Unknown	Swing Tank	6,354,155	4,257,284	2009	AST	Group 3C	Unknown	Unknown	On Land	No Tank Failure	0%	10%	0	425,728
4	Chevron	CH164	-122.7410379	45.56490644	Swing Tank	6,354,155	4,257,284	2009	AST	Group 3C	Unknown	Unknown	On Land	No Tank Failure	0%	10%	0	425,728
4	Chevron	CH17	Unknown	Unknown	ExxonMobile EHC45	29,327	19,649	1913	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	9,825	19,649
4	Chevron	CH176	Unknown	Unknown	Blended Oil	2,632	1,763	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	882	1,763

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Area	Property	Tank ID[1]	Latitude	Longitude	Contents	Capacity (Gal)	Expected Fill (Gal) (67% of Capacity)[9]	Year	Type	Tank Group	Flammability Category	Hazardous Category	Damage Zone	Tank Age Failures	Percent Lost Min	Percent Lost Max	Volume Lost Min	Volume Lost Max
4	Chevron	CH177	Unknown	Unknown	Blended Oil	2,632	1,763	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	882	1,763
4	Chevron	CH178	Unknown	Unknown	Blended Oil	2,632	1,763	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	882	1,763
4	Chevron	CH179	Unknown	Unknown	Blended Oil	2,632	1,763	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	882	1,763
4	Chevron	CH18	Unknown	Unknown	Oloa 550006L	29,583	19,821	1913	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	9,910	19,821
4	Chevron	CH180	Unknown	Unknown	Blended Oil	4,700	3,149	1993	Fixed Roof	Group 3B	Unknown	Yes	On Land	No Tank Failure[8]	0%	10%	0	315
4	Chevron	CH181	Unknown	Unknown	Blended Oil	4,700	3,149	1993	Fixed Roof	Group 3B	Unknown	Yes	On Land	No Tank Failure[8]	0%	10%	0	315
4	Chevron	CH182	Unknown	Unknown	Blended Oil	11,374	7,621	1994	Fixed Roof	Group 3B	Unknown	Yes	On Land	No Tank Failure[8]	0%	10%	0	762
4	Chevron	CH183	Unknown	Unknown	Blended Oil	11,374	7,621	1994	Fixed Roof	Group 3B	Unknown	Yes	On Land	No Tank Failure[8]	0%	10%	0	762
4	Chevron	CH184	Unknown	Unknown	Blended Oil	11,374	7,621	1994	Fixed Roof	Group 3B	Unknown	Yes	On Land	No Tank Failure[8]	0%	10%	0	762
4	Chevron	CH185	Unknown	Unknown	Blended Oil	11,374	7,621	1994	Fixed Roof	Group 3B	Unknown	Yes	On Land	No Tank Failure[8]	0%	10%	0	762
4	Chevron	CH186	Unknown	Unknown	Blended Oil	11,374	7,621	1994	Fixed Roof	Group 3B	Unknown	Yes	On Land	No Tank Failure[8]	0%	10%	0	762
4	Chevron	CH187	Unknown	Unknown	Blended Oil	11,374	7,621	1994	Fixed Roof	Group 3B	Unknown	Yes	On Land	No Tank Failure[8]	0%	10%	0	762
4	Chevron	CH188	Unknown	Unknown	Blended Oil	11,374	7,621	1994	Fixed Roof	Group 3B	Unknown	Yes	On Land	No Tank Failure[8]	0%	10%	0	762
4	Chevron	CH19	Unknown	Unknown	Empty	29,071	19,478	NA	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH20	Unknown	Unknown	Pennzoil 75HC	29,071	19,478	1914	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	9,739	19,478
4	Chevron	CH21	Unknown	Unknown	Empty	29,583	19,821	1992	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH22	Unknown	Unknown	Clarity PM 220	13,982	9,368	1954	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	4,684	9,368
4	Chevron	CH23	Unknown	Unknown	Empty	13,982	9,368	1997	Fixed Roof	Group 2	None	None	On Land	No Tank Failure[8]	0%	10%	NA	NA
4	Chevron	CH24	Unknown	Unknown	Empty	8,859	5,936	1993	Fixed Roof	Group 2	None	None	On Land	No Tank Failure[8]	0%	10%	NA	NA
4	Chevron	CH25	Unknown	Unknown	Clarity PM 150	8,665	5,806	1913	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	2,903	5,806
4	Chevron	CH26	Unknown	Unknown	Rykon Prem 32	29,447	19,729	1913	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	9,865	19,729
4	Chevron	CH27	Unknown	Unknown	Chevron 7075F	29,613	19,841	1913	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	9,920	19,841
4	Chevron	CH28	Unknown	Unknown	Blend Mix/ Line Wash	29,071	19,478	1913	Fixed Roof	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	9,739	19,478
4	Chevron	CH28	Unknown	Unknown	Industrial EP 150	17,771	11,907	1949	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,953	11,907
4	Chevron	CH29	Unknown	Unknown	Empty	11,750	7,873	1949	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH29	Unknown	Unknown	Unavailable	17,724	11,875	1949	Fixed Roof	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	5,938	11,875
4	Chevron	CH3	-122.7417869	45.56487609	Unleaded Gasoline	2,392,178	1,602,759	1999	Fixed Roof	Group 3B	Category 1	Yes	On Land	No Tank Failure	0%	10%	0	160,276
4	Chevron	CH30	Unknown	Unknown	Empty	11,750	7,873	1949	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH31	Unknown	Unknown	SynFluid $, 4CST	8,712	5,837	1953	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	2,919	5,837
4	Chevron	CH32	Unknown	Unknown	Viscoplex 7-305	13,918	9,325	1950	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	4,663	9,325
4	Chevron	CH33	Unknown	Unknown	Viscoplex 1-604	13,997	9,378	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	4,689	9,378
4	Chevron	CH34	Unknown	Unknown	Empty	25,379	17,004	NA	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH35	Unknown	Unknown	FAMM Tara 30 DP 30	25,379	17,004	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	8,502	17,004
4	Chevron	CH36	Unknown	Unknown	Shell MV1 100	25,379	17,004	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	8,502	17,004
4	Chevron	CH37	Unknown	Unknown	Drive Train Fluid HD 10	17,378	11,643	1949	Fixed Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	5,822	11,643
4	Chevron	CH4	Unknown	Unknown	Neutral 220R	435,761	291,960	1913	Fixed Roof	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	145,980	291,960
4	Chevron	CH40	Unknown	Unknown	Empty	18,018	12,072	NA	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH41	Unknown	Unknown	Clarity Saw Guide 46	17,331	11,612	1949	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,806	11,612
4	Chevron	CH42	Unknown	Unknown	Empty	29,583	19,821	1913	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH43	-122.7420833	45.56380088	Base Oil	837,085	560,847	1993	Fixed Roof	Group 3B	Unknown	Yes	On Land	No Tank Failure	0%	10%	0	56,085
4	Chevron	CH44	-122.7423374	45.56351791	Base Oil	835,393	559,713	1920	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	279,857	559,713
4	Chevron	CH45	-122.7413834	45.56448431	Ethanol	958,693	642,324	1999	Fixed Roof	Group 3B	Category 3	Yes	On Land	No Tank Failure	0%	10%	0	64,232
4	Chevron	CH46	Unknown	Unknown	Red Chain Bar 150	11,750	7,873	1924	Fixed Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	3,936	7,873
4	Chevron	CH47	-122.7427205	45.56392263	Unleaded Gasoline	3,609,743	2,418,528	1929	Fixed Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	1,209,264	2,418,528
4	Chevron	CH48	-122.7416967	45.56427618	Water/Oil Slop	396,547	265,686	1979	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	132,843	265,686
4	Chevron	CH5	Unknown	Unknown	Neutral Oil	365,834	245,109	1913	Fixed Roof	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	122,554	245,109
4	Chevron	CH51	-122.7411057	45.56422328	Unavailable	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH56	Unknown	Unknown	GST ISO 100	25,379	17,004	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	8,502	17,004
4	Chevron	CH57	Unknown	Unknown	Citgo Brt Stock 150	152,433	102,130	1921	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	51,065	102,130
4	Chevron	CH6	Unknown	Unknown	GEO HDAX L ASH 40	100,277	67,186	1913	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	33,593	67,186
4	Chevron	CH60	-122.7419626	45.56331505	Unleaded Gasoline	4,999,697	3,349,797	2001	Fixed Roof	Group 3B	Category 1	Yes	On Land	No Tank Failure	0%	10%	0	334,980
4	Chevron	CH61	Unknown	Unknown	Neutral 600R	400,379	268,254	1941	Fixed Roof	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	134,127	268,254
4	Chevron	CH62	-122.741521	45.56385926	Unleaded Gasoline	6,812,135	4,564,130	2000	Fixed Roof	Group 3B	Category 1	Yes	On Land	No Tank Failure	0%	10%	0	456,413
4	Chevron	CH64	-122.7407524	45.56450931	Diesel	844,275	565,664	1947	Fixed Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	282,832	565,664
4	Chevron	CH65	Unknown	Unknown	Lubrizol 4991	17,524	11,741	1938	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,871	11,741
4	Chevron	CH7	Unknown	Unknown	Famm Taro Sepcial 70	100,594	67,398	1913	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	33,699	67,398
4	Chevron	CH72	Unknown	Unknown	Saw Guide 150	17,284	11,580	1959	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,790	11,580
4	Chevron	CH75	-122.7422779	45.56410059	Jet Fuel	1,004,586	673,073	1952	Fixed Roof	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	336,536	673,073
4	Chevron	CH76	-122.7414661	45.56418238	Base Oil	498,258	333,833	1960	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	166,916	333,833
4	Chevron	CH77	Unknown	Unknown	RPM HDMO 15W40	128,511	86,102	1960	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	43,051	86,102
4	Chevron	CH78	Unknown	Unknown	Paratone 8451	311,722	208,854	1960	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	104,427	208,854
4	Chevron	CH79	Unknown	Unknown	Empty	17,378	11,643	1960	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH8	Unknown	Unknown	Rykon Prem MV	104,897	70,281	1913	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	35,140	70,281
4	Chevron	CH80	Unknown	Unknown	Out of Service	17,378	11,643	NA	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH81	Unknown	Unknown	Empty	17,724	11,875	1951	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH82	Unknown	Unknown	Infineum M7038	17,624	11,808	1951	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,904	11,808
4	Chevron	CH83	Unknown	Unknown	RPM HDMO 15W40	17,331	11,612	1951	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,806	11,612
4	Chevron	CH84	Unknown	Unknown	Empty	17,184	11,513	1952	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH85	Unknown	Unknown	Oloa 44200	17,671	11,840	1952	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,920	11,840
4	Chevron	CH87	Unknown	Unknown	Lubrizol 4991	17,430	11,678	1913	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,839	11,678
4	Chevron	CH88	Unknown	Unknown	Empty	17,624	11,808	1850	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH89	Unknown	Unknown	Oil Stop	19,431	13,019	1952	Fixed Roof	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	6,509	13,019
4	Chevron	CH9	Unknown	Unknown	Chevron 7075F	169,193	113,359	1949	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	56,680	113,359
4	Chevron	CH90	Unknown	Unknown	Delo 400-15W40	208,848	139,928	1954	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	69,964	139,928
4	Chevron	CH91	Unknown	Unknown	Oloa 9740C	17,671	11,840	1961	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,920	11,840
4	Chevron	CH92	Unknown	Unknown	Out of Service	17,577	11,777	1961	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH94	Unknown	Unknown	Rykon Oil 68	67,419	45,171	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	22,585	45,171
4	Chevron	CH96	-122.7427141	45.56429393	Additive	17,624	11,808	1966	Fixed Roof	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	5,904	11,808
4	Chevron	CH97	Unknown	Unknown	Additive	17,624	11,808	1966	Fixed Roof	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	5,904	11,808
4	Chevron	CH98	Unknown	Unknown	Rykon Oil 46	91,364	61,214	1968	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	30,607	61,214
4	Chevron	CH99	Unknown	Unknown	RPM UGL 80W90	62,033	41,562	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	20,781	41,562
5	Equilon	T-13519	Unknown	Unknown	Diesel	560,112	375,275	NA	Cone Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	187,638	375,275
5	Equilon	T-13520	Unknown	Unknown	Diesel	558,852	374,431	NA	Cone Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	187,215	374,431
5	Equilon	T-13521	Unknown	Unknown	Diesel	559,986	375,191	NA	Cone Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	187,595	375,191
5	Equilon	T-13522	Unknown	Unknown	Diesel	558,432	374,149	NA	Cone Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	187,075	374,149
5	Equilon	T-13523	Unknown	Unknown	Out of Service	565,320	378,764	NA	Cone Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	189,382	378,764
5	Equilon	T-13524	Unknown	Unknown	Diesel	559,146	374,628	NA	Cone Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	187,314	374,628
5	Equilon	T-36002	Unknown	Unknown	Diesel	1,537,704	1,030,262	NA	Cone Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	515,131	1,030,262
5	Equilon	T-55000	Unknown	Unknown	Gasoline	1,986,264	1,330,797	NA	Internal Fixed Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	665,398	1,330,797
5	Equilon	T-55001	Unknown	Unknown	Ethanol	2,331,714	1,562,248	NA	Internal Fixed Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	781,124	1,562,248
5	Equilon	T-80103	Unknown	Unknown	Diesel	3,303,636	2,213,436	NA	Cone Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	1,106,718	2,213,436
5	Equilon	T-80104	Unknown	Unknown	Gasoline	3,348,912	2,243,771	NA	Internal Fixed Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	1,121,886	2,243,771
5	Equilon	T-80110	Unknown	Unknown	Gasoline	3,317,622	2,222,807	NA	Internal Fixed Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	1,111,403	2,222,807
5	Equilon	T-84200	Unknown	Unknown	Gasoline	3,528,756	2,364,267	NA	Internal Fixed Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	1,182,133	2,364,267
5	Equilon	T-7017	Unknown	Unknown	Water	267,456	179,196	NA	External Fixed Roof	Group 3A	Not Flammable	No	On Land	Tank Failure	50%	100%	89,598	179,196

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Area	Property	Tank ID[1]	Latitude	Longitude	Contents	Capacity (Gal)	Expected Fill (Gal) (67% of Capacity)[9]	Year	Type	Tank Group	Flammability Category	Hazardous Category	Damage Zone	Tank Age Failures	Percent Lost Min	Percent Lost Max	Volume Lost Min	Volume Lost Max
1	Kinder Morgan North	KML10007	-122.7874617	45.60392099	Out of Service	418,278	179,196	1922	Vertical Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML11017	-122.7862918	45.60312207	Out of Service	469,938	179,196	1941	Internal Floating Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML11019	-122.7863772	45.60325802	Out of Service	469,896	179,196	1941	Internal Floating Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML17018	-122.7859262	45.6031471	Gasoline	735,714	179,196	1941	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	89,598	179,196
1	Kinder Morgan North	KML17020	-122.7860185	45.60333534	Gasoline	742,896	179,196	1941	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	89,598	179,196
1	Kinder Morgan North	KML17027	-122.7857571	45.60292581	Gasoline	739,074	179,196	1954	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	89,598	179,196
1	Kinder Morgan North	KML20011	-122.7866833	45.60270641	Diesel	856,506	179,196	1932	Vertical Fixed Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	89,598	179,196
1	Kinder Morgan North	KML2024	-122.7876809	45.603684	Out of Service	92,896	179,196	1937	Vertical Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML30016	-122.7861755	45.60285543	Diesel	1,253,784	840,035	1941	Vertical Fixed Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	420,018	840,035
1	Kinder Morgan North	KML3034	Unknown	Unknown	Storm Water	137,046	91,821	1925	Vertical Fixed Roof	Group 3A	Not Flammable	Unknown	Material in Water	Tank Failure	50%	100%	45,910	91,821
1	Kinder Morgan North	KML305	Unknown	Unknown	Out of Service	12,936	8,667	1926	Vertical Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML306	Unknown	Unknown	Out of Service	12,936	8,667	1926	Vertical Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML309	Unknown	Unknown	Out of Service	12,936	8,667	1926	Vertical Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML310	Unknown	Unknown	Out of Service	12,936	8,667	1926	Vertical Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML312	Unknown	Unknown	Out of Service	12,936	8,667	1926	Vertical Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML313	Unknown	Unknown	Out of Service	12,936	8,667	1926	Vertical Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML314	Unknown	Unknown	Out of Service	12,936	8,667	1926	Vertical Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML315	Unknown	Unknown	Out of Service	12,936	8,667	1926	Vertical Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML326	Unknown	Unknown	Out of Service	12,600	8,442	NA	Vertical Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML330	Unknown	Unknown	Out of Service	12,012	8,048	1926	Vertical Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML331	Unknown	Unknown	Out of Service	12,936	8,667	1926	Vertical Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML45028	-122.7858017	45.60266188	Gasoline	1,889,538	1,265,990	1955	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	632,995	1,265,990
1	Kinder Morgan North	KML532	Unknown	Unknown	Out of Service	29,908	20,038	1965	Vertical Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML55008	-122.7868222	45.60301106	Out of Service	2,288,832	1,533,517	1933	Vertical Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML55022	-122.7869825	45.60331957	Gasoline	2,309,286	1,547,222	1928	Vertical Fixed Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	773,611	1,547,222
1	Kinder Morgan North	KML55023	-122.7872335	45.60367514	Out of Service	2,312,016	1,549,051	1944	Internal Floating Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML59029	-122.7863092	45.60250695	Gasoline	2,454,060	1,644,220	1955	Vertical Fixed Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	822,110	1,644,220
1	Kinder Morgan North	KML72021	-122.7875141	45.60336489	Diesel	2,842,297	1,904,339	2011	Vertical Fixed Roof	Group 3C	Category 3	Yes	Material in Water	No Tank Failure	0%	10%	0	190,434
1	Kinder Morgan North	KMLSalt tower	Unknown	Unknown	Contact Water	22,890	15,336	NA	Vertical Fixed Roof	Group 3A	Not Flammable	Unknown	Material in Water	Tank Failure	50%	100%	7,668	15,336
4	Kinder Morgan South	KMW10	Unknown	Unknown	Out of Service	22,722	15,224	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW100	-122.7450631	45.56630332	Diesel	3,381,000	2,265,270	1949	Vertical Fixed Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	1,132,635	2,265,270
4	Kinder Morgan South	KMW101	-122.7446768	45.56671985	Gasoline	3,381,000	2,265,270	1949	Internal Floating Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	1,132,635	2,265,270
4	Kinder Morgan South	KMW102	-122.7449134	45.56581185	Out of Service	306,600	205,422	1951	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW103	-122.7450576	45.5658951	Out of Service	168,000	112,560	1950	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW104	-122.7452213	45.56589451	Lubricity Additive	168,000	112,560	1950	Vertical Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	56,280	112,560
4	Kinder Morgan South	KMW105	-122.7451319	45.5657998	Ethanol	168,000	112,560	1951	Internal Floating Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	56,280	112,560
4	Kinder Morgan South	KMW106	-122.7450207	45.56569496	Out of Service	302,546	202,706	1951	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW11	Unknown	Unknown	Out of Service	22,722	15,224	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW116	-122.7449925	45.56714896	Gasoline	3,385,200	2,268,084	1961	Internal Floating Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	1,134,042	2,268,084
4	Kinder Morgan South	KMW117	-122.7457153	45.56637261	Biodiesel	567,000	379,890	1951	Internal Floating Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	189,945	379,890
4	Kinder Morgan South	KMW118	-122.7460259	45.56666204	Gasoline	2,360,400	1,581,468	1951	Internal Floating Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	790,734	1,581,468
4	Kinder Morgan South	KMW12	Unknown	Unknown	Out of Service	22,722	15,224	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW12001	-122.7420717	45.56569288	Jet A	5,040,000	3,376,800	2012	Internal Floating Roof	Group 3C	Category 2	Yes	On Land	No Tank Failure	0%	10%	0	337,680
4	Kinder Morgan South	KMW12002	-122.7428327	45.56573364	Diesel	5,040,000	3,376,800	2012	Internal Floating Roof	Group 3C	Category 3	Yes	On Land	No Tank Failure	0%	10%	0	337,680
4	Kinder Morgan South	KMW12003	-122.7438959	45.56671288	Gasoline	5,040,000	3,376,800	2012	Internal Floating Roof	Group 3C	Category 1	Yes	On Land	No Tank Failure	0%	10%	0	337,680
4	Kinder Morgan South	KMW123	-122.7449048	45.5679582	Gasoline	3,322,200	2,225,874	1952	Internal Floating Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	1,112,937	2,225,874
4	Kinder Morgan South	KMW124	-122.7453868	45.56674273	Gasoline	3,393,600	2,273,712	1952	Internal Floating Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	1,136,856	2,273,712
4	Kinder Morgan South	KMW125	Unknown	Unknown	Out of Service	12,525	8,392	1946	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW126	Unknown	Unknown	Out of Service	24,703	16,551	1923	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW127	Unknown	Unknown	Out of Service	24,703	16,551	1923	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW128	-122.745293	45.56757832	Gasoline	2,347,800	1,573,026	1953	Internal Floating Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	786,513	1,573,026
4	Kinder Morgan South	KMW129	Unknown	Unknown	Out of Service	7,728	5,178	1927	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW13	Unknown	Unknown	Out of Service	2,856	1,914	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW131	Unknown	Unknown	Out of Service	4,737	3,174	1954	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW134	-122.7456716	45.5671514	Gasoline	2,364,600	1,584,282	1955	Internal Floating Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	792,141	1,584,282
4	Kinder Morgan South	KMW137	-122.7453716	45.56593857	Out of Service	222,936	149,367	1956	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW138	-122.7456704	45.56616745	Avgas	571,830	383,126	1956	Internal Floating Roof	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	191,563	383,126
4	Kinder Morgan South	KMW139	-122.7459749	45.56627102	Out of Service	572,628	383,661	1956	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW14	Unknown	Unknown	Out of Service	2,856	1,914	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW140	-122.7444371	45.56708638	Storm Water	630,000	422,100	1956	Vertical Fixed Roof	Group 3A	Not Flammable	Unknown	On Land	Tank Failure	50%	100%	211,050	422,100
4	Kinder Morgan South	KMW141	-122.7448053	45.5675197	Out of Service	730,800	489,636	1956	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW143	-122.7454429	45.56604664	Out of Service	252,927	169,461	1959	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW145	Unknown	Unknown	Out of Service	7,980	5,347	1960	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW146	Unknown	Unknown	Out of Service	7,980	5,347	1960	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW147	Unknown	Unknown	Out of Service	7,980	5,347	1961	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW148	Unknown	Unknown	Out of Service	7,980	5,347	1961	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW15	Unknown	Unknown	Out of Service	2,856	1,914	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW152	-122.7446024	45.56640741	Ethanol	47,800	32,026	1964	Internal Floating Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	16,013	32,026
4	Kinder Morgan South	KMW153	Unknown	Unknown	Out of Service	7,637	5,117	1965	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW154	Unknown	Unknown	Out of Service	7,637	5,117	1965	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW155	-122.7435566	45.56503165	Out of Service	4,200	2,814	1965	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW156	-122.7435017	45.56501857	Out of Service	7,667	5,137	1965	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW157	-122.7430586	45.56489556	Out of Service	24,868	16,662	1969	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW158	-122.7430072	45.56487726	Out of Service	24,851	16,650	1969	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW159	-122.7429628	45.56485983	Out of Service	21,000	14,070	1969	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW16	Unknown	Unknown	Out of Service	2,814	1,885	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW160	-122.7429305	45.56484327	Out of Service	24,860	16,656	1969	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW161	-122.7430843	45.56485752	Out of Service	24,863	16,658	1969	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW162	-122.7430344	45.56484154	Out of Service	24,850	16,650	1969	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW163	-122.7429882	45.56481757	Out of Service	24,856	16,654	1969	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW166	Unknown	Unknown	Contact Water	33,600	22,512	1970	Vertical Fixed Roof	Group 3A	Not Flammable	Unknown	On Land	Tank Failure	50%	100%	11,256	22,512
4	Kinder Morgan South	KMW167	Unknown	Unknown	Contact Water	24,024	16,096	1928	Vertical Fixed Roof	Group 3A	Not Flammable	Unknown	On Land	Tank Failure	50%	100%	8,048	16,096
4	Kinder Morgan South	KMW169	-122.7429258	45.56478793	Out of Service	24,990	16,743	1928	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW17	Unknown	Unknown	Out of Service	2,814	1,885	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW170	-122.7428713	45.56476642	Out of Service	24,990	16,743	1928	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW171	-122.7428392	45.56480378	Out of Service	24,990	16,743	NA	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW172	-122.742892	45.56482416	Out of Service	24,990	16,743	NA	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW173	Unknown	Unknown	Jet A	49,980	33,487	1972	Vertical Fixed Roof	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	16,743	33,487
4	Kinder Morgan South	KMW176	-122.7427958	45.56478098	Out of Service	25,353	16,987	NA	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW177	-122.7428246	45.56474361	Out of Service	24,457	16,386	NA	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW18	Unknown	Unknown	Out of Service	2,814	1,885	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW186	-122.7427577	45.56474615	Out of Service	25,604	17,155	NA	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW187	-122.7427878	45.56470877	Out of Service	24,000	16,080	NA	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW188	-122.7427039	45.56472388	Out of Service	24,600	16,482	NA	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW189	-122.7427401	45.56468845	Out of Service	24,035	16,103	NA	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA

Exhibit List 788

Area	Property	Tank ID[1]	Latitude	Longitude	Contents	Capacity (Gal)	Expected Fill (Gal) (67% of Capacity)[9]	Year	Type	Tank Group	Flammability Category	Hazardous Category	Damage Zone	Tank Age Failures	Percent Lost Min	Percent Lost Max	Volume Lost Min	Volume Lost Max
4	Kinder Morgan South	KMW190	Unknown	Unknown	Additive	8,400	5,628	NA	Horizontal Tank	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	2,814	5,628
4	Kinder Morgan South	KMW192	Unknown	Unknown	Additive	8,064	5,403	NA	Horizontal Tank	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	2,701	5,403
4	Kinder Morgan South	KMW193	Unknown	Unknown	Additive	10,080	6,754	NA	Horizontal Tank	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	3,377	6,754
4	Kinder Morgan South	KMW194	Unknown	Unknown	Slop Water	6,300	4,221	NA	Horizontal Tank	Group 3A	Not Flammable	Unknown	On Land	Tank Failure	50%	100%	2,111	4,221
4	Kinder Morgan South	KMW2	-122.7437849	45.56538264	Jet A	3,175,200	2,127,384	1915	Vertical Fixed Roof	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	1,063,692	2,127,384
4	Kinder Morgan South	KMW22	Unknown	Unknown	Out of Service	11,760	7,879	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW23	Unknown	Unknown	Out of Service	11,718	7,851	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW25	Unknown	Unknown	Out of Service	11,760	7,879	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW26	Unknown	Unknown	Out of Service	22,806	15,280	1916	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW3	-122.7434053	45.56515531	Out of Service	553,350	370,745	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW30	Unknown	Unknown	Out of Service	11,718	7,851	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW31	Unknown	Unknown	Out of Service	11,760	7,879	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW32	Unknown	Unknown	Out of Service	11,472	7,686	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW33	Unknown	Unknown	Out of Service	17,472	11,706	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW34	Unknown	Unknown	Out of Service	17,481	11,712	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW35	Unknown	Unknown	Out of Service	4,397	2,946	1924	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW36	Unknown	Unknown	Out of Service	4,368	2,927	1924	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW37	Unknown	Unknown	Out of Service	4,368	2,927	1924	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW38	Unknown	Unknown	Out of Service	4,368	2,927	1924	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW39	Unknown	Unknown	Out of Service	4,397	2,946	1924	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW4	Unknown	Unknown	Out of Service	215,754	144,555	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW40	Unknown	Unknown	Out of Service	5,544	3,714	1923	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW41	Unknown	Unknown	Out of Service	5,502	3,686	1923	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW42	Unknown	Unknown	Out of Service	5,502	3,686	1923	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW43	Unknown	Unknown	Out of Service	5,502	3,686	1923	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW44	Unknown	Unknown	Out of Service	5,515	3,695	1923	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW45	Unknown	Unknown	Out of Service	5,540	3,712	1923	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW46	Unknown	Unknown	Out of Service	11,642	7,800	1923	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW47	Unknown	Unknown	Out of Service	11,600	7,772	1923	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW48	Unknown	Unknown	Out of Service	11,642	7,800	1923	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW49	Unknown	Unknown	Out of Service	11,677	7,824	1923	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW5	-122.7432504	45.56534229	Out of Service	439,605	294,535	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW50	Unknown	Unknown	Out of Service	11,507	7,710	1923	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW51	Unknown	Unknown	Out of Service	11,634	7,795	1923	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW52	-122.743387	45.56582216	Jet A	3,229,800	2,163,966	1923	Vertical Fixed Roof	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	1,081,983	2,163,966
4	Kinder Morgan South	KMW54	-122.7430861	45.56614789	Diesel	3,435,600	2,301,852	1929	Vertical Fixed Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	1,150,926	2,301,852
4	Kinder Morgan South	KMW56	Unknown	Unknown	Out of Service	19,867	13,311	1929	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW57	Unknown	Unknown	Out of Service	19,800	13,266	1929	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW58	Unknown	Unknown	Out of Service	19,800	13,266	1929	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW59	Unknown	Unknown	Out of Service	19,855	13,303	1929	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW6	-122.7431268	45.56515305	Out of Service	215,166	144,161	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW60	Unknown	Unknown	Out of Service	19,824	13,282	1929	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW61	-122.7438671	45.56518029	Out of Service	25,200	16,884	1929	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW62	-122.7437893	45.56515017	Out of Service	11,676	7,823	1929	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW63	-122.7431296	45.56487495	Out of Service	24,766	16,593	1929	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW65	Unknown	Unknown	Jet A	861,336	577,095	1930	Vertical Fixed Roof	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	288,548	577,095
4	Kinder Morgan South	KMW66	Unknown	Unknown	Out of Service	856,800	574,056	1930	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW69	-122.7423084	45.56526554	Jet A	3,431,400	2,299,038	1937	Vertical Fixed Roof	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	1,149,519	2,299,038
4	Kinder Morgan South	KMW7	-122.7430954	45.56552925	Out of Service	440,538	295,160	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW70	-122.7425286	45.56489969	Jet A	1,461,600	979,272	1938	Vertical Fixed Roof	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	489,636	979,272
4	Kinder Morgan South	KMW71	-122.7426672	45.56612458	Transmix	862,260	577,714	1937	Vertical Fixed Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	288,857	577,714
4	Kinder Morgan South	KMW72	Unknown	Unknown	Out of Service	549,024	367,846	1937	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW73	-122.7427748	45.56519298	Transmix	546,714	366,298	1937	Vertical Fixed Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	183,149	366,298
4	Kinder Morgan South	KMW74	-122.7427851	45.56545285	Out of Service	305,712	204,827	1937	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW75	-122.7431136	45.56492422	Out of Service	25,000	16,750	1938	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW76	-122.7434435	45.56499117	Out of Service	25,000	16,750	1938	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW77	Unknown	Unknown	Out of Service	25,741	17,246	1938	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW8	-122.7429629	45.56533084	Out of Service	216,804	145,259	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW82	Unknown	Unknown	Out of Service	11,642	7,800	1923	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW83	Unknown	Unknown	Out of Service	19,867	13,311	1923	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW84	-122.7444933	45.56604701	Gasoline	2,356,200	1,578,654	1948	Internal Floating Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	789,327	1,578,654
4	Kinder Morgan South	KMW85	-122.7442008	45.56638834	Diesel	2,347,800	1,573,026	1948	Vertical Fixed Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	786,513	1,573,026
4	Kinder Morgan South	KMW86	-122.7445855	45.56569038	Out of Service	222,805	149,279	1948	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW87	-122.7447579	45.56573139	Out of Service	222,469	149,054	1948	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW88	-122.7446782	45.5655895	Out of Service	222,574	149,125	1948	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW89	-122.7448503	45.56562528	Out of Service	222,919	149,356	1948	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW9	Unknown	Unknown	Out of Service	22,722	15,224	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW90	Unknown	Unknown	Out of Service	2,982	1,998	1946	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	McCall Oil	MC1	-122.7355852	45.5646169	Asphalt	11,247,180	7,535,611	1976	Cone Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	3,767,805	7,535,611
4	McCall Oil	MC10	-122.7356888	45.56405291	Biodiesel	469,392	314,493	1974	Internal Floating Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	157,246	314,493
4	McCall Oil	MC11	-122.7339086	45.56372321	Oil and water	20,160	13,507	1974	Cone Roof	Group 3A	Not Flammable	Unknown	Material in Water	Tank Failure	50%	100%	6,754	13,507
4	McCall Oil	MC12	-122.734043	45.56382734	Oil and water	10,080	6,754	1974	Cone Roof	Group 3A	Not Flammable	Unknown	Material in Water	Tank Failure	50%	100%	3,377	6,754
4	McCall Oil	MC15	Unknown	Unknown	Flux	21,840	14,633	1986	Cone Roof	Group 3A	Unknown	Unknown	Potentially in Water	Tank Failure	50%	100%	7,316	14,633
4	McCall Oil	MC16	Unknown	Unknown	Flux	30,198	20,233	1989	Cone Roof	Group 3A	Unknown	Unknown	Potentially in Water	Tank Failure	50%	100%	10,116	20,233
4	McCall Oil	MC18	Unknown	Unknown	Anti-strip	4,914	3,292	1989	Cone Roof	Group 3A	Unknown	Unknown	Potentially in Water	Tank Failure	50%	100%	1,646	3,292
4	McCall Oil	MC19	-122.7356113	45.56250143	Asphalt	427,770	286,606	1954	Cone Roof	Group 3A	Category 1	Yes	Potentially in Water	Tank Failure	50%	100%	143,303	286,606
4	McCall Oil	MC2	-122.734734	45.56402897	Asphalt	11,787,300	7,897,491	1973	Cone Roof	Group 3A	Category 1	Yes	Potentially in Water	Tank Failure	50%	100%	3,948,746	7,897,491
4	McCall Oil	MC20	-122.7357784	45.56237886	Asphalt	427,770	286,606	1954	Cone Roof	Group 3A	Category 1	Yes	Potentially in Water	Tank Failure	50%	100%	143,303	286,606
4	McCall Oil	MC21	-122.7359904	45.56226527	Asphalt	428,064	286,803	1954	Cone Roof	Group 3A	Category 1	Yes	Potentially in Water	Tank Failure	50%	100%	143,401	286,803
4	McCall Oil	MC22	-122.7359969	45.56203989	Asphalt	18,942	12,691	1954	Cone Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	6,346	12,691
4	McCall Oil	MC23	Unknown	Unknown	Asphalt	18,942	12,691	1954	Cone Roof	Group 3A	Category 1	Yes	Potentially in Water	Tank Failure	50%	100%	6,346	12,691
4	McCall Oil	MC24	Unknown	Unknown	Asphalt	19,068	12,776	2000	Cone Roof	Group 3B	Category 1	Yes	Potentially in Water	No Tank Failure[8]	0%	10%	0	1,278
4	McCall Oil	MC25	Unknown	Unknown	Asphalt	79,800	53,466	2000	Cone Roof	Group 3B	Category 1	Yes	Potentially in Water	No Tank Failure[8]	0%	10%	0	5,347
4	McCall Oil	MC26	Unknown	Unknown	Asphalt	79,800	53,466	2000	Cone Roof	Group 3B	Category 1	Yes	Potentially in Water	No Tank Failure[8]	0%	10%	0	5,347
4	McCall Oil	MC27	Unknown	Unknown	Asphalt	79,800	53,466	2000	Cone Roof	Group 3B	Category 1	Yes	Potentially in Water	No Tank Failure[8]	0%	10%	0	5,347
4	McCall Oil	MC28	Unknown	Unknown	Boiler Fuel	8,358	5,600	1954	Cone Roof	Group 3A	Category 1	Yes	Potentially in Water	Tank Failure	50%	100%	2,800	5,600
4	McCall Oil	MC29	Unknown	Unknown	Unichem	11,000	7,370	1974	Cone Roof	Group 3A	Unknown	Unknown	Potentially in Water	Tank Failure	50%	100%	3,685	7,370
4	McCall Oil	MC33	Unknown	Unknown	Polyphosphoric Acid	5,405	3,621	2005	Cone Roof	Group 3C	Not Flammable	Yes	Potentially in Water	No Tank Failure	0%	10%	0	362
4	McCall Oil	MC4	-122.7345227	45.56321617	Bunker	9,357,936	6,269,817	1976	Cone Roof	Group 3A	Category 2	Yes	Material in Water	Tank Failure	50%	100%	3,134,909	6,269,817
4	McCall Oil	MC5	-122.7339134	45.56356388	Biodiesel	27,216	18,235	1974	Cone Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	9,117	18,235
4	McCall Oil	MC6	-122.7339333	45.56345972	Biodiesel	27,216	18,235	1974	Cone Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	9,117	18,235
4	McCall Oil	MC7	-122.7357425	45.56376754	Diesel	2,658,726	1,781,346	1978	Internal Floating Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	890,673	1,781,346
4	McCall Oil	MC8	-122.7353491	45.56346153	Diesel	2,680,482	1,795,923	1977	Internal Floating Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	897,961	1,795,923
4	McCall Oil	MC9	-122.7340625	45.5636368	Biodiesel	473,004	316,913	1979	Cone Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	158,456	316,913

Exhibit List 789

Area	Property	Tank ID[1]	Latitude	Longitude	Contents	Capacity (Gal)	Expected Fill (Gal) (67% of Capacity)[9]	Year	Type	Tank Group	Flammability Category	Hazardous Category	Damage Zone	Tank Age Failures	Percent Lost Min	Percent Lost Max	Volume Lost Min	Volume Lost Max
3	Northwest Natural Gas	*NWN-Tank 001*	Unknown	Unknown	Liquefied Natural Gas	7,100,000	4,757,000	2005	NA	Group 3C	Category 1	Yes	On Land	No Tank Failure	0%	10%	0	475,700
2	Shore Terminals	NU10026	-122.7726379	45.58809999	Gasoline/Diesel[3]	4,200,000	2,814,000	2007	Internal Floating Roof	Group 3C	Category 1	Yes	Material in Water	No Tank Failure	0%	10%	0	281,400
2	Shore Terminals	NU10027	-122.7727619	45.58853083	Gasoline/Diesel[3]	4,200,000	2,814,000	2007	Internal Floating Roof	Group 3C	Category 1	Yes	Material in Water	No Tank Failure	0%	10%	0	281,400
2	Shore Terminals	NU1009	-122.7741313	45.58949818	Gasoline/Diesel[3]	392,887	263,234	1981	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	131,617	263,234
2	Shore Terminals	NU1010	-122.773869	45.58924206	Gasoline/Diesel[3]	393,264	263,487	1980	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	131,743	263,487
2	Shore Terminals	NU1011	-122.7736576	45.58905227	Ethanol/Gasoline[2]	393,149	263,410	1980	Internal Floating Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	131,705	263,410
2	Shore Terminals	NU1315	Unknown	Unknown	Out of Service	56,124	37,603	1938	Cone	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
2	Shore Terminals	NU1316	Unknown	Unknown	Out of Service	56,112	37,595	1938	Cone	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
2	Shore Terminals	NU181	Unknown	Unknown	Gasoline/Diesel Additive[4]	7,685	5,149	NA	Cone	Group 3A	Category 2	Yes	Material in Water	Tank Failure	50%	100%	2,574	5,149
2	Shore Terminals	NU195	Unknown	Unknown	Unavailable	NA	NA	NA	NA	Group 1	Unknown	Unknown	Material in Water	Tank Failure	50%	100%	NA	NA
2	Shore Terminals	NU2020	-122.7766875	45.59125128	Gasoline	821,940	550,700	1935	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	275,350	550,700
2	Shore Terminals	NU2021	-122.7764639	45.59143329	Gasoline	832,032	557,461	1935	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	278,731	557,461
2	Shore Terminals	NU2022	-122.776409	45.59161904	Gasoline	832,032	557,461	1935	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	278,731	557,461
2	Shore Terminals	NU2113	-122.7783372	45.59310793	Biodiesel	865,857	580,124	1938	Internal Floating Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	290,062	580,124
2	Shore Terminals	NU212	Unknown	Unknown	Unavailable	NA	NA	NA	NA	Group 1	Unknown	Unknown	Material in Water	Tank Failure	50%	100%	NA	NA
2	Shore Terminals	NU23	Unknown	Unknown	Gasoline/Diesel Additive[4]	10,048	6,732	NA	Cone	Group 3A	Category 2	Yes	Material in Water	Tank Failure	50%	100%	3,366	6,732
2	Shore Terminals	NU24	Unknown	Unknown	Biodiesel Additive[7]	NA	NA	NA	Horizontal Tank	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	NA	NA
2	Shore Terminals	NU2511	-122.7777244	45.59261216	Marine Fuel Oil	1,060,587	710,593	1925	Cone	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	355,297	710,593
2	Shore Terminals	NU2512	-122.7774697	45.59239859	Marine Fuel Oil	1,049,587	703,223	1925	Cone	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	351,612	703,223
2	Shore Terminals	NU2705	-122.7737092	45.58884477	Diesel	1,158,532	776,216	1980	Internal Floating Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	388,108	776,216
2	Shore Terminals	NU2706	-122.7739516	45.58904652	Gasoline/Diesel[3]	1,085,895	727,550	1980	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	363,775	727,550
2	Shore Terminals	NU30	Unknown	Unknown	Unavailable	NA	NA	NA	NA	Group 1	Unknown	Unknown	Material in Water	Tank Failure	50%	100%	NA	NA
2	Shore Terminals	NU3201	-122.7740642	45.58976931	Ethanol	1,264,793	847,411	1979	Internal Floating Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	423,706	847,411
2	Shore Terminals	NU3203	-122.7735485	45.58932425	Gasoline/Diesel[3]	1,265,942	848,181	1979	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	424,091	848,181
2	Shore Terminals	NU3204	-122.7732816	45.5891061	Gasoline/Diesel[3]	1,267,302	849,092	1979	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	424,546	849,092
2	Shore Terminals	NU3510	-122.7788207	45.5928867	Ethanol	1,456,019	975,533	1937	Internal Floating Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	487,766	975,533
2	Shore Terminals	NU3605	-122.7781073	45.59288672	Marine Fuel Oil	1,442,470	966,455	1938	Cone	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	483,227	966,455
2	Shore Terminals	NU3614	-122.7773272	45.59172431	Gasoline/Diesel[3]	1,398,810	937,203	1958	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	468,601	937,203
2	Shore Terminals	NU4402	-122.7738333	45.58953782	Gasoline/Diesel[3]	1,761,801	1,180,407	1979	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	590,203	1,180,407
2	Shore Terminals	NU4507	-122.7742007	45.58926922	Out of Service	1,849,692	1,239,294	1980	Internal Floating Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
2	Shore Terminals	NU5209	Unknown	Unknown	Gasoline/Diesel[3]	2,190,678	1,467,754	1971	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	733,877	1,467,754
2	Shore Terminals	NU5618	-122.7768358	45.59187153	Gasoline	2,220,204	1,487,537	1958	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	743,768	1,487,537
2	Shore Terminals	NU5901	-122.7779346	45.59221306	Gasoline	2,414,958	1,618,022	1929	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	809,011	1,618,022
2	Shore Terminals	NU5902	-122.7782457	45.59245726	Diesel	2,386,734	1,599,112	1929	Internal Floating Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	799,556	1,599,112
2	Shore Terminals	NU5919	-122.7769585	45.59154822	Diesel	2,147,688	1,438,951	1935	Cone	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	719,475	1,438,951
2	Shore Terminals	NU6408	-122.7744878	45.58954172	Gasoline/Diesel[3]	2,649,782	1,775,354	1981	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	887,677	1,775,354
2	Shore Terminals	NU703	-122.7784691	45.59276671	Cutter	309,498	207,364	1938	Internal Floating Roof	Group 3A	Unknown	Unknown	Material in Water	Tank Failure	50%	100%	103,682	207,364
2	Shore Terminals	NU8006	-122.7758206	45.59059861	Gasoline/Diesel[3]	3,379,698	2,264,398	1953	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	1,132,199	2,264,398
2	Shore Terminals	NU8007	-122.7753257	45.59022907	Gasoline	3,338,748	2,236,961	1953	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	1,118,481	2,236,961
2	Shore Terminals	NU8308	-122.774695	45.59022889	Gasoline/Diesel[3]	3,352,746	2,246,340	1969	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	1,123,170	2,246,340
3	Pacific Terminal Services	PA1	-122.760951	45.58009285	Residual Oil[6]	60,000	40,200	1980	NA	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	20,100	40,200
3	Pacific Terminal Services	PA2	-122.7614372	45.5801335	Diesel Oil	60,000	40,200	1980	NA	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	20,100	40,200
3	Pacific Terminal Services	PA3	-122.7612778	45.57987482	Residual Oil[6]	20,000	13,400	1980	NA	Group 3A	Category 1	Yes	Potentially in Water	Tank Failure	50%	100%	6,700	13,400
3	Pacific Terminal Services	PA4	-122.7593325	45.57970575	Residual Oil[6]	80,000	53,600	1940	NA	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	26,800	53,600
3	Pacific Terminal Services	PA5	-122.7598176	45.57956533	Residual Oil[6]	55,000	36,850	1940	NA	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	18,425	36,850
3	Pacific Terminal Services	PA6	Unknown	Unknown	Diesel Oil	12	8	1988	NA	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	4	8
3	Pacific Terminal Services	PA7	Unknown	Unknown	Residual Oil[6]	475	318	1993	NA	Group 3B	Category 1	Yes	Material in Water	No Tank Failure[8]	0%	10%	0	32
4	Conoco Phillips	PH1471	Unknown	Unknown	Hydraulic Tractor Oil	17,300	11,591	1921	Riveted Steel	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	5,796	11,591
4	Conoco Phillips	PH2561	-122.7406622	45.56199187	Marine Fuel Oil	1,569,582	1,051,620	1929	Riveted Steel	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	525,810	1,051,620
4	Conoco Phillips	PH2579	-122.7409117	45.56141165	Hydraulic Tractor Oil	1,800	1,206	1929	Welded Steel	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	603	1,206
4	Conoco Phillips	PH2669	-122.7408642	45.56177225	Marine Diesel	449,694	301,295	1931	Riveted Steel	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	150,647	301,295
4	Conoco Phillips	PH2713	-122.7407984	45.56149485	Unax AW 46	109,000	73,030	1937	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	36,515	73,030
4	Conoco Phillips	PH2714	-122.740692	45.56143945	Guardol 15W/40	109,000	73,030	1937	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	36,515	73,030
4	Conoco Phillips	PH2783	-122.7402992	45.56190648	Decant Oil	948,066	635,204	1937	Riveted Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	317,602	635,204
4	Conoco Phillips	PH2784	-122.7405757	45.56158066	Diesel #2	1,439,130	964,217	1937	Riveted Steel	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	482,109	964,217
4	Conoco Phillips	PH2915	-122.740277	45.5627496	Unleaded Gasoline	3,262,056	2,185,578	1938	Welded Steel	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	1,092,789	2,185,578
4	Conoco Phillips	PH2916	-122.7398776	45.56312098	Diesel #2	1,652,196	1,106,971	1938	Welded Steel	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	553,486	1,106,971
4	Conoco Phillips	PH2917	-122.7407079	45.56226216	RLOP 220 N	612,000	410,040	1938	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	205,020	410,040
4	Conoco Phillips	PH2982	-122.7402796	45.56314045	Diesel #1	416,262	278,896	1941	Welded Steel	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	139,448	278,896
4	Conoco Phillips	PH2983	-122.7400919	45.5633032	RLOP 220 N	304,000	203,680	1941	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	101,840	203,680
4	Conoco Phillips	PH3407	-122.7398529	45.56395207	Unleaded Gasoline	2,955,540	1,980,212	1949	Welded Steel	Group 3A	Category 1	Yes	Potentially in Water	Tank Failure	50%	100%	990,106	1,980,212
4	Conoco Phillips	PH3408	-122.739388	45.56361948	Unleaded Gasoline	1,639,680	1,098,586	1949	Welded Steel	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	549,293	1,098,586
4	Conoco Phillips	PH3409	-122.7395889	45.56334027	Unleaded Gasoline	948,654	635,598	1949	Welded Steel	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	317,799	635,598
4	Conoco Phillips	PH3410	-122.7402231	45.56349476	Ethanol	278,964	186,906	1949	Welded Steel	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	93,453	186,906
4	Conoco Phillips	PH3411	-122.7401167	45.56361542	Unleaded Gasoline	259,350	173,765	1949	Welded Steel	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	86,882	173,765
4	Conoco Phillips	PH3412	-122.7399924	45.56340515	Diesel #1	279,426	187,215	1949	Welded Steel	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	93,608	187,215
4	Conoco Phillips	PH3413	-122.7398959	45.56351805	Unleaded Gasoline	259,560	173,905	1949	Welded Steel	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	86,953	173,905
4	Conoco Phillips	PH3414	-122.7396817	45.56134632	RLOP 220 N	200,000	134,000	1949	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	67,000	134,000
4	Conoco Phillips	PH3415	-122.7395902	45.56145247	SUN 525	200,000	134,000	1949	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	67,000	134,000
4	Conoco Phillips	PH3416	-122.7395377	45.56128538	RLOP 100N	200,000	134,000	1949	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	67,000	134,000
4	Conoco Phillips	PH3417	-122.7394374	45.56138948	ULTRA S-4	200,000	134,000	1949	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	67,000	134,000
4	Conoco Phillips	PH3579	-122.7392115	45.56094009	Industrial Fuel Oil	3,307,668	2,216,138	1950	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	1,108,069	2,216,138
4	Conoco Phillips	PH36	-122.7411435	45.56199381	Stop Oil	20,496	13,732	1907	Riveted Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	6,866	13,732
4	Conoco Phillips	PH3623	-122.7409866	45.56259514	HiTech 6576	18,228	12,213	1950	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	6,106	12,213
4	Conoco Phillips	PH3639	-122.7405906	45.56137658	SUP SYN BL 5W/30	120,000	80,400	1951	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	40,200	80,400
4	Conoco Phillips	PH3739	-122.7397933	45.56123003	SUN 150 B/S	200,000	134,000	1954	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	67,000	134,000
4	Conoco Phillips	PH3740	-122.7396297	45.56115996	RLOP 600 N	277,000	185,590	1954	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	92,795	185,590
4	Conoco Phillips	PH3741	-122.7409459	45.56055917	Ramar CLF 17E	17,500	11,725	1954	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH3742	-122.7409159	45.56059316	MP Gear Lube 80/90	17,500	11,725	1954	Welded Steel	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH3743	-122.7408862	45.56062497	Utility	18,600	12,462	1954	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	6,231	12,462
4	Conoco Phillips	PH3744	-122.7408949	45.56053695	HYNAP N100	17,500	11,725	1954	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH3745	-122.7408657	45.56056919	HITEC 5751	17,500	11,725	1954	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH3746	-122.7408383	45.56060274	Lubrizol 4998C	17,500	11,725	1954	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH3747	-122.7407864	45.5605766	Lubrizol 4990CH	17,500	11,725	1954	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH3757	-122.7408161	45.56054566	HITEC 1193	17,500	11,725	1954	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH3760	-122.7408457	45.56051211	Raffene 750L	17,500	11,725	1954	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH3761	-122.7385003	45.56040356	Diesel #2	3,240,342	2,171,029	1954	Welded Steel	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	1,085,515	2,171,029
4	Conoco Phillips	PH4191	-122.7407385	45.56055481	Lubrizol 48254	17,500	11,725	1964	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH4192	-122.7407651	45.56052213	Lubrizol 7075F	17,500	11,725	1964	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH4223	Unknown	Unknown	Slop Oil	18,690	12,522	1968	Welded Steel	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	6,261	12,522
4	Conoco Phillips	PH4241	20.3925991	-122.740796	UNAX AW 68	17,500	11,725	1968	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH4242	20.3925991	-122.7407481	UNAX AW 68	17,500	11,725	1968	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725

Exhibit List 790

Area	Property	Tank ID[1]	Latitude	Longitude	Contents	Capacity (Gal)	Expected Fill (Gal) (67% of Capacity)[9]	Year	Type	Tank Group	Flammability Category	Hazardous Category	Damage Zone	Tank Age Failures	Percent Lost Min	Percent Lost Max	Volume Lost Min	Volume Lost Max
4	Conoco Phillips	PH4243	20.3925991	-122.7407215	HT4/10W	17,500	11,725	1968	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH4244	20.3925991	-122.7395284	Mohawk 450	17,500	11,725	1968	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH4245	20.3925991	-122.7394836	SUN 525	17,500	11,725	1968	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH4252	27.0837994	-122.7396113	Residual Fuel Oil[6]	458,640	307,289	1968	Welded Steel	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	153,644	307,289
4	Conoco Phillips	PH4253	24.6357994	-122.7394345	Residual Fuel Oil[6]	451,290	302,364	1968	Welded Steel	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	151,182	302,364
4	Conoco Phillips	PH4254	25.1194992	-122.7392325	PS 300	459,312	307,739	1968	Welded Steel	Group 3A	Category 1	No	On Land	Tank Failure	50%	100%	153,870	307,739
4	Conoco Phillips	PH4255	22.1005993	-122.739039	Biodiesel	404,250	270,848	1968	Welded Steel	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	135,424	270,848
4	Conoco Phillips	PH4256	35.1484985	-122.7390611	Out of Service	195,408	130,923	1968	Welded Steel	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Conoco Phillips	PH4257	6.8944898	-122.7389296	Out of Service	38,367	25,706	1968	Welded Steel	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Conoco Phillips	PH4258	20.9752007	-122.7394522	Line Clippings	18,000	12,060	1968	Welded Steel	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	6,030	12,060
4	Conoco Phillips	PH4259	22.4150009	-122.740323	Transmix	205,506	137,689	1968	Welded Steel	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	68,845	137,689
4	Conoco Phillips	PH4266	20.3925991	-122.7394953	Flush	17,500	11,725	1968	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH4281	20.3925991	-122.7406945	Versa Tran ATF	17,500	11,725	1969	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH4300	29.7148991	-122.7410065	Ramar CLF 17E	25,500	17,085	1969	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	8,543	17,085
4	Conoco Phillips	PH4302	20.3925991	-122.7393842	RLOP 600N	17,500	11,725	1971	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH4303	20.3925991	-122.7393433	RLOP 100N	17,500	11,725	1971	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH4305	10.3711004	-122.7392923	Out of Service	8,900	5,963	1971	Welded Steel	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Conoco Phillips	PH4306	35.9230995	-122.7393363	RLOP 100N	200,000	134,000	1971	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	67,000	134,000
4	Conoco Phillips	PH4318	28.8628006	-122.7387696	Diesel #2	1,422,456	953,046	1973	Welded Steel	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	476,523	953,046
4	Conoco Phillips	PH4320	24.1548004	-122.7390204	Sup Syn BL 10W/30	35,000	23,450	1973	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	11,725	23,450
4	Conoco Phillips	PH4321	24.1548004	-122.7389672	Uniguide II 100	35,000	23,450	1973	Welded Steel	Group 3A	Category 1	No	On Land	Tank Failure	50%	100%	11,725	23,450
4	Conoco Phillips	PH4322	18.7318001	-122.7389181	T5X HD 15W/40	35,000	23,450	1973	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	11,725	23,450
4	Conoco Phillips	PH4323	24.6152992	-122.7388612	Super ATF	35,000	23,450	1973	Welded Steel	Group 3A	Category 2	No	On Land	Tank Failure	50%	100%	11,725	23,450
4	Conoco Phillips	PH4327	Unknown	Unknown	Gasoline Slops[5]	10,080	6,754	1974	Welded Steel	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	3,377	6,754
4	Conoco Phillips	PH4331	29.7148991	-122.7409703	Ethyl HITEC 6888E	25,500	17,085	1973	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	8,543	17,085
4	Conoco Phillips	PH4332	20.3925991	-122.7406396	Super ATF	17,500	11,725	1973	Welded Steel	Group 3A	Category 2	No	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH4333	20.3925991	-122.7406705	Point Premier 10W/30	17,500	11,725	1973	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH4334	20.3925991	-122.740698	Super 5W/20	17,500	11,725	1973	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH4369	12.0774002	-122.7408036	RLOP 220 N	17,500	11,725	1979	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH4388	15.7313995	-122.7410139	Utility	13,500	9,045	1984	Welded Steel	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4389	15.7313995	-122.7410435	Utility	13,500	9,045	1984	Welded Steel	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4390	15.7313995	-122.741078	Bar & Chain 150	13,500	9,045	1985	Welded Steel	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4391	15.7313995	-122.7411106	Utility	13,500	9,045	1985	Welded Steel	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4392	15.7313995	-122.7410505	Utility	13,500	9,045	1985	Welded Steel	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4393	15.7313995	-122.7410832	Utility	13,500	9,045	1985	Welded Steel	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4394	15.7313995	-122.7411133	Utility	13,500	9,045	1985	Welded Steel	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4395	15.7313995	-122.7411464	Utility	13,500	9,045	1985	Welded Steel	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4397	15.7313995	-122.7410945	Lubrizol 9692A	13,500	9,045	1985	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4398	15.7313995	-122.741125	HITEC 1193A	13,500	9,045	1985	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4399	15.7313995	-122.7411564	Firebird 15W/40	13,500	9,045	1985	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4400	15.7313995	-122.7411847	Guardol 30	13,500	9,045	1985	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4401	Unknown	Unknown	Mohawk 150	13,500	9,045	1985	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4402	Unknown	Unknown	TSX HD10	13,500	9,045	1985	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4403	15.7313995	-122.7411917	HT4/30W	13,500	9,045	1985	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4404	15.7313995	-122.7412239	Fleet Sup EC 15W/40	13,500	9,045	1985	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4405	15.7313995	-122.7411642	HITEC 3472	13,500	9,045	1987	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4406	15.7313995	-122.741196	Lubrizol 9990A	13,500	9,045	1987	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4407	15.7313995	-122.7412283	Ethyl HITEC 388	13,500	9,045	1987	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4408	15.7313995	-122.741261	Ethyl HITEC 5756	13,500	9,045	1987	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4441	12.8697004	-122.741032	Octel 9056	18,648	12,494	1993	Welded Steel	Group 3B	Unknown	Yes	On Land	No Tank Failure	0%	10%	0	1,249
4	Conoco Phillips	PHF103	Unknown	Unknown	UTRA 58	25,500	17,085	1973	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	8,543	17,085
4	Conoco Phillips	PHF104	Unknown	Unknown	UTRA 59	17,500	11,725	1973	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Zenith Energy	Tank 129	Unknown	Unknown	Asphalt	NA	NA	NA	NA	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 128	Unknown	Unknown	Asphalt	NA	NA	NA	NA	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 127	Unknown	Unknown	Asphalt	NA	NA	NA	NA	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 70	Unknown	Unknown	Asphalt	NA	NA	NA	NA	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 125	Unknown	Unknown	Asphalt	NA	NA	NA	NA	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 124	Unknown	Unknown	Asphalt	NA	NA	NA	NA	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 123	Unknown	Unknown	Asphalt	NA	NA	NA	NA	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 122	Unknown	Unknown	Asphalt	NA	NA	NA	NA	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 121	Unknown	Unknown	Asphalt	NA	NA	NA	NA	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 120	Unknown	Unknown	Asphalt	NA	NA	NA	NA	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 112	Unknown	Unknown	Asphalt	NA	NA	NA	NA	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 110	Unknown	Unknown	Asphalt	NA	NA	NA	NA	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 101	Unknown	Unknown	Asphalt	NA	NA	NA	NA	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 126	Unknown	Unknown	Asphalt	NA	NA	NA	NA	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 003	Unknown	Unknown	Asphalt	NA	NA	NA	NA	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 71	Unknown	Unknown	Avgas	NA	1,402,380	NA	Internal Floating Roof	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	701,190	1,402,380
4	Zenith Energy	Tank 184	Unknown	Unknown	Biodiesel	NA	222,000	NA	NA	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	111,000	222,000
4	Zenith Energy	Tank 307	Unknown	Unknown	Caustic	NA	NA	NA	NA	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 74	Unknown	Unknown	Charge Stock	NA	NA	NA	NA	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 100	Unknown	Unknown	Charge Stock	NA	NA	NA	NA	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 102	Unknown	Unknown	Charge Stock	NA	NA	NA	NA	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 106	Unknown	Unknown	Crude Oil	NA	5,611,788	NA	External Floating Roof	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	2,805,894	5,611,788
4	Zenith Energy	Tank 67	Unknown	Unknown	Crude Oil	NA	3,234,000	NA	NA	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	1,617,000	3,234,000
4	Zenith Energy	Tank 93	Unknown	Unknown	Crude Oil	NA	2,829,918	NA	NA	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	1,414,959	2,829,918
4	Zenith Energy	Tank 69	Unknown	Unknown	Crude Oil	NA	NA	NA	NA	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 130	Unknown	Unknown	Crude Oil	NA	3,200,000	NA	Internal Floating Roof	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	1,600,000	3,200,000
4	Zenith Energy	Tank 68	Unknown	Unknown	Crude Oil	NA	2,900,000	NA	NA	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	1,450,000	2,900,000
4	Zenith Energy	Tank 63	Unknown	Unknown	Crude Oil	NA	4,763,472	NA	Internal Floating Roof	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	2,381,736	4,763,472
4	Zenith Energy	Tank 104	Unknown	Unknown	Crude Oil	NA	NA	NA	NA	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 105	Unknown	Unknown	Crude Oil	NA	5,241,684	NA	External Floating Roof	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	2,620,842	5,241,684
4	Zenith Energy	Tank 001	Unknown	Unknown	Crude Oil	NA	NA	NA	NA	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 308	Unknown	Unknown	Murol	NA	NA	NA	NA	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 182	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 183	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 185	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 202	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 203	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 209	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 213	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 208	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 211	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 306	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tanks 95	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA

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Area	Property	Tank ID[1]	Latitude	Longitude	Contents	Capacity (Gal)	Expected Fill (Gal) (67% of Capacity)[9]	Year	Type	Tank Group	Flammability Category	Hazardous Category	Damage Zone	Tank Age Failures	Percent Lost Min	Percent Lost Max	Volume Lost Min	Volume Lost Max
4	Zenith Energy	Tank 114	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 302	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 162	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 166	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 167	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 168	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 169	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 170	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 171	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 172	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 20	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 173	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 174	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 180	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 179	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 206	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 210	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 177	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 176	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 178	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 181	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 200	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 201	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	N2	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 317	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	BAS #2	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	KO T#5	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	BAS #3	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	BAS #4	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 160	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 161	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 314	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 002	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	KO T#2	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	CAS #5	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	BAS #1	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 305	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	KO T#1	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 163	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 164	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 165	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 152	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 151	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 158	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 157	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 156	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 148	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 149	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 150	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 142	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 143	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 144	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 147	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 146	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 145	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 140	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 141	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 300	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	K-23	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	TW-2	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 207	Unknown	Unknown	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 66	Unknown	Unknown	Universal Low-Sulfer Diesel	NA	3,188,598	NA	NA	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	1,594,299	3,188,598
4	Zenith Energy	Tank 111	Unknown	Unknown	Wastewater	NA	NA	NA	NA	Group 3A	Not Flammable	No	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 113	Unknown	Unknown	Wastewater	NA	NA	NA	NA	Group 3A	Not Flammable	No	On Land	Tank Failure	50%	100%	NA	NA

Notes:

[1]Tanks noted in satellite images, but not listed in available GIS data, are given the designation based on property ID and count, and are *italicized*. Example: Kinder Morgan North = "*KML-Tank 1*"

[2] Tank contents were listed as both gasoline and ethanol; flammability and hazard category are for gasoline.

[3] Tank contents were listed as both gasoline and diesel; flammability and hazard category are for gasoline.

[4] Tank contents were listed as both gasoline and diesel additives; flammability and hazard category are for gasoline.

[5] Tank contents were listed as gasoline slops; flammability and hazard category are for gasoline.

[6] Residual Oil and Residual Fuel Oil is a general classification for heavier oils that remain after the distillate fuel oil and lighter hydrocarbons are removed. The type of lighter hydrocarbon is unknown and therefore defaulted to the most flammable category.

[7] Tank contents were listed as biodiesel additive; flammability and hazard category are for biodiesel.

[8] Tank data provided by COP without geographic location; failure assumption made from satellite imagry.

[9] Zenith Energy tank fill provided directly from Portland Fire and Rescue.

Category 1 - Liquids with flashpoints below 73.4°F (23°C) and boiling points at or below 95°F (35°C).

Category 2 - Liquids with flashpoints below 73.4°F (23°C) and boiling points at or above 95°F (35°C).

Category 3 - Liquids with flashpoints at or above 73.4°F (23°C) and at or below 140°F (60°C).

Category 4 - Liquids having flashpoints above 140°F (60°C) and at or below 199.4°F (93°C).

NA - Data not available

No - Tank substance is not hazardous.

None - Flammability category and/or hazard category is not applicable due to tank status of Out of Service.

Not Flammable - Tank contents are not flammable and do not fall into Category 1-4.

Unknown - Flammability category or hazard category unknown due to unknown tank contents, or tank contents not defined in a suitable way to ascertain flammability or hazard categories.

Yes - Tank substance is hazardous.

APPENDIX B
Tanks with Potential to Release to Willamette River

Exhibit List 793

Appendix B: Tanks with Potential to Release to Willamette River

Area	Property	Tank ID[1]	Contents	Capacity (Gal)	Expected Fill (Gal) (67% of Capacity)[9]	Year	Type	Tank Group	Flammability Category	Hazardous Category	Damage Zone	Tank Age Failures	Percent Lost Min	Percent Lost Max	Volume Lost Min	Volume Lost Max
2	BP	BP1	Gasoline	3,808,434	2,551,651	1940	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	1,275,825	2,551,651
2	BP	BP10	Diesel	1,008,840	675,923	1941	Fixed Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	337,961	675,923
2	BP	BP11	Gasoline	1,354,122	907,262	1940	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	453,631	907,262
2	BP	BP12	Ethanol	605,346	405,582	1961	Internal Floating Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	202,791	405,582
2	BP	BP13	Ethanol	602,994	404,006	1961	Internal Floating Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	202,003	404,006
2	BP	BP14	Diesel	1,121,736	751,563	1942	Fixed Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	375,782	751,563
2	BP	BP15	Biodiesel	804,972	539,331	1943	Fixed Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	269,666	539,331
2	BP	BP17	Diesel	3,329,340	2,230,658	1940	Fixed Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	1,115,329	2,230,658
2	BP	BP18	Diesel	1,104,726	740,166	1945	Fixed Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	370,083	740,166
2	BP	BP19	Oily Wastewater	198,828	133,215	1961	Internal Floating Roof	Group 3A	Not Flammable	Unknown	Material in Water	Tank Failure	50%	100%	66,607	133,215
2	BP	BP2	Groundwater Remediation	1,231,000	824,770	1957	Internal Floating Roof	Group 3A	Not Flammable	Unknown	Material in Water	Tank Failure	50%	100%	412,385	824,770
2	BP	BP21	Gasoline Additive	220,080	147,454	1961	Fixed Roof	Group 3A	Category 2	Yes	Material in Water	Tank Failure	50%	100%	73,727	147,454
2	BP	BP23a	Diesel Additive	2,000	1,340	2005	Fixed Roof	Group 3C	Category 3	Yes	Material in Water	No Tank Failure	0%	10%	0	134
2	BP	BP23b	Diesel Lubricity Additive	2,100	1,407	2005	Horizontal Tank	Group 3C	Category 3	Yes	Material in Water	No Tank Failure	0%	10%	0	141
2	BP	BP24	Gasoline Additive	20,286	13,592	1970	Fixed Roof	Group 3A	Category 2	Yes	Material in Water	Tank Failure	50%	100%	6,796	13,592
2	BP	BP25	Gasoline Additive	20,241	13,561	1966	Fixed Roof	Group 3A	Category 2	Yes	Material in Water	Tank Failure	50%	100%	6,781	13,561
2	BP	BP3	Gasoline	1,584,366	1,061,525	1957	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	530,763	1,061,525
2	BP	BP4	Gasoline	1,105,860	740,926	1957	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	370,463	740,926
2	BP	BP40	Unavailable	0	0	1954	Fixed Roof	Group 1	Unknown	Unknown	Material in Water	Tank Failure	50%	100%	0	0
2	BP	BP41	Out of Service	0	0	1954	Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
2	BP	BP42	Out of Service	0	0	1954	Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
2	BP	BP43	Out of Service	0	0	1954	Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
2	BP	BP44	Out of Service	0	0	1954	Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
2	BP	BP45	Unavailable	0	0	1954	Fixed Roof	Group 1	Unknown	Unknown	Material in Water	Tank Failure	50%	100%	0	0
2	BP	BP46	Biodiesel	221,970	148,720	1954	Fixed Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	74,360	148,720
2	BP	BP5	Gasoline	895,314	599,860	1957	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	299,930	599,860
2	BP	BP6	Gasoline	1,014,384	679,637	1957	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	339,819	679,637
2	BP	BP7	Gasoline	648,018	434,172	1957	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	217,086	434,172
2	BP	BP8	Gasoline	790,272	529,482	1957	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	264,741	529,482
2	BP	BP9	Diesel	2,295,636	1,538,076	1940	Fixed Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	769,038	1,538,076
1	Kinder Morgan North	KML10007	Out of Service	418,278	179,196	1922	Vertical Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML11017	Out of Service	469,938	179,196	1941	Internal Floating Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML11019	Out of Service	469,896	179,196	1941	Internal Floating Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML17018	Gasoline	735,714	179,196	1941	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	89,598	179,196
1	Kinder Morgan North	KML17020	Gasoline	742,896	179,196	1941	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	89,598	179,196
1	Kinder Morgan North	KML17027	Gasoline	739,074	179,196	1954	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	89,598	179,196
1	Kinder Morgan North	KML20011	Diesel	856,506	179,196	1932	Vertical Fixed Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	89,598	179,196
1	Kinder Morgan North	KML2024	Out of Service	92,896	179,196	1937	Vertical Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML30016	Diesel	1,253,784	840,035	1941	Vertical Fixed Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	420,018	840,035
1	Kinder Morgan North	KML3034	Storm Water	137,046	91,821	1925	Vertical Fixed Roof	Group 3A	Not Flammable	Unknown	Material in Water	Tank Failure	50%	100%	45,910	91,821
1	Kinder Morgan North	KML305	Out of Service	12,936	8,667	1926	Vertical Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML306	Out of Service	12,936	8,667	1926	Vertical Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML309	Out of Service	12,936	8,667	1926	Vertical Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML310	Out of Service	12,936	8,667	1926	Vertical Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML312	Out of Service	12,936	8,667	1926	Vertical Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML313	Out of Service	12,936	8,667	1926	Vertical Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML314	Out of Service	12,936	8,667	1926	Vertical Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML315	Out of Service	12,936	8,667	1926	Vertical Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML326	Out of Service	12,600	8,442	NA	Vertical Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML330	Out of Service	12,012	8,048	1926	Vertical Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML331	Out of Service	12,936	8,667	1926	Vertical Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML45028	Gasoline	1,889,538	1,265,990	1955	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	632,995	1,265,990
1	Kinder Morgan North	KML532	Out of Service	29,908	20,038	1965	Vertical Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML55008	Out of Service	2,288,832	1,533,517	1933	Vertical Fixed Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML55022	Gasoline	2,309,286	1,547,222	1928	Vertical Fixed Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	773,611	1,547,222
1	Kinder Morgan North	KML55023	Out of Service	2,312,016	1,549,051	1944	Internal Floating Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
1	Kinder Morgan North	KML59029	Gasoline	2,454,060	1,644,220	1955	Vertical Fixed Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	822,110	1,644,220
1	Kinder Morgan North	KML72021	Diesel	2,842,297	1,904,339	2011	Vertical Fixed Roof	Group 3C	Category 3	Yes	Material in Water	No Tank Failure	0%	10%	0	190,434
1	Kinder Morgan North	KMLSalt tower	Contact Water	22,890	15,336	NA	Vertical Fixed Roof	Group 3A	Not Flammable	Unknown	Material in Water	Tank Failure	50%	100%	7,668	15,336
4	McCall Oil	MC1	Asphalt	11,247,180	7,535,611	1976	Cone Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	3,767,805	7,535,611
4	McCall Oil	MC10	Biodiesel	469,392	314,493	1974	Internal Floating Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	157,246	314,493
4	McCall Oil	MC11	Oil and water	20,160	13,507	1974	Cone Roof	Group 3A	Not Flammable	Unknown	Material in Water	Tank Failure	50%	100%	6,754	13,507
4	McCall Oil	MC12	Oil and water	10,080	6,754	1974	Cone Roof	Group 3A	Not Flammable	Unknown	Material in Water	Tank Failure	50%	100%	3,377	6,754
4	McCall Oil	MC4	Bunker	9,357,936	6,269,817	1976	Cone Roof	Group 3A	Category 2	Yes	Material in Water	Tank Failure	50%	100%	3,134,909	6,269,817
4	McCall Oil	MC5	Biodiesel	27,216	18,235	1974	Cone Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	9,117	18,235
4	McCall Oil	MC6	Biodiesel	27,216	18,235	1974	Cone Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	9,117	18,235
4	McCall Oil	MC7	Diesel	2,658,726	1,781,346	1978	Internal Floating Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	890,673	1,781,346
4	McCall Oil	MC8	Diesel	2,680,482	1,795,923	1977	Internal Floating Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	897,961	1,795,923
4	McCall Oil	MC9	Biodiesel	473,004	316,913	1979	Cone Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	158,456	316,913
2	Shore Terminals	NU10026	Gasoline/Diesel[3]	4,200,000	2,814,000	2007	Internal Floating Roof	Group 3C	Category 1	Yes	Material in Water	No Tank Failure	0%	10%	0	281,400
2	Shore Terminals	NU10027	Gasoline/Diesel[3]	4,200,000	2,814,000	2007	Internal Floating Roof	Group 3C	Category 1	Yes	Material in Water	No Tank Failure	0%	10%	0	281,400
2	Shore Terminals	NU1009	Gasoline/Diesel[3]	392,887	263,234	1981	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	131,617	263,234
2	Shore Terminals	NU1010	Gasoline/Diesel[3]	393,264	263,487	1980	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	131,743	263,487
2	Shore Terminals	NU1011	Ethanol/Gasoline[2]	393,149	263,410	1980	Internal Floating Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	131,705	263,410
2	Shore Terminals	NU1315	Out of Service	56,124	37,603	1938	Cone	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
2	Shore Terminals	NU1316	Out of Service	56,112	37,595	1938	Cone	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
2	Shore Terminals	NU181	Gasoline/Diesel Additive[4]	7,685	5,149	NA	Cone	Group 3A	Category 2	Yes	Material in Water	Tank Failure	50%	100%	2,574	5,149
2	Shore Terminals	NU195	Unavailable	NA	NA	NA	NA	Group 1	Unknown	Unknown	Material in Water	Tank Failure	50%	100%	NA	NA
2	Shore Terminals	NU2020	Gasoline	821,940	550,700	1935	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	275,350	550,700
2	Shore Terminals	NU2021	Gasoline	832,032	557,461	1935	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	278,731	557,461
2	Shore Terminals	NU2022	Gasoline	832,032	557,461	1935	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	278,731	557,461
2	Shore Terminals	NU2113	Biodiesel	865,857	580,124	1938	Internal Floating Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	290,062	580,124
2	Shore Terminals	NU212	Unavailable	NA	NA	NA	NA	Group 1	Unknown	Unknown	Material in Water	Tank Failure	50%	100%	NA	NA
2	Shore Terminals	NU23	Gasoline/Diesel Additive[4]	10,048	6,732	NA	Cone	Group 3A	Category 2	Yes	Material in Water	Tank Failure	50%	100%	3,366	6,732
2	Shore Terminals	NU24	Biodiesel Additive[7]	NA	NA	NA	Horizontal Tank	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	NA	NA
2	Shore Terminals	NU2511	Marine Fuel Oil	1,060,587	710,593	1925	Cone	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	355,297	710,593
2	Shore Terminals	NU2512	Marine Fuel Oil	1,049,587	703,223	1925	Cone	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	351,612	703,223

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Area	Property	Tank ID[1]	Contents	Capacity (Gal)	Expected Fill (Gal) (67% of Capacity)[9]	Year	Type	Tank Group	Flammability Category	Hazardous Category	Damage Zone	Tank Age Failures	Percent Lost Min	Percent Lost Max	Volume Lost Min	Volume Lost Max
2	Shore Terminals	NU2705	Diesel	1,158,532	776,216	1980	Internal Floating Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	388,108	776,216
2	Shore Terminals	NU2706	Gasoline/Diesel[3]	1,085,895	727,550	1980	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	363,775	727,550
2	Shore Terminals	NU30	Unavailable	NA	NA	NA	NA	Group 1	Unknown	Unknown	Material in Water	Tank Failure	50%	100%	NA	NA
2	Shore Terminals	NU3201	Ethanol	1,264,793	847,411	1979	Internal Floating Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	423,706	847,411
2	Shore Terminals	NU3203	Gasoline/Diesel[3]	1,265,942	848,181	1979	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	424,091	848,181
2	Shore Terminals	NU3204	Gasoline/Diesel[3]	1,267,302	849,092	1979	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	424,546	849,092
2	Shore Terminals	NU3510	Ethanol	1,456,019	975,533	1937	Internal Floating Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	487,766	975,533
2	Shore Terminals	NU3605	Marine Fuel Oil	1,442,470	966,455	1938	Cone	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	483,227	966,455
2	Shore Terminals	NU3614	Gasoline/Diesel[3]	1,398,810	937,203	1958	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	468,601	937,203
2	Shore Terminals	NU4402	Gasoline/Diesel[3]	1,761,801	1,180,407	1979	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	590,203	1,180,407
2	Shore Terminals	NU4507	Out of Service	1,849,692	1,239,294	1980	Internal Floating Roof	Group 2	None	None	Material in Water	Tank Failure	50%	100%	NA	NA
2	Shore Terminals	NU5209	Gasoline/Diesel[3]	2,190,678	1,467,754	1971	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	733,877	1,467,754
2	Shore Terminals	NU5618	Gasoline	2,220,204	1,487,537	1958	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	743,768	1,487,537
2	Shore Terminals	NU5901	Gasoline	2,414,958	1,618,022	1929	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	809,011	1,618,022
2	Shore Terminals	NU5902	Diesel	2,386,734	1,599,112	1929	Internal Floating Roof	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	799,556	1,599,112
2	Shore Terminals	NU5919	Diesel	2,147,688	1,438,951	1935	Cone	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	719,475	1,438,951
2	Shore Terminals	NU6408	Gasoline/Diesel[3]	2,649,782	1,775,354	1981	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	887,677	1,775,354
2	Shore Terminals	NU703	Cutter	309,498	207,364	1938	Internal Floating Roof	Group 3A	Unknown	Unknown	Material in Water	Tank Failure	50%	100%	103,682	207,364
2	Shore Terminals	NU8006	Gasoline/Diesel[3]	3,379,698	2,264,398	1953	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	1,132,199	2,264,398
2	Shore Terminals	NU8007	Gasoline	3,338,748	2,236,961	1953	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	1,118,481	2,236,961
2	Shore Terminals	NU8308	Gasoline/Diesel[3]	3,352,746	2,246,340	1969	Internal Floating Roof	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	1,123,170	2,246,340
3	Pacific Terminal Services	PA1	Residual Oil[6]	60,000	40,200	1980	NA	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	20,100	40,200
3	Pacific Terminal Services	PA2	Diesel Oil	60,000	40,200	1980	NA	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	20,100	40,200
3	Pacific Terminal Services	PA4	Residual Oil[6]	80,000	53,600	1940	NA	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	26,800	53,600
3	Pacific Terminal Services	PA5	Residual Oil[6]	55,000	36,850	1940	NA	Group 3A	Category 1	Yes	Material in Water	Tank Failure	50%	100%	18,425	36,850
3	Pacific Terminal Services	PA6	Diesel Oil	12	8	1988	NA	Group 3A	Category 3	Yes	Material in Water	Tank Failure	50%	100%	4	8
3	Pacific Terminal Services	PA7	Residual Oil[6]	475	318	1993	NA	Group 3B	Category 1	Yes	Material in Water	No Tank Failure[8]	0%	10%	0	32

Notes:

[1] Tanks noted in satellite images, but not listed in available GIS data, are given the designation based on property ID and count, and are *italicized*. Example: Kinder Morgan North = "*KML-Tank 1*"

[2] Tank contents were listed as both gasoline and ethanol; flammability and hazard category are for gasoline.

[3] Tank contents were listed as both gasoline and diesel; flammability and hazard category are for gasoline.

[4] Tank contents were listed as both gasoline and diesel additives; flammability and hazard category are for gasoline.

[5] Tank contents were listed as gasoline slops; flammability and hazard category are for gasoline.

[6] Residual Oil and Residual Fuel Oil is a general classification for heavier oils that remain after the distillate fuel oil and lighter hydrocarbons are removed. The type of lighter hydrocarbon is unknown and therefore defaulted to the most flammable category.

[7] Tank contents were listed as biodiesel additive; flammability and hazard category are for biodiesel.

[8] Tank data provided by COP without geographic location; failure assumption made from satellite imagry.

[9] Zenith Energy tank fill provided directly from Portland Fire and Rescue.

Category 1 - Liquids with flashpoints below 73.4°F (23°C) and boiling points at or below 95°F (35°C).
Category 2 - Liquids with flashpoints below 73.4°F (23°C) and boiling points at or above 95°F (35°C).
Category 3 - Liquids with flashpoints at or above 73.4°F (23°C) and at or below 140°F (60°C).
Category 4 - Liquids having flashpoints above 140°F (60°C) and at or below 199.4°F (93°C).
NA - Data not available
No - Tank substance is not hazardous.
None - Flammability category and/or hazard category is not applicable due to tank status of Out of Service.
Not Flammable - Tank contents are not flammable and do not fall into Category 1-4.
Unknown - Flammability category or hazard category unknown due to unknown tank contents, or tank contents not defined in a suitable way to ascertain flammability or hazard categories.
Yes - Tank substance is hazardous.

APPENDIX C
Tanks with Potential to Release and Flow to Willamette River

Exhibit List 796

Appendix C: Tanks with Potential to Release and Flow to Willamette River

Area	Property	Tank ID[1]	Contents	Capacity (Gal)	Expected Fill (Gal) (67% of Capacity)[9]	Year	Type	Tank Group	Flammability Category	Hazardous Category	Damage Zone	Tank Age Failures	Percent Lost Min	Percent Lost Max	Volume Lost Min	Volume Lost Max
4	Chevron	CH1	Unleaded Gasoline	3,412,315	2,286,251	1997	Internal Floating Roof	Group 3B	Category 1	Yes	Potentially in Water	Tank Failure	0%	10%	0	228,625
4	McCall Oil	MC15	Flux	21,840	14,633	1986	Cone Roof	Group 3A	Unknown	Unknown	Potentially in Water	Tank Failure	50%	100%	7,316	14,633
4	McCall Oil	MC16	Flux	30,198	20,233	1989	Cone Roof	Group 3A	Unknown	Unknown	Potentially in Water	Tank Failure	50%	100%	10,116	20,233
4	McCall Oil	MC18	Anti-strip	4,914	3,292	1989	Cone Roof	Group 3A	Unknown	Unknown	Potentially in Water	Tank Failure	50%	100%	1,646	3,292
4	McCall Oil	MC19	Asphalt	427,770	286,606	1954	Cone Roof	Group 3A	Category 1	Yes	Potentially in Water	Tank Failure	50%	100%	143,303	286,606
4	McCall Oil	MC2	Asphalt	11,787,300	7,897,491	1973	Cone Roof	Group 3A	Category 1	Yes	Potentially in Water	Tank Failure	50%	100%	3,948,746	7,897,491
4	McCall Oil	MC20	Asphalt	427,770	286,606	1954	Cone Roof	Group 3A	Category 1	Yes	Potentially in Water	Tank Failure	50%	100%	143,303	286,606
4	McCall Oil	MC21	Asphalt	428,064	286,803	1954	Cone Roof	Group 3A	Category 1	Yes	Potentially in Water	Tank Failure	50%	100%	143,401	286,803
4	McCall Oil	MC23	Asphalt	18,942	12,691	1954	Cone Roof	Group 3A	Category 1	Yes	Potentially in Water	Tank Failure	50%	100%	6,346	12,691
4	McCall Oil	MC24	Asphalt	19,068	12,776	2000	Cone Roof	Group 3B	Category 1	Yes	Potentially in Water	No Tank Failure[8]	0%	10%	0	1,278
4	McCall Oil	MC25	Asphalt	79,800	53,466	2000	Cone Roof	Group 3B	Category 1	Yes	Potentially in Water	No Tank Failure[8]	0%	10%	0	5,347
4	McCall Oil	MC26	Asphalt	79,800	53,466	2000	Cone Roof	Group 3B	Category 1	Yes	Potentially in Water	No Tank Failure[8]	0%	10%	0	5,347
4	McCall Oil	MC27	Asphalt	79,800	53,466	2000	Cone Roof	Group 3B	Category 1	Yes	Potentially in Water	No Tank Failure[8]	0%	10%	0	5,347
4	McCall Oil	MC28	Boiler Fuel	8,358	5,600	1954	Cone Roof	Group 3A	Category 1	Yes	Potentially in Water	Tank Failure	50%	100%	2,800	5,600
4	McCall Oil	MC29	Unichem	11,000	7,370	1974	Cone Roof	Group 3A	Unknown	Unknown	Potentially in Water	Tank Failure	50%	100%	3,685	7,370
4	McCall Oil	MC33	Polyphosphoric Acid	5,405	3,621	2005	Cone Roof	Group 3C	Not Flammable	Yes	Potentially in Water	No Tank Failure	0%	10%	0	362
3	Pacific Terminal Services	PA3	Residual Oil[6]	20,000	13,400	1980	NA	Group 3A	Category 1	Yes	Potentially in Water	Tank Failure	50%	100%	6,700	13,400
4	Conoco Phillips	PH3407	Unleaded Gasoline	2,955,540	1,980,212	1949	Welded Steel	Group 3A	Category 1	Yes	Potentially in Water	Tank Failure	50%	100%	990,106	1,980,212

Notes:

[1]Tanks noted in satellite images, but not listed in available GIS data, are given the designation based on property ID and count, and are *italicized* . Example: Kinder Morgan North = "*KML-Tank 1* "

[2] Tank contents were listed as both gasoline and ethanol; flammability and hazard category are for gasoline.

[3] Tank contents were listed as both gasoline and diesel; flammability and hazard category are for gasoline.

[4] Tank contents were listed as both gasoline and diesel additives; flammability and hazard category are for gasoline.

[5] Tank contents were listed as gasoline slops; flammability and hazard category are for gasoline.

[6] Residual Oil and Residual Fuel Oil is a general classification for heavier oils that remain after the distillate fuel oil and lighter hydrocarbons are removed. The type of lighter hydrocarbon is unknown and therefore defaulted to the most flammable category.

[7] Tank contents were listed as biodiesel additive; flammability and hazard category are for biodiesel.

[8] Tank data provided by COP without geographic location; failure assumption made from satellite imagry.

Category 1 - Liquids with flashpoints below 73.4°F (23°C) and boiling points at or below 95°F (35°C).

Category 2 - Liquids with flashpoints below 73.4°F (23°C) and boiling points at or above 95°F (35°C).

Category 3 - Liquids with flashpoints at or above 73.4°F (23°C) and at or below 140°F (60°C).

Category 4 - Liquids having flashpoints above 140°F (60°C) and at or below 199.4°F (93°C).

NA - Data not available

No - Tank substance is not hazardous.

None - Flammability category and/or hazard category is not applicable due to tank status of Out of Service.

Not Flammable - Tank contents are not flammable and do not fall into Category 1-4.

Unknown - Flammability category or hazard category unknown due to unknown tank contents, or tank contents not defined in a suitable way to ascertain flammability or hazard categories.

Yes - Tank substance is hazardous.

APPENDIX D
Tanks with Potential to Release to Ground Surface

Exhibit List 798

Appendix D: Tanks with Potential to Release to Ground Surface

Area	Property	Tank ID[4]	Contents	Capacity (Gal)	Expected Fill (Gal) (67% of Capacity)[9]	Year	Type	Tank Group	Flammability Category	Hazardous Category	Damage Zone	Tank Age Failures	Percent Lost Min	Percent Lost Max	Volume Lost Min	Volume Lost Max
4	Chevron	CH10	Paratone 8451	169,616	113,643	1950	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	56,821	113,643
4	Chevron	CH100	Gear Lube	17,624	11,808	1946	Fixed Roof	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	5,904	11,808
4	Chevron	CH101	Compressor Oil	17,284	11,580	1958	Fixed Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	5,790	11,580
4	Chevron	CH102	Out of Service	12,954	NA	1978	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH103	Out of Service	13,006	NA	1978	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH104	Texaco Havoline 5S30	17,331	11,612	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,806	11,612
4	Chevron	CH105	Empty	17,624	NA	1969	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH106	Delo G/L 80/90	17,818	11,938	1969	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,969	11,938
4	Chevron	CH108	Techron Additive	208,425	139,645	1970	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	69,822	139,645
4	Chevron	CH109	Delo GL 80/90	17,624	11,808	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,904	11,808
4	Chevron	CH11	Lubrizol 4991D	211,915	141,983	1950	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	70,992	141,983
4	Chevron	CH110	GST ISO 32	17,624	11,808	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,904	11,808
4	Chevron	CH112	Oloa 6073EV	17,818	11,938	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,969	11,938
4	Chevron	CH113	Hybase C414	17,378	11,643	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,822	11,643
4	Chevron	CH114	Industrial EP 220	17,624	11,808	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,904	11,808
4	Chevron	CH116	Empty	17,724	NA	1976	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH117	Raffene 2000L	17,624	11,808	1976	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,904	11,808
4	Chevron	CH118	Blend Mix/ Line Wash	17,577	11,777	1976	Fixed Roof	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	5,888	11,777
4	Chevron	CH119	Out of Service	19,593	NA	1977	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH12	ExxonMobil EM-100	586,302	392,822	1950	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	196,411	392,822
4	Chevron	CH120	Out of Service	19,593	NA	1977	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH121	Out of Service	NA	NA	1978	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH122	1000 THF	61,864	41,449	NA	Fixed Roof	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	20,724	41,449
4	Chevron	CH123	Delo 400-40	61,864	41,449	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	20,724	41,449
4	Chevron	CH127	ATF dex 111	109,976	73,684	NA	Fixed Roof	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	36,842	73,684
4	Chevron	CH128	Rykon Prem 32	74,586	49,973	NA	AST	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	24,986	49,973
4	Chevron	CH129	Base Oil	642,935	430,766	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	215,383	430,766
4	Chevron	CH13	Raffene 750L	45,682	30,607	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	15,303	30,607
4	Chevron	CH130	Base Oil	255,112	170,925	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	85,463	170,925
4	Chevron	CH131	Hybase C414	17,577	11,777	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,888	11,777
4	Chevron	CH132	Empty	18,165	NA	NA	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH133	CVX 3105	17,577	11,777	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,888	11,777
4	Chevron	CH135	Out of Service	19,379	NA	1982	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH136	Out of Service	20,303	NA	1982	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH137	Oloa 2000	60,757	40,707	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	20,354	40,707
4	Chevron	CH138	Drive Train Fluid HD 10	17,378	11,643	NA	Fixed Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	5,822	11,643
4	Chevron	CH139	Blend Mix/ Line Wash	25,591	17,146	NA	Fixed Roof	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	8,573	17,146
4	Chevron	CH14	Delo 6170 CFO 20W40	190,343	127,530	1950	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	63,765	127,530
4	Chevron	CH140	Out of Service	83,234	NA	NA	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH141	Out of Service	140,308	NA	NA	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH142	Base Oil	648,620	434,575	1984	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	217,288	434,575
4	Chevron	CH143	Supreme 5W30	62,033	41,562	NA	Fixed Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	20,781	41,562
4	Chevron	CH144	Havoline 10W30	61,864	41,449	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	20,724	41,449
4	Chevron	CH145	Out of Service	61,864	NA	NA	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH146	Transmix	25,447	17,049	NA	Fixed Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	8,525	17,049
4	Chevron	CH147	Delo 100-40	25,523	17,100	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	8,550	17,100
4	Chevron	CH148	VER 800 Mar 30	33,839	22,672	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	11,336	22,672
4	Chevron	CH149	RPM HDMO 30	26,311	17,628	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	8,814	17,628
4	Chevron	CH15	Rykon Prem 32	28,951	19,397	1913	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	9,699	19,397
4	Chevron	CH150	Delo 400-10	25,311	16,958	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	8,479	16,958
4	Chevron	CH151	MAR EO 9250-40	17,724	11,875	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,938	11,875
4	Chevron	CH152	Empty	17,624	NA	NA	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH154	Map 100	83,422	55,893	NA	Fixed Roof	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	27,946	55,893
4	Chevron	CH155	Delo 400-15W40	83,422	55,893	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	27,946	55,893
4	Chevron	CH156	Delo 400-30	83,022	55,625	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	27,812	55,625
4	Chevron	CH157	Turbine Oil	52,872	35,424	NA	AST	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	17,712	35,424
4	Chevron	CH158	Out of Service	NA	NA	NA	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH159	Out of Service	25,379	NA	1987	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH16	Clarity PM 220	29,447	19,729	1913	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	9,865	19,729
4	Chevron	CH160	Empty	25,447	NA	NA	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH163	Swing Tank	6,354,155	4,257,284	2009	AST	Group 3C	Unknown	Unknown	On Land	No Tank Failure	0%	10%	0	425,728
4	Chevron	CH164	Swing Tank	6,354,155	4,257,284	2009	AST	Group 3C	Unknown	Unknown	On Land	No Tank Failure	0%	10%	0	425,728
4	Chevron	CH17	ExxonMobile EHC45	29,327	19,649	1913	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	9,825	19,649
4	Chevron	CH176	Blended Oil	2,632	1,763	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	882	1,763
4	Chevron	CH177	Blended Oil	2,632	1,763	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	882	1,763
4	Chevron	CH178	Blended Oil	2,632	1,763	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	882	1,763
4	Chevron	CH179	Blended Oil	2,632	1,763	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	882	1,763
4	Chevron	CH18	Oloa 550006L	29,583	19,821	1913	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	9,910	19,821
4	Chevron	CH180	Blended Oil	4,700	3,149	1993	Fixed Roof	Group 3B	Unknown	Yes	On Land	No Tank Failure[8]	0%	10%	0	315
4	Chevron	CH181	Blended Oil	4,700	3,149	1993	Fixed Roof	Group 3B	Unknown	Yes	On Land	No Tank Failure[8]	0%	10%	0	315
4	Chevron	CH182	Blended Oil	11,374	7,621	1994	Fixed Roof	Group 3B	Unknown	Yes	On Land	No Tank Failure[8]	0%	10%	0	762
4	Chevron	CH183	Blended Oil	11,374	7,621	1994	Fixed Roof	Group 3B	Unknown	Yes	On Land	No Tank Failure[8]	0%	10%	0	762
4	Chevron	CH184	Blended Oil	11,374	7,621	1994	Fixed Roof	Group 3B	Unknown	Yes	On Land	No Tank Failure[8]	0%	10%	0	762
4	Chevron	CH185	Blended Oil	11,374	7,621	1994	Fixed Roof	Group 3B	Unknown	Yes	On Land	No Tank Failure[8]	0%	10%	0	762
4	Chevron	CH186	Blended Oil	11,374	7,621	1994	Fixed Roof	Group 3B	Unknown	Yes	On Land	No Tank Failure[8]	0%	10%	0	762
4	Chevron	CH187	Blended Oil	11,374	7,621	1994	Fixed Roof	Group 3B	Unknown	Yes	On Land	No Tank Failure[8]	0%	10%	0	762
4	Chevron	CH188	Blended Oil	11,374	7,621	1994	Fixed Roof	Group 3B	Unknown	Yes	On Land	No Tank Failure[8]	0%	10%	0	762
4	Chevron	CH19	Empty	29,071	NA	NA	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH20	Pennzoil 75HC	29,071	19,478	1914	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	9,739	19,478
4	Chevron	CH21	Empty	29,583	NA	1992	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH22	Clarity PM 220	13,982	9,368	1954	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	4,684	9,368
4	Chevron	CH23	Empty	13,982	NA	1997	Fixed Roof	Group 3B	None	None	On Land	No Tank Failure[8]	0%	10%	NA	NA
4	Chevron	CH24	Empty	8,859	NA	1993	Fixed Roof	Group 3B	None	None	On Land	No Tank Failure[8]	0%	10%	NA	NA
4	Chevron	CH25	Clarity PM 150	8,665	5,806	1913	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	2,903	5,806
4	Chevron	CH26	Rykon Prem 32	29,447	19,729	1913	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	9,865	19,729
4	Chevron	CH27	Chevron 7075F	29,613	19,841	1913	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	9,920	19,841

Exhibit List 799

Area	Property	Tank ID[1]	Contents	Capacity (Gal)	Expected Fill (Gal) (67% of Capacity)[9]	Year	Type	Tank Group	Flammability Category	Hazardous Category	Damage Zone	Tank Age Failures	Percent Lost Min	Percent Lost Max	Volume Lost Min	Volume Lost Max
4	Chevron	CH28	Blend Mix/ Line Wash	29,071	19,478	1913	Fixed Roof	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	9,739	19,478
4	Chevron	CH28	Industrial EP 150	17,771	11,907	1949	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,953	11,907
4	Chevron	CH29	Empty	11,750	NA	1949	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH29	Undefined Petroleum	17,724	11,875	1949	Fixed Roof	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	5,938	11,875
4	Chevron	CH3	Unleaded Gasoline	2,392,178	1,602,759	1999	Fixed Roof	Group 3B	Category 1	Yes	On Land	No Tank Failure	0%	10%	0	160,276
4	Chevron	CH30	Empty	11,750	NA	1949	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH31	SynFluid $, 4CST	8,712	5,837	1953	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	2,919	5,837
4	Chevron	CH32	Viscoplex 7-305	13,918	9,325	1950	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	4,663	9,325
4	Chevron	CH33	Viscoplex 1-604	13,997	9,378	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	4,689	9,378
4	Chevron	CH34	Empty	25,379	NA	NA	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH35	FAMM Tara 30 DP 30	25,379	17,004	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	8,502	17,004
4	Chevron	CH36	Shell MV1 100	25,379	17,004	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	8,502	17,004
4	Chevron	CH37	Drive Train Fluid HD 10	17,378	11,643	1949	Fixed Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	5,822	11,643
4	Chevron	CH4	Neutral 220R	435,761	291,960	1913	Fixed Roof	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	145,980	291,960
4	Chevron	CH40	Empty	18,018	NA	NA	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH41	Clarity Saw Guide 46	17,331	11,612	1949	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,806	11,612
4	Chevron	CH42	Empty	29,583	NA	1913	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH43	Base Oil	837,085	560,847	1993	Fixed Roof	Group 3B	Unknown	Yes	On Land	No Tank Failure	0%	10%	0	56,085
4	Chevron	CH44	Base Oil	835,393	559,713	1920	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	279,857	559,713
4	Chevron	CH45	Ethanol	958,693	642,324	1999	Fixed Roof	Group 3B	Category 3	Yes	On Land	No Tank Failure	0%	10%	0	64,232
4	Chevron	CH46	Red Chain Bar 150	11,750	7,873	1924	Fixed Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	3,936	7,873
4	Chevron	CH47	Unleaded Gasoline	3,609,743	2,418,528	1929	Fixed Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	1,209,264	2,418,528
4	Chevron	CH48	Water/Oil Slop	396,547	265,686	1979	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	132,843	265,686
4	Chevron	CH5	Neutral Oil	365,834	245,109	1913	Fixed Roof	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	122,554	245,109
4	Chevron	CH51	Unavailable	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH56	GST ISO 100	25,379	17,004	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	8,502	17,004
4	Chevron	CH57	Citgo Brt Stock 150	152,433	102,130	1921	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	51,065	102,130
4	Chevron	CH6	GEO HDAX L ASH 40	100,277	67,186	1913	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	33,593	67,186
4	Chevron	CH60	Unleaded Gasoline	4,999,697	3,349,797	2001	Fixed Roof	Group 3B	Category 1	Yes	On Land	No Tank Failure	0%	10%	0	334,980
4	Chevron	CH61	Neutral 600R	400,379	268,254	1941	Fixed Roof	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	134,127	268,254
4	Chevron	CH62	Unleaded Gasoline	6,812,135	4,564,130	2000	Fixed Roof	Group 3B	Category 1	Yes	On Land	No Tank Failure	0%	10%	0	456,413
4	Chevron	CH64	Diesel	844,275	565,664	1947	Fixed Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	282,832	565,664
4	Chevron	CH65	Lubrizol 4991	17,524	11,741	1938	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,871	11,741
4	Chevron	CH7	Famm Taro Sepcial 70	100,594	67,398	1913	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	33,699	67,398
4	Chevron	CH72	Saw Guide 150	17,284	11,580	1959	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,790	11,580
4	Chevron	CH75	Jet Fuel	1,004,586	673,073	1952	Fixed Roof	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	336,536	673,073
4	Chevron	CH76	Base Oil	498,258	333,833	1960	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	166,916	333,833
4	Chevron	CH77	RPM HDMO 15W40	128,511	86,102	1960	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	43,051	86,102
4	Chevron	CH78	Paratone 8451	311,722	208,854	1960	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	104,427	208,854
4	Chevron	CH79	Empty	17,378	NA	1960	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH8	Rykon Prem MV	104,897	70,281	1913	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	35,140	70,281
4	Chevron	CH80	Out of Service	17,378	NA	NA	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH81	Empty	17,724	NA	1951	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH82	Infineum M7038	17,624	11,808	1951	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,904	11,808
4	Chevron	CH83	RPM HDMO 15W40	17,331	11,612	1951	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,806	11,612
4	Chevron	CH84	Empty	17,184	NA	1952	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH85	Oloa 44200	17,671	11,840	1952	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,920	11,840
4	Chevron	CH87	Lubrizol 4991	17,430	11,678	1913	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,839	11,678
4	Chevron	CH88	Empty	17,624	NA	1850	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH89	Oil Stop	19,431	13,019	1952	Fixed Roof	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	6,509	13,019
4	Chevron	CH9	Chevron 7075F	169,193	113,359	1949	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	56,680	113,359
4	Chevron	CH90	Delo 400-15W40	208,848	139,928	1954	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	69,964	139,928
4	Chevron	CH91	Oloa 9740C	17,671	11,840	1961	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,920	11,840
4	Chevron	CH92	Out of Service	17,577	NA	1961	Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Chevron	CH94	Rykon Oil 68	67,419	45,171	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	22,585	45,171
4	Chevron	CH96	Additive	17,624	11,808	1966	Fixed Roof	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	5,904	11,808
4	Chevron	CH97	Additive	17,624	11,808	1966	Fixed Roof	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	5,904	11,808
4	Chevron	CH98	Rykon Oil 46	91,364	61,214	1968	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	30,607	61,214
4	Chevron	CH99	RPM UGL 80W90	62,033	41,562	NA	Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	20,781	41,562
5	Equilon	T-13519	Diesel	560,112	375,275	NA	Cone Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	187,638	375,275
5	Equilon	T-13520	Diesel	558,852	374,431	NA	Cone Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	187,215	374,431
5	Equilon	T-13521	Diesel	559,986	375,191	NA	Cone Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	187,595	375,191
5	Equilon	T-13522	Diesel	558,432	374,149	NA	Cone Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	187,075	374,149
5	Equilon	T-13523	Out of Service	565,320	378,764	NA	Cone Roof	Group 3A	None	None	On Land	Tank Failure	50%	100%	189,382	378,764
5	Equilon	T-13524	Diesel	559,146	374,628	NA	Cone Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	187,314	374,628
5	Equilon	T-36002	Diesel	1,537,704	1,030,262	NA	Cone Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	515,131	1,030,262
5	Equilon	T-55000	Gasoline	1,986,264	1,330,797	NA	Internal Fixed Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	665,398	1,330,797
5	Equilon	T-55001	Ethanol	2,331,714	1,562,248	NA	Internal Fixed Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	781,124	1,562,248
5	Equilon	T-80103	Diesel	3,303,636	2,213,436	NA	Cone Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	1,106,718	2,213,436
5	Equilon	T-80104	Gasoline	3,348,912	2,243,771	NA	Internal Fixed Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	1,121,886	2,243,771
5	Equilon	T-80110	Gasoline	3,317,622	2,222,807	NA	Internal Fixed Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	1,111,403	2,222,807
5	Equilon	T-84200	Gasoline	3,528,756	2,364,267	NA	Internal Fixed Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	1,182,133	2,364,267
5	Equilon	T-7017	Water	267,456	179,196	NA	External Fixed Roof	Group 3A	Not Flammable	No	On Land	Tank Failure	50%	100%	89,598	179,196
4	Kinder Morgan South	KMW10	Out of Service	22,722	NA	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW100	Diesel	3,381,000	2,265,270	1949	Vertical Fixed Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	1,132,635	2,265,270
4	Kinder Morgan South	KMW101	Gasoline	3,381,000	2,265,270	1949	Internal Floating Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	1,132,635	2,265,270
4	Kinder Morgan South	KMW102	Out of Service	306,600	NA	1951	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW103	Out of Service	168,000	NA	1950	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW104	Lubricity Additive	168,000	112,560	1950	Vertical Fixed Roof	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	56,280	112,560
4	Kinder Morgan South	KMW105	Ethanol	168,000	112,560	1951	Internal Floating Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	56,280	112,560
4	Kinder Morgan South	KMW106	Out of Service	302,546	NA	1951	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW11	Out of service	22,722	NA	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW116	Gasoline	3,385,200	2,268,084	1961	Internal Floating Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	1,134,042	2,268,084
4	Kinder Morgan South	KMW117	Biodiesel	567,000	379,890	1951	Internal Floating Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	189,945	379,890
4	Kinder Morgan South	KMW118	Gasoline	2,360,400	1,581,468	1951	Internal Floating Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	790,734	1,581,468
4	Kinder Morgan South	KMW12	Out of service	22,722	NA	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW12001	Jet A	5,040,000	3,376,800	2012	Internal Floating Roof	Group 3C	Category 2	Yes	On Land	No Tank Failure	0%	10%	0	337,680

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Area	Property	Tank ID[1]	Contents	Capacity (Gal)	Expected Fill (Gal) (67% of Capacity)[9]	Year	Type	Tank Group	Flammability Category	Hazardous Category	Damage Zone	Tank Age Failures	Percent Lost Min	Percent Lost Max	Volume Lost Min	Volume Lost Max
4	Kinder Morgan South	KMW12002	Diesel	5,040,000	3,376,800	2012	Internal Floating Roof	Group 3C	Category 3	Yes	On Land	No Tank Failure	0%	10%	0	337,680
4	Kinder Morgan South	KMW12003	Gasoline	5,040,000	3,376,800	2012	Internal Floating Roof	Group 3C	Category 1	Yes	On Land	No Tank Failure	0%	10%	0	337,680
4	Kinder Morgan South	KMW123	Gasoline	3,322,200	2,225,874	1952	Internal Floating Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	1,112,937	2,225,874
4	Kinder Morgan South	KMW124	Gasoline	3,393,600	2,273,712	1952	Internal Floating Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	1,136,856	2,273,712
4	Kinder Morgan South	KMW125	Out of service	12,525	NA	1946	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW126	Out of service	24,703	NA	1923	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW127	Out of service	24,703	NA	1923	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW128	Gasoline	2,347,800	1,573,026	1953	Internal Floating Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	786,513	1,573,026
4	Kinder Morgan South	KMW129	Out of service	7,728	NA	1927	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW13	Out of service	2,856	NA	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW131	Out of service	4,737	NA	1954	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW134	Gasoline	2,364,600	1,584,282	1955	Internal Floating Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	792,141	1,584,282
4	Kinder Morgan South	KMW137	Out of Service	222,936	NA	1956	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW138	Avgas	571,830	383,126	1956	Internal Floating Roof	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	191,563	383,126
4	Kinder Morgan South	KMW139	Out of Service	572,628	NA	1956	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW14	Out of service	2,856	NA	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW140	Storm Water	630,000	422,100	1956	Vertical Fixed Roof	Group 3A	Not Flammable	Unknown	On Land	Tank Failure	50%	100%	211,050	422,100
4	Kinder Morgan South	KMW141	Out of Service	730,800	NA	1956	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW143	Out of Service	252,927	NA	1959	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW145	Out of service	7,980	NA	1960	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW146	Out of service	7,980	NA	1960	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW147	Out of service	7,980	NA	1961	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW148	Out of service	7,980	NA	1961	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW15	Out of service	2,856	NA	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW152	Ethanol	47,800	32,026	1964	Internal Floating Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	16,013	32,026
4	Kinder Morgan South	KMW153	Out of service	7,637	NA	1965	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW154	Out of service	7,637	NA	1965	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW155	Out of Service	4,200	NA	1965	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW156	Out of Service	7,667	NA	1965	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW157	Out of Service	24,868	NA	1969	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW158	Out of Service	24,851	NA	1969	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW159	Out of Service	21,000	NA	1969	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW16	Out of service	2,814	NA	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW160	Out of Service	24,860	NA	1969	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW161	Out of Service	24,863	NA	1969	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW162	Out of Service	24,850	NA	1969	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW163	Out of Service	24,856	NA	1969	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW166	Contact Water	33,600	22,512	1970	Vertical Fixed Roof	Group 3A	Not Flammable	Unknown	On Land	Tank Failure	50%	100%	11,256	22,512
4	Kinder Morgan South	KMW167	Contact Water	24,024	16,096	1928	Vertical Fixed Roof	Group 3A	Not Flammable	Unknown	On Land	Tank Failure	50%	100%	8,048	16,096
4	Kinder Morgan South	KMW169	Out of Service	24,990	NA	1928	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW17	Out of service	2,814	NA	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW170	Out of Service	24,990	NA	1928	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW171	Out of Service	24,990	NA	NA	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW172	Out of Service	24,990	NA	NA	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW173	Jet A	49,980	33,487	1972	Vertical Fixed Roof	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	16,743	33,487
4	Kinder Morgan South	KMW176	Out of Service	25,353	NA	NA	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW177	Out of Service	24,457	NA	NA	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW18	Out of Service	2,814	NA	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW186	Out of Service	25,604	NA	NA	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW187	Out of Service	24,000	NA	NA	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW188	Out of Service	24,600	NA	NA	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW189	Out of Service	24,035	NA	NA	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW190	Additive	8,400	5,628	NA	Horizontal Tank	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	2,814	5,628
4	Kinder Morgan South	KMW192	Additive	8,064	5,403	NA	Horizontal Tank	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	2,701	5,403
4	Kinder Morgan South	KMW193	Additive	10,080	6,754	NA	Horizontal Tank	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	3,377	6,754
4	Kinder Morgan South	KMW194	Slop Water	6,300	4,221	NA	Horizontal Tank	Group 3A	Not Flammable	Unknown	On Land	Tank Failure	50%	100%	2,111	4,221
4	Kinder Morgan South	KMW2	Jet A	3,175,200	2,127,384	1915	Vertical Fixed Roof	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	1,063,692	2,127,384
4	Kinder Morgan South	KMW22	Out of Service	11,760	NA	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW23	Out of Service	11,718	NA	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW25	Out of Service	11,760	NA	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW26	Out of Service	22,806	NA	1916	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW3	Out of Service	553,350	NA	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW30	Out of Service	11,718	NA	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW31	Out of Service	11,760	NA	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW32	Out of Service	11,472	NA	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW33	Out of Service	17,472	NA	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW34	Out of Service	17,481	NA	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW35	Out of Service	4,397	NA	1924	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW36	Out of Service	4,368	NA	1924	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW37	Out of Service	4,368	NA	1924	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW38	Out of Service	4,368	NA	1924	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW39	Out of Service	4,397	NA	1924	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW4	Out of Service	215,754	NA	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW40	Out of Service	5,544	NA	1923	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW41	Out of Service	5,502	NA	1923	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW42	Out of Service	5,502	NA	1923	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW43	Out of Service	5,502	NA	1923	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW44	Out of Service	5,515	NA	1923	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW45	Out of Service	5,540	NA	1923	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW46	Out of Service	11,642	NA	1923	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW47	Out of Service	11,600	NA	1923	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW48	Out of Service	11,642	NA	1923	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW49	Out of Service	11,677	NA	1923	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW5	Out of Service	439,605	NA	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW50	Out of Service	11,507	NA	1923	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW51	Out of Service	11,634	NA	1923	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW52	Jet A	3,229,800	2,163,966	1923	Vertical Fixed Roof	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	1,081,983	2,163,966

Exhibit List 801

Area	Property	Tank ID[1]	Contents	Capacity (Gal)	Expected Fill (Gal) (67% of Capacity)[9]	Year	Type	Tank Group	Flammability Category	Hazardous Category	Damage Zone	Tank Age Failures	Percent Lost Min	Percent Lost Max	Volume Lost Min	Volume Lost Max
4	Kinder Morgan South	KMW54	Diesel	3,435,600	2,301,852	1929	Vertical Fixed Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	1,150,926	2,301,852
4	Kinder Morgan South	KMW56	Out of Service	19,867	NA	1929	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW57	Out of Service	19,800	NA	1929	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW58	Out of Service	19,800	NA	1929	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW59	Out of Service	19,855	NA	1929	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW6	Out of Service	215,166	NA	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW60	Out of Service	19,824	NA	1929	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW61	Out of Service	25,200	NA	1929	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW62	Out of Service	11,676	NA	1929	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW63	Out of Service	24,766	NA	1929	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW65	Jet A	861,336	577,095	1930	Vertical Fixed Roof	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	288,548	577,095
4	Kinder Morgan South	KMW66	Out of Service	856,800	NA	1930	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW69	Jet A	3,431,400	2,299,038	1937	Vertical Fixed Roof	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	1,149,519	2,299,038
4	Kinder Morgan South	KMW7	Out of Service	440,538	NA	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW70	Jet A	1,461,600	979,272	1938	Vertical Fixed Roof	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	489,636	979,272
4	Kinder Morgan South	KMW71	Transmix	862,260	577,714	1937	Vertical Fixed Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	288,857	577,714
4	Kinder Morgan South	KMW72	Out of Service	549,024	NA	1937	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW73	Transmix	546,714	366,298	1937	Vertical Fixed Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	183,149	366,298
4	Kinder Morgan South	KMW74	Out of Service	305,712	NA	1937	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW75	Out of Service	25,000	NA	1938	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW76	Out of Service	25,000	NA	1938	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW77	Out of Service	25,741	NA	1938	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW8	Out of Service	216,804	NA	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW82	Out of Service	11,642	NA	1923	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW83	Out of Service	19,867	NA	1923	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW84	Gasoline	2,356,200	1,578,654	1948	Internal Floating Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	789,327	1,578,654
4	Kinder Morgan South	KMW85	Diesel	2,347,800	1,573,026	1948	Vertical Fixed Roof	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	786,513	1,573,026
4	Kinder Morgan South	KMW86	Out of Service	222,805	NA	1948	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW87	Out of Service	222,469	NA	1948	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW88	Out of Service	222,574	NA	1948	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW89	Out of Service	222,919	NA	1948	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW9	Out of Service	22,722	NA	1915	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Kinder Morgan South	KMW90	Out of Service	2,982	NA	1946	Vertical Fixed Roof	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	McCall Oil	MC22	Asphalt	18,942	12,691	1954	Cone Roof	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	6,346	12,691
3	Northwest Natural Gas	*NWN-Tank 001*	Liquefied Natural Gas	7,100,000	4,757,000	NA	NA	Group 3C	Category 1	Yes	On Land	No Tank Failure	0%	10%	0	475,700
4	Conoco Phillips	PH1471	Hydraulic Tractor Oil	17,300	11,591	1921	Riveted Steel	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	5,796	11,591
4	Conoco Phillips	PH2561	Marine Fuel Oil	1,569,582	1,051,620	1929	Riveted Steel	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	525,810	1,051,620
4	Conoco Phillips	PH2579	Hydraulic Tractor Oil	1,800	1,206	1929	Welded Steel	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	603	1,206
4	Conoco Phillips	PH2669	Marine Diesel	449,694	301,295	1931	Riveted Steel	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	150,647	301,295
4	Conoco Phillips	PH2713	Unax AW 46	109,000	73,030	1937	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	36,515	73,030
4	Conoco Phillips	PH2714	Guardol 15W/40	109,000	73,030	1937	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	36,515	73,030
4	Conoco Phillips	PH2783	Decant Oil	948,066	635,204	1937	Riveted Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	317,602	635,204
4	Conoco Phillips	PH2784	Diesel #2	1,439,130	964,217	1937	Riveted Steel	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	482,109	964,217
4	Conoco Phillips	PH2915	Unleaded Gasoline	3,262,056	2,185,578	1938	Welded Steel	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	1,092,789	2,185,578
4	Conoco Phillips	PH2916	Diesel #2	1,652,196	1,106,971	1938	Welded Steel	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	553,486	1,106,971
4	Conoco Phillips	PH2917	RLOP 220 N	612,000	410,040	1938	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	205,020	410,040
4	Conoco Phillips	PH2982	Diesel #1	416,262	278,896	1941	Welded Steel	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	139,448	278,896
4	Conoco Phillips	PH2983	RLOP 220 N	304,000	203,680	1941	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	101,840	203,680
4	Conoco Phillips	PH3408	Unleaded Gasoline	1,639,680	1,098,586	1949	Welded Steel	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	549,293	1,098,586
4	Conoco Phillips	PH3409	Unleaded Gasoline	948,654	635,598	1949	Welded Steel	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	317,799	635,598
4	Conoco Phillips	PH3410	Ethanol	278,964	186,906	1949	Welded Steel	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	93,453	186,906
4	Conoco Phillips	PH3411	Unleaded Gasoline	259,350	173,765	1949	Welded Steel	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	86,882	173,765
4	Conoco Phillips	PH3412	Diesel #1	279,426	187,215	1949	Welded Steel	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	93,608	187,215
4	Conoco Phillips	PH3413	Unleaded Gasoline	259,560	173,905	1949	Welded Steel	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	86,953	173,905
4	Conoco Phillips	PH3414	RLOP 220 N	200,000	134,000	1949	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	67,000	134,000
4	Conoco Phillips	PH3415	SUN 525	200,000	134,000	1949	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	67,000	134,000
4	Conoco Phillips	PH3416	RLOP 100N	200,000	134,000	1949	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	67,000	134,000
4	Conoco Phillips	PH3417	ULTRA S-4	200,000	134,000	1949	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	67,000	134,000
4	Conoco Phillips	PH3579	Industrial Fuel Oil	3,307,668	2,216,138	1950	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	1,108,069	2,216,138
4	Conoco Phillips	PH36	Stop Oil	20,496	13,732	1907	Riveted Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	6,866	13,732
4	Conoco Phillips	PH3623	HiTech 6576	18,228	12,213	1950	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	6,106	12,213
4	Conoco Phillips	PH3639	SUP SYN BL 5W/30	120,000	80,400	1951	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	40,200	80,400
4	Conoco Phillips	PH3739	SUN 150 B/S	200,000	134,000	1954	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	67,000	134,000
4	Conoco Phillips	PH3740	RLOP 600 N	277,000	185,590	1954	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	92,795	185,590
4	Conoco Phillips	PH3741	Ramar CLF 17E	17,500	11,725	1954	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH3742	MP Gear Lube 80/90	17,500	11,725	1954	Welded Steel	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH3743	Utility	18,600	12,462	1954	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	6,231	12,462
4	Conoco Phillips	PH3744	HYNAP N100	17,500	11,725	1954	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH3745	HITEC 5751	17,500	11,725	1954	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH3746	Lubrizol 4998C	17,500	11,725	1954	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH3747	Lubrizol 4990CH	17,500	11,725	1954	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH3757	HITEC 1193	17,500	11,725	1954	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH3760	Raffene 750L	17,500	11,725	1954	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH3761	Diesel #2	3,240,342	2,171,029	1954	Welded Steel	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	1,085,515	2,171,029
4	Conoco Phillips	PH4191	Lubrizol 48254	17,500	11,725	1964	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH4192	Lubrizol 7075F	17,500	11,725	1964	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH4223	Slop Oil	18,690	12,522	1968	Welded Steel	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	6,261	12,522
4	Conoco Phillips	PH4241	UNAX AW 68	17,500	11,725	1968	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH4242	UNAX AW 68	17,500	11,725	1968	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH4243	HT4/10W	17,500	11,725	1968	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH4244	Mohawk 450	17,500	11,725	1968	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH4245	SUN 525	17,500	11,725	1968	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH4252	Residual Fuel Oil[6]	458,640	307,289	1968	Welded Steel	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	153,644	307,289
4	Conoco Phillips	PH4253	Residual Fuel Oil[6]	451,290	302,364	1968	Welded Steel	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	151,182	302,364
4	Conoco Phillips	PH4254	PS 300	459,312	307,739	1968	Welded Steel	Group 3A	Category 1	No	On Land	Tank Failure	50%	100%	153,870	307,739
4	Conoco Phillips	PH4255	Biodiesel	404,250	270,848	1968	Welded Steel	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	135,424	270,848
4	Conoco Phillips	PH4256	Out of Service	195,408	NA	1968	Welded Steel	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA

Exhibit List 802

Area	Property	Tank ID[1]	Contents	Capacity (Gal)	Expected Fill (Gal) (67% of Capacity)[9]	Year	Type	Tank Group	Flammability Category	Hazardous Category	Damage Zone	Tank Age Failures	Percent Lost Min	Percent Lost Max	Volume Lost Min	Volume Lost Max
4	Conoco Phillips	PH4257	Out of Service	38,367	NA	1968	Welded Steel	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Conoco Phillips	PH4258	Line Clippings	18,000	12,060	1968	Welded Steel	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	6,030	12,060
4	Conoco Phillips	PH4259	Transmix	205,506	137,689	1968	Welded Steel	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	68,845	137,689
4	Conoco Phillips	PH4266	Flush	17,500	11,725	1968	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH4281	Versa Tran ATF	17,500	11,725	1969	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH4300	Ramar CLF 17E	25,500	17,085	1969	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	8,543	17,085
4	Conoco Phillips	PH4302	RLOP 600N	17,500	11,725	1971	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH4303	RLOP 100N	17,500	11,725	1971	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH4305	Out of Service	8,900	NA	1971	Welded Steel	Group 2	None	None	On Land	Tank Failure	50%	100%	NA	NA
4	Conoco Phillips	PH4306	RLOP 100N	200,000	134,000	1971	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	67,000	134,000
4	Conoco Phillips	PH4318	Diesel #2	1,422,456	953,046	1973	Welded Steel	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	476,523	953,046
4	Conoco Phillips	PH4320	Sup Syn BL 10W/30	35,000	23,450	1973	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	11,725	23,450
4	Conoco Phillips	PH4321	Uniguide II 100	35,000	23,450	1973	Welded Steel	Group 3A	Category 1	No	On Land	Tank Failure	50%	100%	11,725	23,450
4	Conoco Phillips	PH4322	T5X HD 15W/40	35,000	23,450	1973	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	11,725	23,450
4	Conoco Phillips	PH4323	Super ATF	35,000	23,450	1973	Welded Steel	Group 3A	Category 2	No	On Land	Tank Failure	50%	100%	11,725	23,450
4	Conoco Phillips	PH4327	Gasoline Slops[5]	10,080	6,754	1974	Welded Steel	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	3,377	6,754
4	Conoco Phillips	PH4331	Ethyl HITEC 6888E	25,500	17,085	1973	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	8,543	17,085
4	Conoco Phillips	PH4332	Super ATF	17,500	11,725	1973	Welded Steel	Group 3A	Category 2	No	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH4333	Point Premier 10W/30	17,500	11,725	1973	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH4334	Super 5W/20	17,500	11,725	1973	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH4369	RLOP 220 N	17,500	11,725	1979	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Conoco Phillips	PH4388	Utility	13,500	9,045	1984	Welded Steel	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4389	Utility	13,500	9,045	1984	Welded Steel	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4390	Bar & Chain 150	13,500	9,045	1985	Welded Steel	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4391	Utility	13,500	9,045	1985	Welded Steel	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4392	Utility	13,500	9,045	1985	Welded Steel	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4393	Utility	13,500	9,045	1985	Welded Steel	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4394	Utility	13,500	9,045	1985	Welded Steel	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4395	Utility	13,500	9,045	1985	Welded Steel	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4397	Lubrizol 9692A	13,500	9,045	1985	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4398	HITEC 1193A	13,500	9,045	1985	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4399	Firebird 15W/40	13,500	9,045	1985	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4400	Guardol 30	13,500	9,045	1985	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4401	Mohawk 150	13,500	9,045	1985	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4402	TSX HD10	13,500	9,045	1985	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4403	HT4/30W	13,500	9,045	1985	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4404	Fleet Sup EC 15W/40	13,500	9,045	1985	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4405	HITEC 3472	13,500	9,045	1987	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4406	Lubrizol 9990A	13,500	9,045	1987	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4407	Ethyl HITEC 388	13,500	9,045	1987	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4408	Ethyl HITEC 5756	13,500	9,045	1987	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	4,523	9,045
4	Conoco Phillips	PH4441	Octel 9056	18,648	12,494	1993	Welded Steel	Group 3B	Unknown	Yes	On Land	No Tank Failure	0%	10%	0	1,249
4	Conoco Phillips	PHF103	UTRA 58	25,500	17,085	1973	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	8,543	17,085
4	Conoco Phillips	PHF104	UTRA 59	17,500	11,725	1973	Welded Steel	Group 3A	Unknown	Yes	On Land	Tank Failure	50%	100%	5,863	11,725
4	Zenith Energy	Tank 129	Asphalt	NA	NA	NA	NA	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 128	Asphalt	NA	NA	NA	NA	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 127	Asphalt	NA	NA	NA	NA	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 70	Asphalt	NA	NA	NA	NA	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 125	Asphalt	NA	NA	NA	NA	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 124	Asphalt	NA	NA	NA	NA	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 123	Asphalt	NA	NA	NA	NA	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 122	Asphalt	NA	NA	NA	NA	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 121	Asphalt	NA	NA	NA	NA	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 120	Asphalt	NA	NA	NA	NA	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 112	Asphalt	NA	NA	NA	NA	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 110	Asphalt	NA	NA	NA	NA	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 101	Asphalt	NA	NA	NA	NA	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 126	Asphalt	NA	NA	NA	NA	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 003	Asphalt	NA	NA	NA	NA	Group 3A	Category 1	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 71	Avgas	NA	1,402,380	NA	Internal Floating Roof	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	701,190	1,402,380
4	Zenith Energy	Tank 184	Biodiesel	NA	222,000	NA	NA	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	111,000	222,000
4	Zenith Energy	Tank 307	Caustic	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 74	Charge Stock	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 100	Charge Stock	NA	NA	NA	NA	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 102	Charge Stock	NA	NA	NA	NA	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 106	Crude Oil	NA	5,611,788	NA	External Floating Roof	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	2,805,894	5,611,788
4	Zenith Energy	Tank 67	Crude Oil	NA	3,234,000	NA	NA	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	1,617,000	3,234,000
4	Zenith Energy	Tank 93	Crude Oil	NA	2,829,918	NA	NA	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	1,414,959	2,829,918
4	Zenith Energy	Tank 69	Crude Oil	NA	NA	NA	NA	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 130	Crude Oil	NA	3,200,000	NA	Internal Floating Roof	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	1,600,000	3,200,000
4	Zenith Energy	Tank 68	Crude Oil	NA	2,900,000	NA	NA	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	1,450,000	2,900,000
4	Zenith Energy	Tank 63	Crude Oil	NA	4,763,472	NA	Internal Floating Roof	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	2,381,736	4,763,472
4	Zenith Energy	Tank 104	Crude Oil	NA	NA	NA	NA	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 105	Crude Oil	NA	5,241,684	NA	External Floating Roof	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	2,620,842	5,241,684
4	Zenith Energy	Tank 001	Crude Oil	NA	NA	NA	NA	Group 3A	Category 2	Yes	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 308	Murol	NA	NA	NA	NA	Group 3A	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 182	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 183	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 185	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 202	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 203	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 209	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 213	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 208	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 211	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 306	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tanks 95	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA

Exhibit List 803

Area	Property	Tank ID[1]	Contents	Capacity (Gal)	Expected Fill (Gal) (67% of Capacity)[9]	Year	Type	Tank Group	Flammability Category	Hazardous Category	Damage Zone	Tank Age Failures	Percent Lost Min	Percent Lost Max	Volume Lost Min	Volume Lost Max
4	Zenith Energy	Tank 114	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 302	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 162	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 166	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 167	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 168	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 169	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 170	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 171	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 172	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 20	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 173	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 174	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 180	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 179	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 206	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 210	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 177	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 176	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 178	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 181	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 200	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 201	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	N2	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 317	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	BAS #2	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	KO T#5	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	BAS #3	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	BAS #4	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 160	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 161	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 314	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 002	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	KO T#2	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	CAS #5	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	BAS #1	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 305	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	KO T#1	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 163	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 164	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 165	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 152	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 151	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 158	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 157	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 156	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 148	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 149	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 150	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 142	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 143	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 144	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 147	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 146	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 145	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 140	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 141	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 300	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	K-23	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	TW-2	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 207	NA	NA	NA	NA	NA	Group 1	Unknown	Unknown	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 66	Universal Low-Sulfer Diesel	NA	3,188,598	NA	NA	Group 3A	Category 3	Yes	On Land	Tank Failure	50%	100%	1,594,299	3,188,598
4	Zenith Energy	Tank 111	Wastewater	NA	NA	NA	NA	Group 3A	Not Flammable	No	On Land	Tank Failure	50%	100%	NA	NA
4	Zenith Energy	Tank 113	Wastewater	NA	NA	NA	NA	Group 3A	Not Flammable	No	On Land	Tank Failure	50%	100%	NA	NA

Notes:

[1]Tanks noted in satellite images, but not listed in available GIS data, are given the designation based on property ID and count, and are *italicized*. Example: Kinder Morgan North = "*KML-Tank 1*"

[2] Tank contents were listed as both gasoline and ethanol; flammability and hazard category are for gasoline.

[3] Tank contents were listed as both gasoline and diesel; flammability and hazard category are for gasoline.

[4] Tank contents were listed as both gasoline and diesel additives; flammability and hazard category are for gasoline.

[5] Tank contents were listed as gasoline slops; flammability and hazard category are for gasoline.

[6] Residual Oil and Residual Fuel Oil is a general classification for heavier oils that remain after the distillate fuel oil and lighter hydrocarbons are removed. The type of lighter hydrocarbon is unknown and therefore defaulted to the most flammable category.

[7] Tank contents were listed as biodiesel additive; flammability and hazard category are for biodiesel.

[8] Tank data provided by COP without geographic location; failure assumption made from satellite imagry.

[9] Zenith Energy tank fill provided directly from Portland Fire and Rescue.

Category 1 - Liquids with flashpoints below 73.4°F (23°C) and boiling points at or below 95°F (35°C).
Category 2 - Liquids with flashpoints below 73.4°F (23°C) and boiling points at or above 95°F (35°C).
Category 3 - Liquids with flashpoints at or above 73.4°F (23°C) and at or below 140°F (60°C).
Category 4 - Liquids having flashpoints above 140°F (60°C) and at or below 199.4°F (93°C).
NA - Data not available
No - Tank substance is not hazardous.
None - Flammability category and/or hazard category is not applicable due to tank status of Out of Service.
Not Flammable - Tank contents are not flammable and do not fall into Category 1-4.
Unknown - Flammability category or hazard category unknown due to unknown tank contents, or tank contents not defined in a suitable way to ascertain flammability or hazard categories.
Yes - Tank substance is hazardous.

APPENDIX E
Tanks with Potential to Release to Unknown Locations

Exhibit List 805

FID	TANK_ID	Owner	Facility	Facility_S	Container	Substance	Average_Fi	Capacity_	Containe_1	Year_Built	Area__ft_2	Radius__ft	Perimeter	Height__ft	Longitude	Latitude	Flammabili	Hazardous	Year_cat	damagezone	fail	Concern
9	BP19	BP	British Petroleum South Tank Farm	BP	19	Oily Wastewater	184000	198828	Internal Floa	1961	1006.89	17.902599	112.48535	26.3976	-122.7785	45.593761	NA	NA	Pre-1993 or	Material in Water	Tank Failure	
10	BP2	BP	British Petroleum North Tank Farm	BP	2	Groundwater Remediation	n/a	1231000	Internal Floa	1957	1141.61	19.0627	119.77448	144.148	-122.7807	45.594645	NA	NA	Pre-1993 or	Material in Water	Tank Failure	
11	BP21	BP	British Petroleum South Tank Farm	BP	21	Gasoline additive	204960	220080	Fixed Roof	1961	1580.65	22.4307	140.93625	18.6129	-122.7783	45.593529	NA	NA	Pre-1993 or	Material in Water	Tank Failure	
14	BP24	BP	British Petroleum North Tank Farm	BP	24	Gasoline additive	15960	20286	Fixed Roof	1970	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
15	BP25	BP	British Petroleum North Tank Farm	BP	25	Gasoline additive	15960	20241	Fixed Roof	1966	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
16	BP26	BP	British Petroleum BioDiesel Tanks	BP	26	Diesel Conductivity Additive	n/a	450	Tote	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
19	BP40	BP	British Petroleum BioDiesel Tanks	BP	40	Unavailable	0	0	Fixed Roof	1954	1006.89	17.902599	112.48535	0	-122.7794	45.594105	NA	NA	Pre-1993 or	Material in Water	Tank Failure	
20	BP41	BP	British Petroleum BioDiesel Tanks	BP	41	Out of service	0	0	Fixed Roof	1954	1006.89	17.902599	112.48535	0	-122.7792	45.594158	None	NA	Pre-1993 or	Material in Water	Tank Failure	
21	BP42	BP	British Petroleum BioDiesel Tanks	BP	42	Out of service	0	0	Fixed Roof	1954	1006.89	17.902599	112.48535	0	-122.7791	45.594209	None	NA	Pre-1993 or	Material in Water	Tank Failure	
22	BP43	BP	British Petroleum BioDiesel Tanks	BP	43	Out of service	0	0	Fixed Roof	1954	1006.89	17.902599	112.48535	0	-122.7789	45.594263	None	NA	Pre-1993 or	Material in Water	Tank Failure	
23	BP44	BP	British Petroleum BioDiesel Tanks	BP	44	Out of service	0	0	Fixed Roof	1954	1006.89	17.902599	112.48535	0	-122.779	45.594108	None	NA	Pre-1993 or	Material in Water	Tank Failure	
24	BP45	BP	British Petroleum BioDiesel Tanks	BP	45	Unavailable	0	0	Fixed Roof	1954	1006.89	17.902599	112.48535	0	-122.7791	45.594056	NA	NA	Pre-1993 or	Material in Water	Tank Failure	
31	BPs	BP	British Petroleum Outside Tank Farm	BP	s	Diesel Conductivity Additive	n/a	450	Tote	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
33	CH10	Chevron	Chevron Willbridge	CH	10	Paratone 8451	153719	169616	Fx	1950	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
34	CH100	Chevron	Chevron Willbridge	CH	100	Gear Lube	17448	17624	Fixed Roof	1946	114.719	6.04287	37.968472	20.5371	-122.7429	45.564268	NA	NA	Pre-1993 or	On Land	Tank Failure	
36	CH102	Chevron	Chevron Willbridge	CH	102	Out of Service	0	12954	Fx	1978	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
37	CH103	Chevron	Chevron Willbridge	CH	103	Out of Service	0	13006	Fx	1978	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
38	CH104	Chevron	Chevron Willbridge	CH	104	Texaco Havoline 5S30	18000	17331	Fx	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
39	CH105	Chevron	Chevron Willbridge	CH	105	Empty	0	17624	Fx	1969	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
40	CH106	Chevron	Chevron Willbridge	CH	106	Delo G/L 80/90	23700	17818	Fx	1969	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
41	CH108	Chevron	Chevron Willbridge	CH	108	Techron Additive	196854	208425	Fx	1970	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
42	CH109	Chevron	Chevron Willbridge	CH	109	Delo GL 80/90	17490	17624	Fixed Roof		114.719	6.04287	37.968472	20.5371	-122.743	45.564195	NA	NA	Pre-1993 or	On Land	Tank Failure	
43	CH11	Chevron	Chevron Willbridge	CH	11	Lubrizol 4991D	195801	211915	Fx	1950	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
44	CH110	Chevron	Chevron Willbridge	CH	110	GST ISO 32	18500	17624	Fx	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
45	CH112	Chevron	Chevron Willbridge	CH	112	Oloa 6073EV	18400	17818	Fx	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
46	CH113	Chevron	Chevron Willbridge	CH	113	Hybase C414	16632	17378	Fx	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
47	CH114	Chevron	Chevron Willbridge	CH	114	Industrial EP 220	18300	17624	Fx	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
48	CH116	Chevron	Chevron Willbridge	CH	116	Empty	0	17724	Fx	1976	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
49	CH117	Chevron	Chevron Willbridge	CH	117	Raffene 2000L	18000	17624	Fx	1976	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
50	CH118	Chevron	Chevron Willbridge	CH	118	Blend Mix/ Line Wash	17800	17577	Fx	1976	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
51	CH119	Chevron	Chevron Willbridge	CH	119	Out of Service	0	19593	Fx	1977	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
52	CH12	Chevron	Chevron Willbridge	CH	12	ExxonMobil EM-100	540311	586302	Fx	1950	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
53	CH120	Chevron	Chevron Willbridge	CH	120	Out of Service	0	19593	Fx	1977	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
54	CH121	Chevron	Chevron Willbridge	CH	121	Out of Service	25379	0	Fx	1978	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
55	CH122	Chevron	Chevron Willbridge	CH	122	1000 THF	57600	61864	Fx	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
56	CH123	Chevron	Chevron Willbridge	CH	123	Delo 400-40	57600	61864	Fx	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
57	CH127	Chevron	Chevron Willbridge	CH	127	ATF dex 111	96500	109976	Fx	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
58	CH128	Chevron	Chevron Willbridge	CH	128	Rykon Prem 32	99448	74586	AST		860.79303	16.5529	104.00494	11.583201	-122.7425	45.563455	NA	NA	Pre-1993 or	On Land	Tank Failure	
60	CH13	Chevron	Chevron Willbridge	CH	13	Raffene 750L	39752	45682	Fx		0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
62	CH131	Chevron	Chevron Willbridge	CH	131	Hybase C414	18400	17577	Fx	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
63	CH132	Chevron	Chevron Willbridge	CH	132	Empty	0	18165	Fx	Unknown	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
64	CH133	Chevron	Chevron Willbridge	CH	133	CVX 3105	19300	17577	Fx	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
65	CH135	Chevron	Chevron Willbridge	CH	135	Out of Service	0	19379	Fx	1982	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
66	CH136	Chevron	Chevron Willbridge	CH	136	Out of Service	0	20303	Fx	1982	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
67	CH137	Chevron	Chevron Willbridge	CH	137	Oloa 2000	96500	60757	Fx	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
69	CH139	Chevron	Chevron Willbridge	CH	139	Blend Mix/ Line Wash	23500	25591	Fx	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
70	CH14	Chevron	Chevron Willbridge	CH	14	Delo 6170 CFO 20W40	Varies	190343	Fx	1950	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
71	CH140	Chevron	Chevron Willbridge	CH	140	Out of Service	0	83234	Fx	Unknown	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
72	CH141	Chevron	Chevron Willbridge	CH	141	Out of Service	0	140308	Fx	Unknown	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
74	CH143	Chevron	Chevron Willbridge	CH	143	Supreme 5W30	55448	62033	Fixed Roof		332.155	10.2824	64.606225	24.9662	-122.7423	45.56487	NA	NA	Pre-1993 or	On Land	Tank Failure	
75	CH144	Chevron	Chevron Willbridge	CH	144	Havoline 10W30	55672	61864	Fixed Roof		332.155	10.2824	64.606225	24.8981	-122.7423	45.564931	NA	NA	Pre-1993 or	On Land	Tank Failure	
76	CH145	Chevron	Chevron Willbridge	CH	145	Out of Service	0	61864	Fixed Roof		332.155	10.2824	64.606225	24.8981	-122.7422	45.565046	None	NA	Pre-1993 or	On Land	Tank Failure	
78	CH147	Chevron	Chevron Willbridge	CH	147	Delo 100-40	23700	25523	Fx	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
79	CH148	Chevron	Chevron Willbridge	CH	148	VER 800 Mar 30	32100	33839	Fx	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
80	CH149	Chevron	Chevron Willbridge	CH	149	RPM HDMO 30	23700	26311	Fx	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
81	CH15	Chevron	Chevron Willbridge	CH	15	Rykon Prem 32	26900	28951	Fx	1913	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
82	CH150	Chevron	Chevron Willbridge	CH	150	Delo 400-10	22792	25311	Fixed Roof		332.155	10.2824	64.606225	10.1868	-122.7422	45.564985	NA	NA	Pre-1993 or	On Land	Tank Failure	
83	CH151	Chevron	Chevron Willbridge	CH	151	MAR EO 9250-40	18200	17724	Fx	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
84	CH152	Chevron	Chevron Willbridge	CH	152	Empty	0	17624	Fx	Unknown	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
85	CH154	Chevron	Chevron Willbridge	CH	154	Map 100	76548	83422	Fixed Roof		393.561	11.1926	70.325182	28.336	-122.7431	45.563846	NA	NA	Pre-1993 or	On Land	Tank Failure	
86	CH155	Chevron	Chevron Willbridge	CH	155	Delo 400-15W40	75400	83422	Fixed Roof		393.561	11.1926	70.325182	28.336	-122.743	45.563782	NA	NA	Pre-1993 or	On Land	Tank Failure	
87	CH156	Chevron	Chevron Willbridge	CH	156	Delo 400-30	75442	83022	Fixed Roof		393.561	11.1926	70.325182	28.2001	-122.7429	45.563724	NA	NA	Pre-1993 or	On Land	Tank Failure	
88	CH157	Chevron	Chevron Willbridge	CH	157	Turbine Oil	70497	52872	AST	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
89	CH158	Chevron	Chevron Willbridge	CH	158	Out of Service	83422	0	Fx	Unknown	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
90	CH159	Chevron	Chevron Willbridge	CH	159	Out of Service	N/A	25379	AST	1987	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
91	CH16	Chevron	Chevron Willbridge	CH	16	Clarity PM 220	26900	29447	Fx	1913	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
92	CH160	Chevron	Chevron Willbridge	CH	160	Empty	0	25447	Fx	Unknown	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
95	CH17	Chevron	Chevron Willbridge	CH	17	ExxonMobile EHC45	26900	29327	Fx	1913	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
96	CH176	Chevron	Chevron Willbridge	CH	176	Blended Oil	2250	2632	Fx	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
97	CH177	Chevron	Chevron Willbridge	CH	177	Blended Oil	2250	2632	Fx	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
98	CH178	Chevron	Chevron Willbridge	CH	178	Blended Oil	2250	2632	Fx	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
99	CH179	Chevron	Chevron Willbridge	CH	179	Blended Oil	2250	2632	Fx	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
100	CH18	Chevron	Chevron Willbridge	CH	18	Oloa 550006L	27342	29583	Fx	1913	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
110	CH19	Chevron	Chevron Willbridge	CH	19	Empty	27342	29071	Fx	Unknown	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
111	CH20	Chevron	Chevron Willbridge	CH	20	Pennzoil 75HC	26900	29071	Fx	1914	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
112	CH21	Chevron	Chevron Willbridge	CH	21	Empty	26900	29583	Fx	1992	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
113	CH22	Chevron	Chevron Willbridge	CH	22	Clarity PM 220	12700	13982	Fx	1954	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
116	CH25	Chevron	Chevron Willbridge	CH	25	Clarity PM 150	8143	8665	Fx	1913	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
117	CH26	Chevron	Chevron Willbridge	CH	26	Rykon Prem 32	Varies	29447	Fx	1913	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
118	CH27	Chevron	Chevron Willbridge	CH	27	Chevron 7075F	Varies	29613	Fx	1913	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
119	CH28	Chevron	Chevron Willbridge	CH	28	Blend Mix/ Line Wash	Varies	29071	Fx	1913	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
120	CH28	Chevron	Chevron Willbridge	CH	28	Industrial EP 150	Varies	17771	Fx	1949	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
121	CH29	Chevron	Chevron Willbridge	CH	29		Varies	17724	Fx	1949	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
122	CH29	Chevron	Chevron Willbridge	CH	29	Empty	0	11750	Fx	1949	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
124	CH30	Chevron	Chevron Willbridge	CH	30	Empty	0	11750	Fx	1949	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
125	CH31	Chevron	Chevron Willbridge	CH	31	SynFluid $, 4CST	11100	8712	Fx	1953	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
126	CH32	Chevron	Chevron Willbridge	CH	32	Viscoplex 7-305	19900	13918	Fx	1950	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
127	CH33	Chevron	Chevron Willbridge	CH	33	Viscoplex 1-604	23900	13997	Fx	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
128	CH34	Chevron	Chevron Willbridge	CH	34	Empty	0	25379	Fx	Unknown	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
129	CH35	Chevron	Chevron Willbridge	CH	35	FAMM Tara 30 DP 30	23400	25379	Fx	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
130	CH36	Chevron	Chevron Willbridge	CH	36	Shell MV1 100	23400	25379	Fx	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
131	CH37	Chevron	Chevron Willbridge	CH	37	Drive Train Fluid HD 10	Varies	17378	Fx	1949	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
132	CH4	Chevron	Chevron Willbridge	CH	4	Neutral 220R	390348	435761	Fx	1913	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
133	CH40	Chevron	Chevron Willbridge	CH	40	Empty	0	18018	Fx	Unknown	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
134	CH41	Chevron	Chevron Willbridge	CH	41	Clarity Saw Guide 46	Varies	17331	Fx	1949	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	

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FID	TANK_ID	Owner	Facility	Facility_S	Container	Substance	Average_Fi	Capacity_	Containe_1	Year_Built	Area__ft_2	Radius__ft	Perimeter	Height__ft	Longitude	Latitude	Flammabili	Hazardous	Year_cat	damagezone	fail	Concern
135	CH42	Chevron	Chevron Willbridge	CH	42	Empty	0	29583	Fx	1913	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
139	CH46	Chevron	Chevron Willbridge	CH	46	Red Chain Bar 150	Varies	11750	Fx	1924	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
141	CH48	Chevron	Chevron Willbridge	CH	48	Water/Oil Slop	384175	396547	Fixed Roof	1979	2030.3	25.421699	159.72925	26.1098	-122.7417	45.564276	NA	NA	Pre-1993 or	On Land	Tank Failure	
142	CH5	Chevron	Chevron Willbridge	CH	5	Neutral Oil	336997	365834	Fx	1913	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
144	CH56	Chevron	Chevron Willbridge	CH	56	GST ISO 100	Varies	25379	Fx	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
145	CH57	Chevron	Chevron Willbridge	CH	57	Citgo Brt Stock 150	Varies	152433	Fx	1921	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
146	CH6	Chevron	Chevron Willbridge	CH	6	GEO HDAX L ASH 40	88565	100277	Fx	1913	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
148	CH61	Chevron	Chevron Willbridge	CH	61	Neutral 600R	Varies	400379	Fx	1941	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
151	CH65	Chevron	Chevron Willbridge	CH	65	Lubrizol 4991	Varies	17524	Fx	1938	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
152	CH7	Chevron	Chevron Willbridge	CH	7	Famm Taro Sepcial 70	89107	100594	Fx	1913	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
153	CH72	Chevron	Chevron Willbridge	CH	72	Saw Guide 150	Varies	17284	Fx	1959	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
156	CH77	Chevron	Chevron Willbridge	CH	77	RPM HDMO 15W40	Varies	128511	Fx	1960	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
157	CH78	Chevron	Chevron Willbridge	CH	78	Paratone 8451	Varies	311722	Fx	1960	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
158	CH79	Chevron	Chevron Willbridge	CH	79	Empty	0	17378	Fx	1960	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
159	CH8	Chevron	Chevron Willbridge	CH	8	Rykon Prem MV	91510	104897	Fx	1913	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
160	CH80	Chevron	Chevron Willbridge	CH	80	Out of Service	Out of Service	17378	Fx	Unknown	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
161	CH81	Chevron	Chevron Willbridge	CH	81	Empty	0	17724	Fx	1951	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
162	CH82	Chevron	Chevron Willbridge	CH	82	Infineum M7038	18000	17624	Fx	1951	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
163	CH83	Chevron	Chevron Willbridge	CH	83	RPM HDMO 15W40	18100	17331	Fx	1951	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
164	CH84	Chevron	Chevron Willbridge	CH	84	Empty	0	17184	Fx	1952	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
165	CH85	Chevron	Chevron Willbridge	CH	85	Oloa 44200	18000	17671	Fx	1952	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
166	CH87	Chevron	Chevron Willbridge	CH	87	Lubrizol 4991	18100	17430	Fx	1913	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
167	CH88	Chevron	Chevron Willbridge	CH	88	Empty	0	17624	Fx	1850	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
168	CH89	Chevron	Chevron Willbridge	CH	89	Oil Stop	17459	19431	Fx	1952	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
169	CH9	Chevron	Chevron Willbridge	CH	9	Chevron 7075F	153277	169193	Fx	1949	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
170	CH90	Chevron	Chevron Willbridge	CH	90	Delo 400-15W40	190000	208848	Fx	1954	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
171	CH91	Chevron	Chevron Willbridge	CH	91	Oloa 9740C	16758	17671	Fx	1961	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
172	CH92	Chevron	Chevron Willbridge	CH	92	Out of Service	Out of Service	17577	Fx	1961	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
174	CH96	Chevron	Chevron Willbridge	CH	96	Additive		17624	Fixed Roof	1966	1426.89	21.3118	133.90599	1.65114	-122.7427	45.564294	NA	NA	Pre-1993 or	On Land	Tank Failure	
175	CH97	Chevron	Chevron Willbridge	CH	97	Additive		17624	Fx	1966	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
176	CH98	Chevron	Chevron Willbridge	CH	98	Rykon Oil 46	469140	91364	Fx	1968	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
177	CH99	Chevron	Chevron Willbridge	CH	99	RPM UGL 80W90	55656	62033	Fx	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
178	KML10007	Kinder Morgan	Kinder Morgan Linnton Terminal	KML	10007	Out of service	250967	418278	Vertical fixe	1922	3078.0801	31.3015	196.67313	18.1658	-122.7875	45.603921	None	NA	Pre-1993 or	Material in Water	Tank Failure	
179	KML11017	Kinder Morgan	Kinder Morgan Linnton Terminal	KML	11017	Out of service	281963	469938	Internal floa	1941	1784.79	23.835199	149.76097	35.198399	-122.7863	45.603122	None	NA	Pre-1993 or	Material in Water	Tank Failure	
180	KML11019	Kinder Morgan	Kinder Morgan Linnton Terminal	KML	11019	Out of service	281938	469896	Internal floa	1941	1784.79	23.835199	149.76097	35.195301	-122.7864	45.603258	None	NA	Pre-1993 or	Material in Water	Tank Failure	
185	KML2024	Kinder Morgan	Kinder Morgan Linnton Terminal	KML	2024	Out of service	55138	92896	Vertical fixe	1937	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
186	KML2501	Kinder Morgan	Kinder Morgan Linnton Terminal	KML	2501	Out of service	61841	103068	Internal floa	1958	1141.61	19.0627	119.77448	12.0691	-122.7877	45.603684	None	NA	Pre-1993 or	Material in Water	Tank Failure	
187	KML2502	Kinder Morgan	Kinder Morgan Linnton Terminal	KML	2502	Out of service	62546	104244	Vertical fixe	1914	1141.61	19.0627	119.77448	12.206801	-122.7877	45.603813	None	NA	Pre-1993 or	Material in Water	Tank Failure	
188	KML2503	Kinder Morgan	Kinder Morgan Linnton Terminal	KML	2503	Out of service	63202	105336	Vertical fixe	1915	1141.61	19.0627	119.77448	12.3347	-122.7879	45.603818	None	NA	Pre-1993 or	Material in Water	Tank Failure	
190	KML3034	Kinder Morgan	Kinder Morgan Linnton Terminal	KML	3034	Storm water	82228	137046	Vertical fixe	1925	0	0	0	0	0	0	None	No	Pre-1993 or	No Data	Tank Failure	
191	KML305	Kinder Morgan	Kinder Morgan Linnton Terminal	KML	305	Out of service	7762	12936	Vertical fixe	1926	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
192	KML306	Kinder Morgan	Kinder Morgan Linnton Terminal	KML	306	Out of service	7762	12936	Vertical fixe	1926	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
193	KML309	Kinder Morgan	Kinder Morgan Linnton Terminal	KML	309	Out of service	7762	12936	Vertical fixe	1926	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
194	KML310	Kinder Morgan	Kinder Morgan Linnton Terminal	KML	310	Out of service	7762	12936	Vertical fixe	1926	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
195	KML312	Kinder Morgan	Kinder Morgan Linnton Terminal	KML	312	Out of service	7762	12936	Vertical fixe	1926	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
196	KML313	Kinder Morgan	Kinder Morgan Linnton Terminal	KML	313	Out of service	7762	12936	Vertical fixe	1926	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
197	KML314	Kinder Morgan	Kinder Morgan Linnton Terminal	KML	314	Out of service	7762	12936	Vertical fixe	1926	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
198	KML315	Kinder Morgan	Kinder Morgan Linnton Terminal	KML	315	Out of service	7762	12936	Vertical fixe	1926	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
199	KML326	Kinder Morgan	Kinder Morgan Linnton Terminal	KML	326	Out of service	7560	12600	Vertical fixe	Unknown	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
200	KML330	Kinder Morgan	Kinder Morgan Linnton Terminal	KML	330	Out of service	7207	12012	Vertical fixe	1926	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
201	KML331	Kinder Morgan	Kinder Morgan Linnton Terminal	KML	331	Out of service	7762	12936	Vertical fixe	1926	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
203	KML5004	Kinder Morgan	Kinder Morgan Linnton Terminal	KML	5004	Out of service	126580	210966	Vertical fixe	1916	1784.79	23.835199	149.76097	15.8014	-122.7879	45.603683	None	NA	Pre-1993 or	Material in Water	Tank Failure	
204	KML532	Kinder Morgan	Kinder Morgan Linnton Terminal	KML	532	Out of service	11945	29908	Vertical fixe	1965	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
205	KML55008	Kinder Morgan	Kinder Morgan Linnton Terminal	KML	55008	Out of service	1373299	2288832	Vertical fixe	1933	10371.9	57.4585	361.0224	29.5002	-122.7868	45.603011	None	NA	Pre-1993 or	Material in Water	Tank Failure	
207	KML55023	Kinder Morgan	Kinder Morgan Linnton Terminal	KML	55023	Out of service	1387210	2312016	Internal floa	1944	10371.9	57.4585	361.0224	29.799	-122.7872	45.603675	None	NA	Pre-1993 or	Material in Water	Tank Failure	
210	KMLSalt towe	Kinder Morgan	Kinder Morgan Linnton Terminal	KML	Salt tower	Contact water	13734	22890	Vertical fixe	Unknown	0	0	0	0	0	0	None	No	Pre-1993 or	No Data	Tank Failure	
211	KMW10	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	10	Out of service		22722	Vertical fixe	1915	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
214	KMW102	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	102	Out of service	0	306600	Vertical fixe	1951	1133.92	18.9984	119.37047	36.145901	-122.7449	45.565812	None	NA	Pre-1993 or	On Land	Tank Failure	
215	KMW103	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	103	Out of service	0	168000	Vertical fixe	1950	579.185	13.5779	85.312461	38.775902	-122.7451	45.565895	None	NA	Pre-1993 or	On Land	Tank Failure	
216	KMW104	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	104	Lubricity additive	100800	168000	Vertical fixe	1950	625.34198	14.1086	88.646946	35.913799	-122.7452	45.565895	NA	NA	Pre-1993 or	On Land	Tank Failure	
218	KMW106	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	106	Out of service		302546	Vertical fixe	1951	1353.04	20.753	130.39495	29.891701	-122.745	45.565695	None	NA	Pre-1993 or	On Land	Tank Failure	
219	KMW11	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	11	Out of service		22722	Vertical fixe	1915	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
223	KMW12	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	12	Out of service		22722	Vertical fixe	1915	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
229	KMW125	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	125	Out of service		12525	Vertical fixe	1946	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
230	KMW126	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	126	Out of service		24703	Vertical fixe	1923	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
231	KMW127	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	127	Out of service		24703	Vertical fixe	1923	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
233	KMW129	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	129	Out of service		7728	Vertical fixe	1927	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
234	KMW13	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	13	Out of service		2856	Vertical fixe	1915	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
235	KMW131	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	131	Out of service		4737	Vertical fixe	1954	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
237	KMW137	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	137	Out of service	0	222936	Vertical fixe	1956	866.76202	16.610201	104.36497	34.383499	-122.7454	45.565939	None	NA	Pre-1993 or	On Land	Tank Failure	
239	KMW139	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	139	Out of service	0	572628	Vertical fixe	1956	2056.52	25.5854	160.75781	37.222801	-122.746	45.566271	None	NA	Pre-1993 or	On Land	Tank Failure	
240	KMW14	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	14	Out of service		2856	Vertical fixe	1915	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
241	KMW140	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	140	Storm water	378000	630000	Vertical fixe	1956	2040.55	25.4858	160.132	41.272701	-122.7444	45.567086	None	No	Pre-1993 or	On Land	Tank Failure	
242	KMW141	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	141	Out of service		730800	Vertical fixe	1956	2944.97	30.617201	192.37355	33.173199	-122.7448	45.56752	None	NA	Pre-1993 or	On Land	Tank Failure	
243	KMW143	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	143	Out of service	0	252927	Vertical fixe	1959	1091.72	18.6415	117.128	30.9709	-122.7454	45.566047	None	NA	Pre-1993 or	On Land	Tank Failure	
244	KMW145	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	145	Out of service		7980	Vertical fixe	1960	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
245	KMW146	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	146	Out of service		7980	Vertical fixe	1960	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
246	KMW147	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	147	Out of service		7980	Vertical fixe	1961	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
247	KMW148	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	148	Out of service		7980	Vertical fixe	1961	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
248	KMW15	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	15	Out of service		2856	Vertical fixe	1915	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
250	KMW153	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	153	Out of service		7637	Vertical fixe	1965	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
251	KMW154	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	154	Out of service		7637	Vertical fixe	1965	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
252	KMW155	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	155	Out of service		4200	Vertical fixe	1965	73.015503	4.82095	30.290922	7.6896	-122.7436	45.565032	None	NA	Pre-1993 or	On Land	Tank Failure	
253	KMW156	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	156	Out of service	0	7667	Vertical fixe	1965	73.015503	4.82095	30.290922	14.0372	-122.7435	45.565019	None	NA	Pre-1993 or	On Land	Tank Failure	
254	KMW157	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	157	Out of service		24868	Vertical fixe	1969	113.765	6.0176902	37.810263	29.2215	-122.7431	45.564896	None	NA	Pre-1993 or	On Land	Tank Failure	
255	KMW158	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	158	Out of service	0	24851	Vertical fixe	1969	113.765	6.0176902	37.810263	29.2015	-122.743	45.564877	None	NA	Pre-1993 or	On Land	Tank Failure	
256	KMW159	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	159	Out of service	0	21000	Vertical fixe	1969	113.765	6.0176902	37.810263	24.6763	-122.743	45.56486	None	NA	Pre-1993 or	On Land	Tank Failure	
257	KMW16	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	16	Out of service		2814	Vertical fixe	1915	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
258	KMW160	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	160	Out of service	0	24860	Vertical fixe	1969	113.765	6.0176902	37.810263	29.212099	-122.7429	45.564843	None	NA	Pre-1993 or	On Land	Tank Failure	
259	KMW161	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	161	Out of service	0	24863	Vertical fixe	1969	99.280998	5.6215801	35.321429	33.477798	-122.7431	45.564858	None	NA	Pre-1993 or	On Land	Tank Failure	
260	KMW162	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	162	Out of service	0	24850	Vertical fixe	1969	104.796	5.77561	36.289228	31.6994	-122.743	45.564842	None	NA	Pre-1993 or	On Land	Tank Failure	
261	KMW163	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	163	Out of service	0	24856	Vertical fixe	1969	117.422	6.1136398	38.413132	28.297701	-122.743	45.564818	None	NA	Pre-1993 or	On Land	Tank Failure	
262	KMW166	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	166	Contact water	20160	33600	Vertical fixe	1970	0	0	0	0	0	0	None	No	Pre-1993 or	No Data	Tank Failure	
263	KMW167	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	167	Contact water	14414	24024	Vertical fixe	1928	0	0	0	0	0	0	None	No	Pre-1993 or	No Data	Tank Failure	
264	KMW169	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	169	Out of service	0	24990	Vertical fixe	1928	96.093102	5.5305901	34.749722	34.765099	-122.7429	45.564788	None	NA	Pre-1993 or	On Land	Tank Failure	

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FID	TANK_ID	Owner	Facility	Facility_S	Container	Substance	Average_Fi	Capacity_	Containe_1	Year_Built	Area__ft_2	Radius__ft	Perimeter	Height__ft	Longitude	Latitude	Flammabili	Hazardous	Year_cat	damagezone	fail	Concern
265	KMW17	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	17	Out of service		2814	Vertical fixe	1915	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
266	KMW170	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	170	Out of service	0	24990	Vertical fixe	1928	128.702	6.4005599	40.215904	25.956801	-122.7429	45.564766	None	NA	Pre-1993 or	On Land	Tank Failure	
267	KMW171	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	171	Out of service	0	24990	Vertical fixe		81.9217	5.1065202	32.085213	40.778999	-122.7428	45.564804	None	NA	Pre-1993 or	On Land	Tank Failure	
268	KMW172	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	172	Out of service	0	24990	Vertical fixe		105.765	5.8022499	36.456611	31.586	-122.7429	45.564824	None	NA	Pre-1993 or	On Land	Tank Failure	
270	KMW176	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	176	Out of service	0	25353	Vertical fixe		106.921	5.8338699	36.655286	31.698299	-122.7428	45.564781	None	NA	Pre-1993 or	On Land	Tank Failure	
271	KMW177	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	177	Out of service	0	24457	Vertical fixe		98.250503	5.59233	35.137646	33.276501	-122.7428	45.564744	None	NA	Pre-1993 or	On Land	Tank Failure	
272	KMW18	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	18	Out of service		2814	Vertical fixe	1915	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
273	KMW186	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	186	Out of service		25604	Vertical fixe		112.875	5.9941001	37.662042	30.3235	-122.7428	45.564746	None	NA	Pre-1993 or	On Land	Tank Failure	
274	KMW187	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	187	Out of service	0	24000	Vertical fixe		114.719	6.04287	37.968472	27.966999	-122.7428	45.564709	None	NA	Pre-1993 or	On Land	Tank Failure	
275	KMW188	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	188	Out of service	0	24600	Vertical fixe		113.765	6.0176902	37.810263	28.9065	-122.7427	45.564724	None	NA	Pre-1993 or	On Land	Tank Failure	
276	KMW189	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	189	Out of service	0	24035	Vertical fixe		99.280998	5.6215801	35.321429	32.3629	-122.7427	45.564688	None	NA	Pre-1993 or	On Land	Tank Failure	
277	KMW190	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	190	Additive	5040	8400	Horizontal T	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
278	KMW192	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	192	Additive	4838	8064	Horizontal T	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
279	KMW193	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	193	Additive	6048	10080	Horizontal T	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
280	KMW194	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	194	Slop water	3780	6300	Horizontal T	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
282	KMW22	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	22	Out of service		11760	Vertical fixe	1915	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
283	KMW23	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	23	Out of service		11718	Vertical fixe	1915	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
284	KMW25	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	25	Out of service		11760	Vertical fixe	1915	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
285	KMW26	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	26	Out of service		22806	Vertical fixe	1916	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
286	KMW3	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	3	Out of service	0	553350	Vertical fixe	1915	2835.3601	30.042	188.75945	26.089199	-122.7434	45.565155	None	NA	Pre-1993 or	On Land	Tank Failure	
287	KMW30	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	30	Out of service		11718	Vertical fixe	1915	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
288	KMW31	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	31	Out of service		11760	Vertical fixe	1915	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
289	KMW32	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	32	Out of service		11472	Vertical fixe	1915	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
290	KMW33	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	33	Out of service		17472	Vertical fixe	1915	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
291	KMW34	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	34	Out of service		17481	Vertical fixe	1915	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
292	KMW35	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	35	Out of service		4397	Vertical fixe	1924	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
293	KMW36	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	36	Out of service		4368	Vertical fixe	1924	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
294	KMW37	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	37	Out of service		4368	Vertical fixe	1924	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
295	KMW38	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	38	Out of service		4368	Vertical fixe	1924	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
296	KMW39	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	39	Out of service		4397	Vertical fixe	1924	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
297	KMW4	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	4	Out of service		215754	Vertical fixe	1915	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
298	KMW40	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	40	Out of service		5544	Vertical fixe	1923	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
299	KMW41	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	41	Out of service		5502	Vertical fixe	1923	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
300	KMW42	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	42	Out of service		5502	Vertical fixe	1923	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
301	KMW43	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	43	Out of service		5502	Vertical fixe	1923	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
302	KMW44	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	44	Out of service		5515	Vertical fixe	1923	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
303	KMW45	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	45	Out of service		5540	Vertical fixe	1923	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
304	KMW46	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	46	Out of service		11642	Vertical fixe	1923	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
305	KMW47	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	47	Out of service		11600	Vertical fixe	1923	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
306	KMW48	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	48	Out of service		11642	Vertical fixe	1923	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
307	KMW49	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	49	Out of service		11677	Vertical fixe	1923	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
308	KMW5	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	5	Out of service	0	439605	Vertical fixe	1915	1745.9	23.574101	148.12044	33.659901	-122.7433	45.565342	None	NA	Pre-1993 or	On Land	Tank Failure	
309	KMW50	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	50	Out of service		11507	Vertical fixe	1923	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
310	KMW51	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	51	Out of service		11634	Vertical fixe	1923	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
313	KMW56	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	56	Out of service		19867	Vertical fixe	1929	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
314	KMW57	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	57	Out of service		19800	Vertical fixe	1929	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
315	KMW58	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	58	Out of service		19800	Vertical fixe	1929	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
316	KMW59	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	59	Out of service		19855	Vertical fixe	1929	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
317	KMW6	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	6	Out of service	0	215166	Vertical fixe	1915	1092.09	18.644699	117.1481	26.3381	-122.7431	45.565153	None	NA	Pre-1993 or	On Land	Tank Failure	
318	KMW60	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	60	Out of service		19824	Vertical fixe	1929	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
319	KMW61	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	61	Out of Service	0	25200	Vertical fixe	1929	147.17101	6.84442	43.004759	22.8901	-122.7439	45.56518	None	NA	Pre-1993 or	On Land	Tank Failure	
320	KMW62	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	62	Out of service	0	11676	Vertical fixe	1929	73.015503	4.82095	30.290922	21.3771	-122.7438	45.56515	None	NA	Pre-1993 or	On Land	Tank Failure	
321	KMW63	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	63	Out of service	0	24766	Vertical fixe	1929	99.280998	5.6215801	35.321429	33.347198	-122.7431	45.564875	None	NA	Pre-1993 or	On Land	Tank Failure	
323	KMW66	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	66	Out of service		856800	Vertical fixe	1930	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
325	KMW7	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	7	Out of service	0	440538	Vertical fixe	1915	2565.3799	28.576	179.5483	22.956301	-122.7431	45.565529	None	NA	Pre-1993 or	On Land	Tank Failure	
328	KMW72	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	72	Out of service		549024	Vertical fixe	1937	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
330	KMW74	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	74	Out of service	0	305712	Vertical fixe	1937	1092.09	18.644699	117.1481	37.4217	-122.7428	45.565453	None	NA	Pre-1993 or	On Land	Tank Failure	
331	KMW75	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	75	Out of service		25000	Vertical fixe	1938	119.016	6.1550002	38.673007	28.0805	-122.7431	45.564924	None	NA	Pre-1993 or	On Land	Tank Failure	
332	KMW76	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	76	Out of service	0	25000	Vertical fixe	1938	147.17101	6.84442	43.004759	22.708401	-122.7434	45.564991	None	NA	Pre-1993 or	On Land	Tank Failure	
333	KMW77	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	77	Out of service		25741	Vertical fixe	1938	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
334	KMW8	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	8	Out of service	0	216804	Vertical fixe	1915	1092.09	18.644699	117.1481	26.538601	-122.743	45.565331	None	NA	Pre-1993 or	On Land	Tank Failure	
335	KMW82	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	82	Out of service		11642	Vertical fixe	1923	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
336	KMW83	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	83	Out of service		19867	Vertical fixe	1923	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
339	KMW86	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	86	Out of service	0	222805	Vertical fixe	1948	843.57397	16.386499	102.95941	35.307899	-122.7446	45.56569	None	NA	Pre-1993 or	On Land	Tank Failure	
340	KMW87	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	87	Out of service		222469	Vertical fixe	1948	843.54401	16.3862	102.95753	35.255901	-122.7448	45.565731	None	NA	Pre-1993 or	On Land	Tank Failure	
341	KMW88	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	88	Out of service		222574	Vertical fixe	1948	962.85602	17.5068	109.99847	30.901699	-122.7447	45.56559	None	NA	Pre-1993 or	On Land	Tank Failure	
342	KMW89	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	89	Out of service	0	222919	Vertical fixe	1948	923.59003	17.146099	107.73212	32.2654	-122.7449	45.565625	None	NA	Pre-1993 or	On Land	Tank Failure	
343	KMW9	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	9	Out of service		22722	Vertical fixe	1915	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
344	KMW90	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	90	Out of service		2982	Vertical fixe	1946	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
345	MC1	McCall	McCall Portland Terminal	MC	1	Asphalt	2021124	11247180	Cone roof	1976	33247.5	102.874	646.37641	45.2225	-122.7356	45.564617	NA	NA	Pre-1993 or	Material in Water	Tank Failure	
347	MC11	McCall	McCall Portland Terminal	MC	11	Oil and water	5000	20160	Cone roof	1974	171.76601	7.3942499	46.459442	15.69	-122.7339	45.563723	NA	NA	Pre-1993 or	Material in Water	Tank Failure	
348	MC12	McCall	McCall Portland Terminal	MC	12	Oil and water	5000	10080	Cone roof	1974	171.76601	7.3942499	46.459442	7.8449998	-122.734	45.563827	NA	NA	Pre-1993 or	Material in Water	Tank Failure	
351	MC18	McCall	McCall Portland Terminal	MC	18	Anti-strip	3276	4914	Cone roof	1989	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
352	MC19	McCall	McCall Portland Terminal	MC	19	Asphalt	285180	427770	Cone roof	1954	1650.62	22.921801	144.02192	34.644402	-122.7356	45.562501	NA	NA	Pre-1993 or	On Land	Tank Failure	
353	MC2	McCall	McCall Portland Terminal	MC	2	Asphalt	1577184	11787300	Cone roof	1973	40071.801	112.939	709.61668	39.322899	-122.7347	45.564029	NA	NA	Pre-1993 or	Material in Water	Tank Failure	
354	MC20	McCall	McCall Portland Terminal	MC	20	Asphalt	285180	427770	Cone roof	1954	1672.0699	23.070299	144.95496	34.200001	-122.7358	45.562379	NA	NA	Pre-1993 or	On Land	Tank Failure	
355	MC21	McCall	McCall Portland Terminal	MC	21	Asphalt	285376	428064	Cone roof	1954	1672.0699	23.070299	144.95496	34.223499	-122.736	45.562265	NA	NA	Pre-1993 or	On Land	Tank Failure	
356	MC22	McCall	McCall Portland Terminal	MC	22	Asphalt	12628	18942	Cone roof	1954	171.76601	7.3942499	46.459442	14.7421	-122.736	45.56204	NA	NA	Pre-1993 or	On Land	Tank Failure	
357	MC23	McCall	McCall Portland Terminal	MC	23	Asphalt	12712	18942	Cone roof	1954	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
362	MC28	McCall	McCall Portland Terminal	MC	28	Boiler fuel	5472	8358	Cone roof	1954	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
363	MC29	McCall	McCall Portland Terminal	MC	29	Unichem	5000	11000	Cone roof	1974	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
373	NU1009	NuStar	Nustar Portland Terminal	NU	1009	Gasoline/Diesel	366366	392887	Internal floa	1981	926.26202	17.1709	107.88795	56.702702	-122.7741	45.589498	NA	NA	Pre-1993 or	Material in Water	Tank Failure	
374	NU1010	NuStar	Nustar Portland Terminal	NU	1010	Gasoline/Diesel	342636	393264	Internal floa	1980	1217.3199	19.684601	123.68199	43.1866	-122.7739	45.589242	NA	NA	Pre-1993 or	Material in Water	Tank Failure	
376	NU1315	NuStar	Nustar Portland Terminal	NU	1315	Out of service	51366	56124	Cone	1938	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
377	NU1316	NuStar	Nustar Portland Terminal	NU	1316	Out of service	51366	56112	Cone	1938	0	0	0	0	0	0	None	NA	Pre-1993 or	No Data	Tank Failure	
378	NU181	NuStar	Nustar Portland Terminal	NU	181	Gasoline/Diesel additive	3000	7685	Cone	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
379	NU195	NuStar	Nustar Portland Terminal	NU	195	N/A	0	0			0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
384	NU212	NuStar	Nustar Portland Terminal	NU	212	N/A	0	0			0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
385	NU23	NuStar	Nustar Portland Terminal	NU	23	Gasoline/Diesel additive	7500	10048	Cone	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
386	NU24	NuStar	Nustar Portland Terminal	NU	24	Biodiesel additive	700	0	Horizontal	Unknown	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
387	NU2511	NuStar	Nustar Portland Terminal	NU	2511	MFO	1001742	1060587	Cone	1925	5070.3701	40.174	252.42069	27.9625	-122.7777	45.592612	NA	NA	Pre-1993 or	Material in Water	Tank Failure	
388	NU2512	NuStar	Nustar Portland Terminal	NU	2512	MFO	1003926	1049587	Cone	1925	4620.2998	38.349602	240.95765	30.368099	-122.7775	45.592399	NA	NA	Pre-1993 or	Material in Water	Tank Failure	
390	NU2706	NuStar	Nustar Portland Terminal	NU	2706	Gasoline/Diesel	1071000	1085895	Internal floa	1980	4450.9302	37.640099	236.49971	32.614201	-122.774	45.589047	NA	NA	Pre-1993 or	Material in Water	Tank Failure	
391	NU30	NuStar	Nustar Portland Terminal	NU	30	N/A	0	0			0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
393	NU3203	NuStar	Nustar Portland Terminal	NU	3203	Gasoline/Diesel	1250071	1265942	Internal floa	1979	4631.6099	38.3965	241.25232	36.538601	-122.7735	45.589324	NA	NA	Pre-1993 or	Material in Water	Tank Failure	

Exhibit List 808

FID	TANK_ID	Owner	Facility	Facility_S	Container	Substance	Average_Fi	Capacity_	Containe_1	Year_Built	Area__ft_2	Radius__ft	Perimeter	Height__ft	Longitude	Latitude	Flammabili	Hazardous	Year_cat	damagezone	fail	Concern
394	NU3204	NuStar	Nustar Portland Terminal	NU	3204	Gasoline/Diesel	1249542	1267302	Internal floa	1979	4629.21	38.386501	241.1895	36.596802	-122.7733	45.589106	NA	NA	Pre-1993 or	Material in Water	Tank Failure	
396	NU3605	NuStar	Nustar Portland Terminal	NU	3605	MFO	1376886	1442470	Cone	1938	4620.8398	38.351799	240.97146	41.730701	-122.7781	45.592887	NA	NA	Pre-1993 or	Material in Water	Tank Failure	
397	NU3614	NuStar	Nustar Portland Terminal	NU	3614	Gasoline/Diesel	1295238	1398810	Internal floa	1958	5336.3398	41.214199	258.95645	35.041699	-122.7773	45.591724	NA	NA	Pre-1993 or	Material in Water	Tank Failure	
398	NU4402	NuStar	Nustar Portland Terminal	NU	4402	Gasoline/Diesel	1738800	1761801	Internal floa	1979	6412.9399	45.180801	283.87935	36.725601	-122.7738	45.589538	NA	NA	Pre-1993 or	Material in Water	Tank Failure	
399	NU4507	NuStar	Nustar Portland Terminal	NU	4507	Out of service	1825740	1849692	Internal floa	1980	6499.3799	45.484299	285.78628	38.044998	-122.7742	45.589269	None	NA	Pre-1993 or	Material in Water	Tank Failure	
400	NU5209	NuStar	Nustar Portland Terminal	NU	5209	Gasoline/Diesel	1997100	2190678	Internal floa	1971	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
405	NU6408	NuStar	Nustar Portland Terminal	NU	6408	Gasoline/Diesel	2594866	2649782	Internal floa	1981	8075.1699	50.6992	318.55247	43.866001	-122.7745	45.589542	NA	NA	Pre-1993 or	Material in Water	Tank Failure	
406	NU703	NuStar	Nustar Portland Terminal	NU	703	Cutter	242718	309498	Internal floa	1938	1247.26	19.9252	125.19372	33.171902	-122.7785	45.592767	NA	NA	Pre-1993 or	Material in Water	Tank Failure	
407	NU8006	NuStar	Nustar Portland Terminal	NU	8006	Gasoline/Diesel	3004722	3379698	Internal floa	1953	9108.3096	53.844799	338.31685	49.603199	-122.7758	45.590599	NA	NA	Pre-1993 or	Material in Water	Tank Failure	
409	NU8308	NuStar	Nustar Portland Terminal	NU	8308	Gasoline/Diesel	3061632	3352746	Internal floa	1969	8486.1201	51.973202	326.55726	52.815498	-122.7747	45.590229	NA	NA	Pre-1993 or	Material in Water	Tank Failure	
410	PA1	Pacific Terminal Se	Pacific Terminal Services Portland Terminal	PA	1	Residual oil	30000	60000		1980	6915.0498	46.916199	294.78317	1.15991	-122.761	45.580093	NA	NA	Pre-1993 or	Material in Water	Tank Failure	
411	PA2	Pacific Terminal Se	Pacific Terminal Services Portland Terminal	PA	2	Diesel oil	10000	60000		1980	7594.0898	49.165798	308.91782	1.0562	-122.7614	45.580134	NA	NA	Pre-1993 or	Material in Water	Tank Failure	
412	PA3	Pacific Terminal Se	Pacific Terminal Services Portland Terminal	PA	3	Residual oil	10000	20000		1980	2769.5701	29.6915	186.55719	0.965356	-122.7613	45.579875	NA	NA	Pre-1993 or	Potentially in Water	Tank Failure	
413	PA4	Pacific Terminal Se	Pacific Terminal Services Portland Terminal	PA	4	Residual oil	40000	80000		1940	11006.4	59.189899	371.90111	0.97166	-122.7593	45.579706	NA	NA	Pre-1993 or	Material in Water	Tank Failure	
414	PA5	Pacific Terminal Se	Pacific Terminal Services Portland Terminal	PA	5	Residual oil	8000	55000		1940	10811.7	58.664101	368.59741	0.680046	-122.7598	45.579565	NA	NA	Pre-1993 or	Material in Water	Tank Failure	
415	PA6	Pacific Terminal Se	Pacific Terminal Services Portland Terminal	PA	6	Diesel oil	6	12		1988	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
421	PH2713	Phillips 66	Phillips 66	PH	2713	Unax AW 46	Not listed	109000	Welded Ste	1937	603.45099	13.8595	87.081806	24.1465	-122.7408	45.561495	NA	NA	Pre-1993 or	On Land	Tank Failure	
422	PH2714	Phillips 66	Phillips 66	PH	2714	Guardol 15W/40	Not listed	109000	Welded Ste	1937	603.45099	13.8595	87.081806	24.1465	-122.7407	45.561439	NA	NA	Pre-1993 or	On Land	Tank Failure	
423	PH2783	Phillips 66	Phillips 66	PH	2783	Decant Oil	Not listed	948066	Riveted Ste	1937	3357.1899	32.689899	205.3967	37.751301	-122.7403	45.561906	NA	NA	Pre-1993 or	On Land	Tank Failure	
427	PH2917	Phillips 66	Phillips 66	PH	2917	RLOP 220 N	Not listed	612000	Welded Ste	1938	2487.24	28.1374	176.7925	32.893002	-122.7407	45.562262	NA	NA	Pre-1993 or	On Land	Tank Failure	
429	PH2983	Phillips 66	Phillips 66	PH	2983	RLOP 220 N	Not listed	304000	Welded Ste	1941	1120.48	18.885401	118.66047	36.269299	-122.7401	45.563303	NA	NA	Pre-1993 or	On Land	Tank Failure	
437	PH3414	Phillips 66	Phillips 66	PH	3414	RLOP 220 N	Not listed	200000	Welded Ste	1949	782.82501	15.7855	99.183219	34.1535	-122.7397	45.561346	NA	NA	Pre-1993 or	On Land	Tank Failure	
438	PH3415	Phillips 66	Phillips 66	PH	3415	SUN 525	Not listed	200000	Welded Ste	1949	772.41803	15.6802	98.5216	34.613602	-122.7396	45.561452	NA	NA	Pre-1993 or	On Land	Tank Failure	
439	PH3416	Phillips 66	Phillips 66	PH	3416	RLOP 100N	Not listed	200000	Welded Ste	1949	588.65399	13.6885	86.007385	45.419201	-122.7395	45.561285	NA	NA	Pre-1993 or	On Land	Tank Failure	
440	PH3417	Phillips 66	Phillips 66	PH	3417	ULTRA S-4	Not listed	200000	Welded Ste	1949	821.435	16.170099	101.59973	32.548199	-122.7394	45.561389	NA	NA	Pre-1993 or	On Land	Tank Failure	
441	PH3579	Phillips 66	Phillips 66	PH	3579	Industrial Fuel Oil	Not listed	3307668	Welded Ste	1950	12916.7	64.121101	402.88476	34.232601	-122.7392	45.56094	NA	NA	Pre-1993 or	On Land	Tank Failure	
442	PH36	Phillips 66	Phillips 66	PH	36	Stop Oil	Not listed	20496	Riveted Ste	1907	193.702	7.8522201	49.336954	14.1451	-122.7411	45.561994	NA	NA	Pre-1993 or	On Land	Tank Failure	
443	PH3623	Phillips 66	Phillips 66	PH	3623	HiTech 6576	Not listed	18228	Welded Ste	1950	193.702	7.8522201	49.336954	12.5798	-122.741	45.562595	NA	NA	Pre-1993 or	On Land	Tank Failure	
444	PH3639	Phillips 66	Phillips 66	PH	3639	SUP SYN BL 5W/30	Not listed	120000	Welded Ste	1951	598.82501	13.8062	86.746913	26.7887	-122.7406	45.561377	NA	NA	Pre-1993 or	On Land	Tank Failure	
445	PH3739	Phillips 66	Phillips 66	PH	3739	SUN 150 B/S	Not listed	200000	Welded Ste	1954	757.995	15.5331	97.597346	35.272301	-122.7398	45.56123	NA	NA	Pre-1993 or	On Land	Tank Failure	
446	PH3740	Phillips 66	Phillips 66	PH	3740	RLOP 600 N	Not listed	277000	Welded Ste	1954	935.18402	17.253401	108.40631	39.5961	-122.7396	45.56116	NA	NA	Pre-1993 or	On Land	Tank Failure	
447	PH3741	Phillips 66	Phillips 66	PH	3741	Ramar CLF 17E	Not listed	17500	Welded Ste	1954	114.719	6.04287	37.968472	20.392599	-122.7409	45.560559	NA	NA	Pre-1993 or	On Land	Tank Failure	
449	PH3743	Phillips 66	Phillips 66	PH	3743	Utility	Not listed	18600	Welded Ste	1954	114.719	6.04287	37.968472	21.6744	-122.7409	45.560625	NA	NA	Pre-1993 or	On Land	Tank Failure	
450	PH3744	Phillips 66	Phillips 66	PH	3744	HYNAP N100	Not listed	17500	Welded Ste	1954	114.719	6.04287	37.968472	20.392599	-122.7409	45.560537	NA	NA	Pre-1993 or	On Land	Tank Failure	
451	PH3745	Phillips 66	Phillips 66	PH	3745	HITEC 5751	Not listed	17500	Welded Ste	1954	114.719	6.04287	37.968472	20.392599	-122.7409	45.560569	NA	NA	Pre-1993 or	On Land	Tank Failure	
452	PH3746	Phillips 66	Phillips 66	PH	3746	Lubrizol 4998C	Not listed	17500	Welded Ste	1954	114.719	6.04287	37.968472	20.392599	-122.7408	45.560603	NA	NA	Pre-1993 or	On Land	Tank Failure	
453	PH3747	Phillips 66	Phillips 66	PH	3747	Lubrizol 4990CH	Not listed	17500	Welded Ste	1954	114.719	6.04287	37.968472	20.392599	-122.7408	45.560577	NA	NA	Pre-1993 or	On Land	Tank Failure	
454	PH3757	Phillips 66	Phillips 66	PH	3757	HITEC 1193	Not listed	17500	Welded Ste	1954	114.719	6.04287	37.968472	20.392599	-122.7408	45.560546	NA	NA	Pre-1993 or	On Land	Tank Failure	
455	PH3760	Phillips 66	Phillips 66	PH	3760	Raffene 750L	Not listed	17500	Welded Ste	1954	114.719	6.04287	37.968472	20.392599	-122.7408	45.560512	NA	NA	Pre-1993 or	On Land	Tank Failure	
457	PH4191	Phillips 66	Phillips 66	PH	4191	Lubrizol 48254	Not listed	17500	Welded Ste	1964	114.719	6.04287	37.968472	20.392599	-122.7407	45.560555	NA	NA	Pre-1993 or	On Land	Tank Failure	
458	PH4192	Phillips 66	Phillips 66	PH	4192	Lubrizol 7075F	Not listed	17500	Welded Ste	1964	114.719	6.04287	37.968472	20.392599	-122.7408	45.560522	NA	NA	Pre-1993 or	On Land	Tank Failure	
459	PH4223	Phillips 66	Phillips 66	PH	4223	Slop Oil	Not listed	18690	Welded Ste	1968	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
460	PH4241	Phillips 66	Phillips 66	PH	4241	UNAX AW 68	Not listed	17500	Welded Ste	1968	114.719	6.04287	37.968472	20.392599	-122.7408	45.56049	NA	NA	Pre-1993 or	On Land	Tank Failure	
461	PH4242	Phillips 66	Phillips 66	PH	4242	UNAX AW 68	Not listed	17500	Welded Ste	1968	114.719	6.04287	37.968472	20.392599	-122.7407	45.560469	NA	NA	Pre-1993 or	On Land	Tank Failure	
462	PH4243	Phillips 66	Phillips 66	PH	4243	HT4/10W	Not listed	17500	Welded Ste	1968	114.719	6.04287	37.968472	20.392599	-122.7407	45.560504	NA	NA	Pre-1993 or	On Land	Tank Failure	
463	PH4244	Phillips 66	Phillips 66	PH	4244	Mohawk 450	Not listed	17500	Welded Ste	1968	114.719	6.04287	37.968472	20.392599	-122.7395	45.561506	NA	NA	Pre-1993 or	On Land	Tank Failure	
464	PH4245	Phillips 66	Phillips 66	PH	4245	SUN 525	Not listed	17500	Welded Ste	1968	114.719	6.04287	37.968472	20.392599	-122.7395	45.561479	NA	NA	Pre-1993 or	On Land	Tank Failure	
465	PH4252	Phillips 66	Phillips 66	PH	4252	Residual Fuel Oil	Not listed	458640	Welded Ste	1968	2263.77	26.843599	168.66331	27.083799	-122.7396	45.560726	NA	NA	Pre-1993 or	On Land	Tank Failure	
466	PH4253	Phillips 66	Phillips 66	PH	4253	Residual Fuel Oil	Not listed	451290	Welded Ste	1968	2448.8301	27.9193	175.42214	24.635799	-122.7394	45.560553	NA	NA	Pre-1993 or	On Land	Tank Failure	
469	PH4256	Phillips 66	Phillips 66	PH	4256	Out of Service	Not listed	195408	Welded Ste	1968	743.20001	15.3808	96.640418	35.148499	-122.7391	45.56059	None	NA	Pre-1993 or	On Land	Tank Failure	
470	PH4257	Phillips 66	Phillips 66	PH	4257	Out of Service	Not listed	38367	Welded Ste	1968	743.91901	15.3882	96.686911	6.8944898	-122.7389	45.560485	None	NA	Pre-1993 or	On Land	Tank Failure	
471	PH4258	Phillips 66	Phillips 66	PH	4258	Line Clippings	Not listed	18000	Welded Ste	1968	114.719	6.04287	37.968472	20.975201	-122.7395	45.561511	NA	NA	Pre-1993 or	On Land	Tank Failure	
473	PH4266	Phillips 66	Phillips 66	PH	4266	Flush	Not listed	17500	Welded Ste	1968	114.719	6.04287	37.968472	20.392599	-122.7395	45.561538	NA	NA	Pre-1993 or	On Land	Tank Failure	
474	PH4281	Phillips 66	Phillips 66	PH	4281	Versa Tran ATF	Not listed	17500	Welded Ste	1969	114.719	6.04287	37.968472	20.392599	-122.7407	45.560534	NA	NA	Pre-1993 or	On Land	Tank Failure	
475	PH4300	Phillips 66	Phillips 66	PH	4300	Ramar CLF 17E	Not listed	25500	Welded Ste	1969	114.719	6.04287	37.968472	29.714899	-122.741	45.560593	NA	NA	Pre-1993 or	On Land	Tank Failure	
476	PH4302	Phillips 66	Phillips 66	PH	4302	RLOP 600N	Not listed	17500	Welded Ste	1971	114.719	6.04287	37.968472	20.392599	-122.7394	45.561448	NA	NA	Pre-1993 or	On Land	Tank Failure	
477	PH4303	Phillips 66	Phillips 66	PH	4303	RLOP 100N	Not listed	17500	Welded Ste	1971	114.719	6.04287	37.968472	20.392599	-122.7393	45.561419	NA	NA	Pre-1993 or	On Land	Tank Failure	
478	PH4305	Phillips 66	Phillips 66	PH	4305	Out of Service	Not listed	8900	Welded Ste	1971	114.719	6.04287	37.968472	10.3711	-122.7393	45.561392	None	NA	Pre-1993 or	On Land	Tank Failure	
479	PH4306	Phillips 66	Phillips 66	PH	4306	RLOP 100N	Not listed	200000	Welded Ste	1971	744.26202	15.3918	96.709531	35.923099	-122.7393	45.561303	NA	NA	Pre-1993 or	On Land	Tank Failure	
481	PH4320	Phillips 66	Phillips 66	PH	4320	Sup Syn BL 10W/30	Not listed	35000	Welded Ste	1973	193.702	7.8522201	49.336954	24.1548	-122.739	45.561162	NA	NA	Pre-1993 or	On Land	Tank Failure	
482	PH4321	Phillips 66	Phillips 66	PH	4321	Uniguide II 100	Not listed	35000	Welded Ste	1973	193.702	7.8522201	49.336954	24.1548	-122.739	45.561127	NA	NA	Pre-1993 or	On Land	Tank Failure	
483	PH4322	Phillips 66	Phillips 66	PH	4322	TSX HD 15W/40	Not listed	35000	Welded Ste	1973	249.78	8.9167004	56.025281	18.7318	-122.7389	45.561085	NA	NA	Pre-1993 or	On Land	Tank Failure	
484	PH4323	Phillips 66	Phillips 66	PH	4323	Super ATF	Not listed	35000	Welded Ste	1973	190.078	7.77842	48.873254	24.615299	-122.7389	45.561043	NA	NA	Pre-1993 or	On Land	Tank Failure	
485	PH4327	Phillips 66	Phillips 66	PH	4327	Gasoline Slops	Not listed	10080	Welded Ste	1974	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
486	PH4331	Phillips 66	Phillips 66	PH	4331	Ethyl HITEC 6888E	Not listed	25500	Welded Ste	1973	114.719	6.04287	37.968472	29.714899	-122.741	45.560631	NA	NA	Pre-1993 or	On Land	Tank Failure	
488	PH4333	Phillips 66	Phillips 66	PH	4333	Point Premier 10W/30	Not listed	17500	Welded Ste	1973	114.719	6.04287	37.968472	20.392599	-122.7407	45.560477	NA	NA	Pre-1993 or	On Land	Tank Failure	
489	PH4334	Phillips 66	Phillips 66	PH	4334	Super 5W/20	Not listed	17500	Welded Ste	1973	114.719	6.04287	37.968472	20.392599	-122.7407	45.560444	NA	NA	Pre-1993 or	On Land	Tank Failure	
490	PH4369	Phillips 66	Phillips 66	PH	4369	RLOP 220 N	Not listed	17500	Welded Ste	1979	193.702	7.8522201	49.336954	12.0774	-122.7408	45.562184	NA	NA	Pre-1993 or	On Land	Tank Failure	
491	PH4388	Phillips 66	Phillips 66	PH	4388	Utility	Not listed	13500	Welded Ste	1984	114.719	6.04287	37.968472	15.7314	-122.741	45.560695	NA	NA	Pre-1993 or	On Land	Tank Failure	
492	PH4389	Phillips 66	Phillips 66	PH	4389	Utility	Not listed	13500	Welded Ste	1984	114.719	6.04287	37.968472	15.7314	-122.741	45.56067	NA	NA	Pre-1993 or	On Land	Tank Failure	
493	PH4390	Phillips 66	Phillips 66	PH	4390	Bar & Chain 150	Not listed	13500	Welded Ste	1985	114.719	6.04287	37.968472	15.7314	-122.7411	45.560641	NA	NA	Pre-1993 or	On Land	Tank Failure	
494	PH4391	Phillips 66	Phillips 66	PH	4391	Utility	Not listed	13500	Welded Ste	1985	114.719	6.04287	37.968472	15.7314	-122.7411	45.560612	NA	NA	Pre-1993 or	On Land	Tank Failure	
495	PH4392	Phillips 66	Phillips 66	PH	4392	Utility	Not listed	13500	Welded Ste	1985	114.719	6.04287	37.968472	15.7314	-122.7411	45.560724	NA	NA	Pre-1993 or	On Land	Tank Failure	
496	PH4393	Phillips 66	Phillips 66	PH	4393	Utility	Not listed	13500	Welded Ste	1985	114.719	6.04287	37.968472	15.7314	-122.7411	45.560698	NA	NA	Pre-1993 or	On Land	Tank Failure	
497	PH4394	Phillips 66	Phillips 66	PH	4394	Utility	Not listed	13500	Welded Ste	1985	114.719	6.04287	37.968472	15.7314	-122.7411	45.560668	NA	NA	Pre-1993 or	On Land	Tank Failure	
498	PH4395	Phillips 66	Phillips 66	PH	4395	Utility	Not listed	13500	Welded Ste	1985	114.719	6.04287	37.968472	15.7314	-122.7411	45.560639	NA	NA	Pre-1993 or	On Land	Tank Failure	
499	PH4397	Phillips 66	Phillips 66	PH	4397	Lubrizol 9692A	Not listed	13500	Welded Ste	1985	114.719	6.04287	37.968472	15.7314	-122.7411	45.560747	NA	NA	Pre-1993 or	On Land	Tank Failure	
500	PH4398	Phillips 66	Phillips 66	PH	4398	HITEC 1193A	Not listed	13500	Welded Ste	1985	114.719	6.04287	37.968472	15.7314	-122.7411	45.560719	NA	NA	Pre-1993 or	On Land	Tank Failure	
501	PH4399	Phillips 66	Phillips 66	PH	4399	Firebird 15W/40	Not listed	13500	Welded Ste	1985	114.719	6.04287	37.968472	15.7314	-122.7412	45.560693	NA	NA	Pre-1993 or	On Land	Tank Failure	
502	PH4400	Phillips 66	Phillips 66	PH	4400	Guardol 30	Not listed	13500	Welded Ste	1985	114.719	6.04287	37.968472	15.7314	-122.7412	45.560664	NA	NA	Pre-1993 or	On Land	Tank Failure	
503	PH4401	Phillips 66	Phillips 66	PH	4401	Mohawk 150	Not listed	13500	Welded Ste	1985	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
504	PH4402	Phillips 66	Phillips 66	PH	4402	TSX HD10	Not listed	13500	Welded Ste	1985	0	0	0	0	0	0	NA	NA	Pre-1993 or	No Data	Tank Failure	
505	PH4403	Phillips 66	Phillips 66	PH	4403	HT4/30W	Not listed	13500	Welded Ste	1985	114.719	6.04287	37.968472	15.7314	-122.7412	45.560719	NA	NA	Pre-1993 or	On Land	Tank Failure	
506	PH4404	Phillips 66	Phillips 66	PH	4404	Fleet Sup EC 15W/40	Not listed	13500	Welded Ste	1985	114.719	6.04287	37.968472	15.7314	-122.7412	45.560692	NA	NA	Pre-1993 or	On Land	Tank Failure	
507	PH4405	Phillips 66	Phillips 66	PH	4405	HITEC 3472	Not listed	13500	Welded Ste	1987	114.719	6.04287	37.968472	15.7314	-122.7412	45.560801	NA	NA	Pre-1993 or	On Land	Tank Failure	
508	PH4406	Phillips 66	Phillips 66	PH	4406	Lubrizol 9990A	Not listed	13500	Welded Ste	1987	114.719	6.04287	37.968472	15.7314	-122.7412	45.560773	NA	NA	Pre-1993 or	On Land	Tank Failure	
509	PH4407	Phillips 66	Phillips 66	PH	4407	Ethyl HITEC 388	Not listed	13500	Welded Ste	1987	114.719	6.04287	37.968472	15.7314	-122.7412	45.560747	NA	NA	Pre-1993 or	On Land	Tank Failure	
510	PH4408	Phillips 66	Phillips 66	PH	4408	Ethyl HITEC 5756	Not listed	13500	Welded Ste	1987	114.719	6.04287	37.968472	15.7314	-122.7413	45.560717	NA	NA	Pre-1993 or	On Land	Tank Failure	
512	PHF103	Phillips 66	Phillips 66	PH	F103	UTRA 58	Not listed	25500	Welded Ste	1973	0	0	0	0	0	0			Pre-1993 or	No Data	Tank Failure	
513	PHF104	Phillips 66	Phillips 66	PH	F104	UTRA 59	Not listed	17500	Welded Ste	1973	0	0	0	0	0	0			Pre-1993 or	No Data	Tank Failure	
511	PH4441	Phillips 66	Phillips 66	PH	4441	Octel 9056	Not listed	18648	Welded Ste	1993	193.702	7.8522201	49.336954	12.8697	-122.741	45.562543	NA	NA	1993 - 2004	On Land	No Tank Failure	
12	BP23a	BP	British Petroleum South Tank Farm	BP	23	Diesel additive	1800	2000	Fixed Roof	2005	0	0	0	0	0	0	NA	NA	Post 2004	No Data	No Tank Failure	
13	BP23b	BP	British Petroleum Outside Tank Farm	BP	23	Diesel Lubricity Additive	2100	2100	Horizontal T	2005	0	0	0	0	0	0	NA	NA	Post 2004	No Data	No Tank Failure	
93	CH163	Chevron	Chevron Willbridge	CH	163	Swing Tank	5684255	6354155	AST	2009	0	0	0	0	0	0	NA	NA	Post 2004	No Data	No Tank Failure	
94	CH164	Chevron	NUChevron WillbridgeLL	CH	163	Swing Tank	5684255	6354155	AST	2009	13583.1	65.754402	413.14709	62.535801	-122.741	45.564906	NA	NA	Post 2004	On Land	No Tank Failure	

Exhibit List 809

FID	TANK_ID	Owner	Facility	Facility_S	Container	Substance	Average_Fi	Capacity_	Containe_1	Year_Built	Area__ft_2	Radius__ft	Perimeter	Height__ft	Longitude	Latitude	Flammabili	Hazardous	Year_cat	damagezone	fail	Concern
371	NU10026	NuStar	Nustar Portland Terminal	NU	10026	Gasoline/diesel	4200000	4200000	Internal floa	2007	12047.4	61.9258	389.09128	46.604301	-122.7726	45.5881	NA	NA	Post 2004	Material in Water	No Tank Failure	
372	NU10027	NuStar	Nustar Portland Terminal	NU	10027	Gasoline/diesel	4200000	4200000	Internal floa	2007	12047.4	61.9258	389.09128	46.604301	-122.7728	45.588531	NA	NA	Post 2004	Material in Water	No Tank Failure	
102	CH181	Chevron	Chevron Willbridge	CH	181	Blended Oil	5000	4700	Fx	1993	0	0	0	0	0	0	NA	NA	1993 - 2004	No Data	Uncertain Location	
103	CH182	Chevron	Chevron Willbridge	CH	182	Blended Oil	10000	11374	Fx	1994	0	0	0	0	0	0	NA	NA	1993 - 2004	No Data	Uncertain Location	
104	CH183	Chevron	Chevron Willbridge	CH	183	Blended Oil	10000	11374	Fx	1994	0	0	0	0	0	0	NA	NA	1993 - 2004	No Data	Uncertain Location	
105	CH184	Chevron	Chevron Willbridge	CH	184	Blended Oil	10000	11374	Fx	1994	0	0	0	0	0	0	NA	NA	1993 - 2004	No Data	Uncertain Location	
106	CH185	Chevron	Chevron Willbridge	CH	185	Blended Oil	10000	11374	Fx	1994	0	0	0	0	0	0	NA	NA	1993 - 2004	No Data	Uncertain Location	
107	CH186	Chevron	Chevron Willbridge	CH	186	Blended Oil	10000	11374	Fx	1994	0	0	0	0	0	0	NA	NA	1993 - 2004	No Data	Uncertain Location	
108	CH187	Chevron	Chevron Willbridge	CH	187	Blended Oil	10000	11374	Fx	1994	0	0	0	0	0	0	NA	NA	1993 - 2004	No Data	Uncertain Location	
109	CH188	Chevron	Chevron Willbridge	CH	188	Blended Oil	10000	11374	Fx	1994	0	0	0	0	0	0	NA	NA	1993 - 2004	No Data	Uncertain Location	
114	CH23	Chevron	Chevron Willbridge	CH	23	Empty	0	13982	Fx	1997	0	0	0	0	0	0	None	NA	1993 - 2004	No Data	Uncertain Location	
115	CH24	Chevron	Chevron Willbridge	CH	24	Empty	0	8859	Fx	1993	0	0	0	0	0	0	None	NA	1993 - 2004	No Data	Uncertain Location	
358	MC24	McCall	McCall Portland Terminal	MC	24	Asphalt	28336	19068	Cone roof	2000	0	0	0	0	0	0	NA	NA	1993 - 2004	No Data	Uncertain Location	
359	MC25	McCall	McCall Portland Terminal	MC	25	Asphalt	28252	79800	Cone roof	2000	0	0	0	0	0	0	NA	NA	1993 - 2004	No Data	Uncertain Location	
360	MC26	McCall	McCall Portland Terminal	MC	26	Asphalt	28336	79800	Cone roof	2000	0	0	0	0	0	0	NA	NA	1993 - 2004	No Data	Uncertain Location	
361	MC27	McCall	McCall Portland Terminal	MC	27	Asphalt	27552	79800	Cone roof	2000	0	0	0	0	0	0	NA	NA	1993 - 2004	No Data	Uncertain Location	
416	PA7	Pacific Terminal Se	Pacific Terminal Services Portland Terminal	PA	7	Residual oil	250	475		1993	0	0	0	0	0	0	NA	NA	1993 - 2004	No Data	Uncertain Location	
101	CH180	Chevron	Chevron Willbridge	CH	180	Blended Oil	5000	4700	Fx	1993	0	0	0	0	0	0	NA	NA	1993 - 2004	No Data	Uncertain Location	
0	BP1	BP	British Petroleum North Tank Farm	BP	1	Gasoline	3641610	3808434	Internal Floa	1940	17351.4	74.317703	466.9519	29.341499	-122.7807	45.59495	Category 1	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
1	BP10	BP	British Petroleum South Tank Farm	BP	10	Diesel	931980	1008840	Fixed Roof	1941	4362.7798	37.265499	234.14604	30.9121	-122.7788	45.593866	Category 3	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
2	BP11	BP	British Petroleum North Tank Farm	BP	11	Gasoline	1129926	1354122	Internal Floa	1940	4632.2002	38.398899	241.2674	39.078701	-122.78	45.594442	Category 1	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
3	BP12	BP	British Petroleum North Tank Farm	BP	12	Ethanol	561204	605346	Internal Floa	1961	1678.34	23.113501	145.22641	48.216301	-122.7802	45.594962	Category 2	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
4	BP13	BP	British Petroleum North Tank Farm	BP	13	Ethanol	559482	602994	Internal Floa	1961	1944.0699	24.875999	156.30051	41.464001	-122.7804	45.595251	Category 2	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
5	BP14	BP	British Petroleum South Tank Farm	BP	14	Diesel	1046388	1121736	Fixed Roof	1942	3466.8301	33.219398	208.72364	43.2542	-122.7794	45.593616	Category 3	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
7	BP17	BP	British Petroleum South Tank Farm	BP	17	Diesel	3125472	3329340	Fixed Roof	1940	11531.8	60.586201	380.67433	38.595001	-122.7787	45.593523	Category 3	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
8	BP18	BP	British Petroleum South Tank Farm	BP	18	Diesel	1046262	1104726	Fixed Roof	1945	3610.9099	33.902599	213.01631	40.898499	-122.7797	45.593508	Category 3	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
17	BP3	BP	British Petroleum North Tank Farm	BP	3	Gasoline	1505448	1584366	Internal Floa	1957	4845.5	39.272999	246.75953	43.710602	-122.7813	45.59483	Category 1	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
18	BP4	BP	British Petroleum North Tank Farm	BP	4	Gasoline	939918	1105860	Internal Floa	1957	2970.8601	30.751499	193.21737	49.760799	-122.7811	45.594575	Category 1	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
25	BP46	BP	British Petroleum BioDiesel Tanks	BP	46	Biodiesel	125571	221970	Fixed Roof	1954	1006.89	17.902599	112.48535	29.4701	-122.7793	45.594005	Category 3	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
26	BP5	BP	British Petroleum North Tank Farm	BP	5	Gasoline	741300	895314	Internal floa	1957	2557.47	28.5319	179.27122	46.798801	-122.7808	45.594341	Category 1	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
27	BP6	BP	British Petroleum North Tank Farm	BP	6	Gasoline	803040	1014384	Internal Floa	1957	2937.49	30.578301	192.12913	46.1632	-122.7804	45.594515	Category 1	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
28	BP7	BP	British Petroleum North Tank Farm	BP	7	Gasoline	450492	648018	Internal Floa	1957	1851.48	24.2764	152.53312	46.7883	-122.7803	45.594769	Category 1	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
29	BP8	BP	British Petroleum North Tank Farm	BP	8	Gasoline	616938	790272	Internal Floa	1957	2404.8501	27.6675	173.84003	43.929699	-122.7804	45.594271	Category 1	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
30	BP9	BP	British Petroleum South Tank Farm	BP	9	Diesel	2161404	2295636	Fixed Roof	1940	10673.9	58.289001	366.2406	28.750799	-122.7793	45.593245	Category 3	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
35	CH101	Chevron	Chevron Willbridge	CH	101	Compressor Oil	17128	17284	Fixed Roof	1958	114.719	6.04287	37.968472	20.1409	-122.7429	45.564228	Category 1	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
68	CH138	Chevron	Chevron Willbridge	CH	138	Drive Train Fluid HD 10	18000	17378	Fx	Unknown	0	0	0	0	0	0	Category 1	Yes	Pre-1993 or	No Data	Tank Failure	Flammable
77	CH146	Chevron	Chevron Willbridge	CH	146	Transmix	22715	25447	Fx	Unknown	0	0	0	0	0	0	Category 2	Yes	Pre-1993 or	No Data	Tank Failure	Flammable
140	CH47	Chevron	Chevron Willbridge	CH	47	Unleaded Gasoline	3237046	3609743	Fixed Roof	1929	11940.8	61.651299	387.36653	40.412201	-122.7427	45.563923	Category 2	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
150	CH64	Chevron	Chevron Willbridge	CH	64	Diesel	754034	844275	Fixed Roof	1947	2902.78	30.3971	190.99061	38.881199	-122.7408	45.564509	Category 3	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
154	CH75	Chevron	Chevron Willbridge	CH	75	Jet Fuel	861104	1004586	Fixed Roof	1952	3238.1399	32.104999	201.72166	41.472599	-122.7423	45.564101	Category 3	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
173	CH94	Chevron	Chevron Willbridge	CH	94	Rykon Oil 68	63000	67419	Fx	Unknown	0	0	0	0	0	0	Category 1	Yes	Pre-1993 or	No Data	Tank Failure	Flammable
181	KML17018	Kinder Morgan	Kinder Morgan Linnton Terminal	KML	17018	Gasoline	441428	735714	Internal floa	1941	3078.0801	31.3015	196.67313	31.952101	-122.7859	45.603147	Category 1	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
182	KML17020	Kinder Morgan	Kinder Morgan Linnton Terminal	KML	17020	Gasoline	445738	742896	Internal floa	1941	3078.0801	31.3015	196.67313	32.264	-122.786	45.603335	Category 1	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
183	KML17027	Kinder Morgan	Kinder Morgan Linnton Terminal	KML	17027	Gasoline	443444	739074	Internal floa	1954	2884.6599	30.302099	190.3937	34.250198	-122.7858	45.602926	Category 1	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
184	KML20011	Kinder Morgan	Kinder Morgan Linnton Terminal	KML	20011	Diesel	513904	856506	Vertical fixe	1932	3965.53	35.5284	223.23152	28.873501	-122.7867	45.602706	Category 3	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
189	KML30016	Kinder Morgan	Kinder Morgan Linnton Terminal	KML	30016	Deisel	752270	1253784	Vertical fixe	1941	6522.73	45.565899	286.29899	25.6959	-122.7862	45.602855	Category 3	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
202	KML45028	Kinder Morgan	Kinder Morgan Linnton Terminal	KML	45028	Gasoline	1133723	1889538	External floa	1955	5517.6699	41.9086	263.3195	45.779301	-122.7858	45.602662	Category 1	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
206	KML55022	Kinder Morgan	Kinder Morgan Linnton Terminal	KML	55022	Gasoline	1385572	2309286	Vertical fixe	1928	10371.9	57.4585	361.0224	29.7638	-122.787	45.60332	Category 1	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
208	KML59029	Kinder Morgan	Kinder Morgan Linnton Terminal	KML	59029	Gasoline	1472436	2454060	Vertical fixe	1955	9125.6504	53.896099	338.63918	35.949299	-122.7863	45.602507	Category 1	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
212	KMW100	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	100	Diesel	2028600	3381000	Vertical fixe	1949	11039.6	59.279099	372.46156	40.941299	-122.7451	45.566303	Category 3	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
213	KMW101	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	101	Gasoline	2028600	3381000	Internal floa	1949	10881.1	58.8521	369.77865	41.537701	-122.7447	45.56672	Category 1	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
217	KMW105	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	105	Ethanol	100800	168000	Internal floa	1951	477.67001	12.3307	77.476072	47.016602	-122.7451	45.5658	Category 2	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
220	KMW116	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	116	Gasoline	2031120	3385200	Internal floa	1961	12590.2	63.3055	397.76019	35.9436	-122.745	45.567149	Category 1	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
222	KMW118	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	118	Gasoline	1416240	2360400	Internal floa	1951	9557.9004	55.1577	346.56605	33.013599	-122.746	45.566662	Category 1	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
227	KMW123	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	123	Gasoline	1993320	3322200	Internal floa	1952	11855.1	61.4296	385.97356	37.461899	-122.7449	45.567958	Category 1	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
228	KMW124	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	124	Gasoline	2036160	3393600	Internal floa	1952	13821.9	66.329903	416.76307	32.8218	-122.7454	45.566743	Category 1	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
232	KMW128	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	128	Gasoline	1408680	2347800	Internal floa	1953	7758.3398	49.694698	312.241	40.453999	-122.7453	45.567578	Category 1	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
236	KMW134	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	134	Gasoline	1418760	2364600	Internal floa	1955	9553.7402	55.145699	346.49064	33.0867	-122.7457	45.567151	Category 1	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
238	KMW138	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	138	Avgas	343098	571830	Internal floa	1956	2069.01	25.662901	161.24476	36.946602	-122.7457	45.566167	Category 2	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
249	KMW152	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	152	Ethanol	287280	47800	Internal floa	1964	1770.41	23.739	149.15654	3.6093099	-122.7446	45.566407	Category 2	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
269	KMW173	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	173	Jet A	29988	49980	Vertical fixe	1972	0	0	0	0	0	0	Category 3	Yes	Pre-1993 or	No Data	Tank Failure	Flammable
281	KMW2	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	2	Jet A	1905120	3175200	Vertical fixe	1915	12419.4	62.8746	395.05276	34.177502	-122.7438	45.565383	Category 3	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
311	KMW52	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	52	Jet A	1937880	3229800	Vertical fixe	1923	10887.1	58.868301	369.88045	39.658199	-122.7434	45.565822	Category 3	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
312	KMW54	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	54	Diesel	2061360	3435600	Vertical fixe	1929	4297.3198	36.984901	232.38299	106.875	-122.7431	45.566148	Category 3	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
322	KMW65	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	65	Jet A	516802	861336	Vertical fixe	1930	0	0	0	0	0	0	Category 3	Yes	Pre-1993 or	No Data	Tank Failure	Flammable
324	KMW69	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	69	Jet A	2058840	3431400	Vertical fixe	1937	13583.1	65.754402	413.14709	33.770901	-122.7423	45.565266	Category 3	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
326	KMW70	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	70	Jet A	876960	1461600	Vertical fixe	1938	4865.6099	39.3545	247.27161	40.157002	-122.7425	45.5649	Category 3	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
327	KMW71	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	71	Transmix	517356	862260	Vertical fixe	1937	2432.77	27.8276	174.84597	47.381302	-122.7427	45.566125	Category 2	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
329	KMW73	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	73	Transmix	328028	546714	Vertical fixe	1937	2447.27	27.9104	175.36622	29.864	-122.7428	45.565193	Category 2	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
337	KMW84	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	84	Gasoline	1413720	2356200	Internal floa	1948	8923.8096	53.2967	334.87304	35.296501	-122.7445	45.566047	Category 1	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
338	KMW85	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	85	Diesel	1408680	2347800	Vertical fixe	1948	7903.8901	50.1586	315.15578	39.709099	-122.7442	45.566388	Category 3	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
365	MC4	McCall	McCall Portland Terminal	MC	4	Bunker	3629766	9357936	Cone roof	1976	32350.699	101.477	637.59878	38.6693	-122.7345	45.563216	Category 2	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
368	MC7	McCall	McCall Portland Terminal	MC	7	Diesel	480942	2658726	Internal floa	1978	9039.71	53.641701	337.04075	39.317799	-122.7357	45.563768	Category 3	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
369	MC8	McCall	McCall Portland Terminal	MC	8	Diesel	369348	2680482	Internal floa	1977	8936.2598	53.3339	335.10678	40.0984	-122.7353	45.563462	Category 3	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
380	NU2020	NuStar	Nustar Portland Terminal	NU	2020	Gasoline	750960	821940	Internal floa	1935	2986.05	30.83	193.7106	36.797001	-122.7767	45.591251	Category 1	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
381	NU2021	NuStar	Nustar Portland Terminal	NU	2021	Gasoline	743148	832032	Internal floa	1935	2953.3601	30.660801	192.64749	37.661099	-122.7765	45.591433	Category 1	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
382	NU2022	NuStar	Nustar Portland Terminal	NU	2022	Gasoline	751748	832032	Internal floa	1935	3323.05	32.523201	204.3493	33.471298	-122.7764	45.591619	Category 1	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
389	NU2705	NuStar	Nustar Portland Terminal	NU	2705	Diesel	981246	1158532	Internal floa	1980	4338.5898	37.161999	233.49572	35.6968	-122.7737	45.588845	Category 3	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
392	NU3201	NuStar	Nustar Portland Terminal	NU	3201	Ethanol	1264793	1264793	Internal floa	1979	4008.3401	35.7197	224.43349	42.181702	-122.7741	45.589769	Category 2	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
395	NU3510	NuStar	Nustar Portland Terminal	NU	3510	Ethanol	1172430	1456019	Internal floa	1937	5692.1699	42.566101	267.4507	34.194698	-122.7788	45.592887	Category 2	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
401	NU5618	NuStar	Nustar Portland Terminal	NU	5618	Gasoline	2142294	2220204	Internal floa	1958	8305.7305	51.4179	323.06819	35.734299	-122.7768	45.591872	Category 1	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
402	NU5901	NuStar	Nustar Portland Terminal	NU	5901	Gasoline	2032182	2414958	Internal floa	1929	9201.9902	54.120998	340.05226	35.083099	-122.7779	45.592213	Category 1	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
403	NU5902	NuStar	Nustar Portland Terminal	NU	5902	Diesel	2006802	2386734	Internal floa	1929	9177.79	54.049801	339.60491	34.7645	-122.7782	45.592457	Category 3	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
404	NU5919	NuStar	Nustar Portland Terminal	NU	5919	Diesel	2259642	2147688	Cone	1935	10791.8	58.6101	368.25812	26.604	-122.777	45.591548	Category 3	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
408	NU8007	NuStar	Nustar Portland Terminal	NU	8007	Gasoline	2662044	3338748	Internal floa	1953	12047.4	61.9258	389.09128	37.0476	-122.7753	45.590229	Category 1	Yes	Pre-1993 or	Material in Water	Tank Failure	Flammable
417	PH1471	Phillips 66	Phillips 66	PH	1471	Hydraulic Tractor Oil	Not listed	17300	Riveted Stee	1921	0	0	0	0	0	0	Category 1	Yes	Pre-1993 or	No Data	Tank Failure	Flammable
418	PH2561	Phillips 66	Phillips 66	PH	2561	Marine Fuel Oil	Not listed	1569582	Riveted Stee	1929	5733.29	42.719601	268.41517	36.597401	-122.7407	45.561992	Category 3	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
419	PH2579	Phillips 66	Phillips 66	PH	2579	Hydraulic Tractor Oil	Not listed	1800	Welded Stee	1929	193.702	7.8522201	49.336954	1.24225	-122.7409	45.561412	Category 1	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
420	PH2669	Phillips 66	Phillips 66	PH	2669	Marine Diesel	Not listed	449694	Riveted Stee	1931	2692.1299	29.273399	183.93019	22.330099	-122.7409	45.561772	Category 4	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
424	PH2784	Phillips 66	Phillips 66	PH	2784	Diesel #2	Not listed	1439130	Riveted Stee	1937	6162.3198	44.2892	278.27725	31.2195	-122.7406	45.561581	Category 3	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
425	PH2915	Phillips 66	Phillips 66	PH	2915	Unleaded Gasoline	Not listed	3262056	Welded Stee	1938	12501	63.080898	396.34897	34.883202	-122.7403	45.56275	Category 2	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
426	PH2916	Phillips 66	Phillips 66	PH	2916	Diesel #2	Not listed	1652196	Welded Stee	1938	5695.3398	42.577999	267.52546	38.7803	-122.7399	45.563121	Category 3	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
428	PH2982	Phillips 66	Phillips 66	PH	2982	Diesel #1	Not listed	416262	Welded Stee	1941	2254.1599	26.7866	168.30517	24.6861	-122.7403	45.56314	Category 3	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
430	PH3407	Phillips 66	Phillips 66	PH	3407	Unleaded Gasoline	Not listed	2955540	Welded Stee	1949	13851.3	66.400398	417.20601	28.524401	-122.7399	45.563952	Category 2	Yes	Pre-1993 or	Potentially in Water	Tank Failure	Flammable
431	PH3408	Phillips 66	Phillips 66	PH	3408	Unleaded Gasoline	Not listed	1639680	Welded Stee	1949	7671.2798	49.415001	310.48361	28.573299	-122.7394	45.563619	Category 2	Yes	Pre-1993 or	On Land	Tank Failure	Flammable

Exhibit List 810

FID	TANK_ID	Owner	Facility	Facility_S	Container	Substance	Average_Fi	Capacity_	Containe_1	Year_Built	Area__ft_2	Radius__ft	Perimeter	Height__ft	Longitude	Latitude	Flammabili	Hazardous	Year_cat	damagezone	fail	Concern
432	PH3409	Phillips 66	Phillips 66	PH	3409	Unleaded Gasoline	Not listed	948654	Welded Ste	1949	4178.0601	36.468102	229.13584	30.3531	-122.7396	45.56334	Category 2	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
433	PH3410	Phillips 66	Phillips 66	PH	3410	Ethanol	Not listed	278964	Welded Ste	1949	1225.84	19.753401	124.11428	30.421699	-122.7402	45.563495	Category 2	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
434	PH3411	Phillips 66	Phillips 66	PH	3411	Unleaded Gasoline	Not listed	259350	Welded Ste	1949	1155.14	19.175301	120.48197	30.0138	-122.7401	45.563615	Category 2	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
435	PH3412	Phillips 66	Phillips 66	PH	3412	Diesel #1	Not listed	279426	Welded Ste	1949	1410.63	21.190001	133.1407	26.480301	-122.74	45.563405	Category 3	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
436	PH3413	Phillips 66	Phillips 66	PH	3413	Unleaded Gasoline	Not listed	259560	Welded Ste	1949	979.96503	17.6616	110.97111	35.4076	-122.7399	45.563518	Category 2	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
448	PH3742	Phillips 66	Phillips 66	PH	3742	MP Gear Lube 80/90	Not listed	17500	Welded Ste	1954	114.719	6.04287	37.968472	20.392599	-122.7409	45.560593	Category 1	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
456	PH3761	Phillips 66	Phillips 66	PH	3761	Diesel #2	Not listed	3240342	Welded Ste	1954	12915.1	64.117104	402.85964	33.540001	-122.7385	45.560404	Category 3	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
472	PH4259	Phillips 66	Phillips 66	PH	4259	Transmix	Not listed	205506	Welded Ste	1968	1225.62	19.7516	124.10296	22.415001	-122.7403	45.5637	Category 2	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
480	PH4318	Phillips 66	Phillips 66	PH	4318	Diesel #2	Not listed	1422456	Welded Ste	1973	6588.2402	45.794102	287.73283	28.862801	-122.7388	45.560751	Category 3	Yes	Pre-1993 or	On Land	Tank Failure	Flammable
32	CH1	Chevron	Chevron Willbridge	CH	1	Unleaded Gasoline	3265616	3412315	Internal floa	1997	12260	62.469898	392.50995	37.207298	-122.7414	45.565257	Category 2	Yes	1993 - 2004	Potentially in Water	Tank Failure	Flammable
123	CH3	Chevron	Chevron Willbridge	CH	3	Unleaded Gasoline	2056421	2392178	Fixed Roof	1999	8141.1099	50.9058	319.85057	39.280701	-122.7418	45.564876	Category 2	Yes	1993 - 2004	On Land	No Tank Failure	Flammable
138	CH45	Chevron	Chevron Willbridge	CH	45	Ethanol	803510	958693	Fixed Roof	1999	3441.5701	33.098099	207.96149	37.238499	-122.7414	45.564484	Category 2	Yes	1993 - 2004	On Land	No Tank Failure	Flammable
143	CH51	Chevron	Chevron Willbridge	CH	51	Ethanol	2366078	2613405	Fixed Roof	2000	7943.1401	50.283001	315.93741	43.982899	-122.7411	45.564223	Category 2	Yes	1993 - 2004	On Land	No Tank Failure	Flammable
147	CH60	Chevron	Chevron Willbridge	CH	60	Unleaded Gasoline	4625739	4999697	Fixed Roof	2001	12515.9	63.118401	396.58461	53.401199	-122.742	45.563315	Category 2	Yes	1993 - 2004	On Land	No Tank Failure	Flammable
149	CH62	Chevron	Chevron Willbridge	CH	62	Unleaded Gasoline	6054327	6812135	Fixed Roof	2000	19337	78.454803	492.94607	47.0938	-122.7415	45.563859	Category 2	Yes	1993 - 2004	On Land	No Tank Failure	Flammable
209	KML72021	Kinder Morgan	Kinder Morgan Linnton Terminal	KML	72021	Diesel	1705378	2842297	Vertical fixe	2011	10371.9	57.4585	361.0224	36.633701	-122.7875	45.603365	Category 3	Yes	Post 2004	Material in Water	No Tank Failure	Flammable
224	KMW12001	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	12001	Jet A	3024000	5040000	Internal floa	2012	19337	78.454803	492.94607	34.842602	-122.7421	45.565693	Category 3	Yes	Post 2004	On Land	No Tank Failure	Flammable
225	KMW12002	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	12002	Diesel	3024000	5040000	Internal floa	2012	8141.1099	50.9058	319.85057	82.7593	-122.7428	45.565734	Category 3	Yes	Post 2004	On Land	No Tank Failure	Flammable
226	KMW12003	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	12003	Gasoline	3024000	5040000	Internal floa	2012	10881.1	58.8521	369.77865	61.919498	-122.7439	45.566713	Category 1	Yes	Post 2004	On Land	No Tank Failure	Flammable
349	MC15	McCall	McCall Portland Terminal	MC	15	Flux	14560	21840	Cone roof	1986	0	0	0	0	0	0	NA	Yes	Pre-1993 or	No Data	Tank Failure	Hazardous but not Flammable
350	MC16	McCall	McCall Portland Terminal	MC	16	Flux	20132	30198	Cone roof	1989	0	0	0	0	0	0	NA	Yes	Pre-1993 or	No Data	Tank Failure	Hazardous but not Flammable
375	NU1011	NuStar	Nustar Portland Terminal	NU	1011	Ethanol/Gasoline	348510	393149	Internal floa	1980	1332	20.591	129.37707	39.456902	-122.7737	45.589052	NA	Yes	Pre-1993 or	Material in Water	Tank Failure	Hazardous but not Flammable
364	MC33	McCall	McCall Portland Terminal	MC	33	Poly phosphoric acid	4054	5405	Cone roof	2005	0	0	0	0	0	0	NA	Yes	Post 2004	No Data	No Tank Failure	Hazardous but not Flammable
6	BP15	BP	British Petroleum South Tank Farm	BP	15	Biodiesel	743400	804972	Fixed Roof	1943	3310.75	32.463001	203.97105	32.502998	-122.7792	45.593738	Category 3	No	Pre-1993 or	Material in Water	Tank Failure	Flammable Not Hazardous
59	CH129	Chevron	Chevron Willbridge	CH	129	Base Oil	601107	642935	Fixed Roof		1919.3101	24.7171	155.30212	44.7808	-122.7426	45.56357	Category 1	No	Pre-1993 or	On Land	Tank Failure	Flammable Not Hazardous
61	CH130	Chevron	Chevron Willbridge	CH	130	Base Oil	239477	255112	Fixed Roof		860.79303	16.5529	104.00494	39.618801	-122.7424	45.563673	Category 1	No	Pre-1993 or	On Land	Tank Failure	Flammable Not Hazardous
73	CH142	Chevron	Chevron Willbridge	CH	142	Base Oil	607148	648620	Fx	1984	1965.16	25.010599	157.14623	44.1227	-122.742	45.563989	Category 1	No	Pre-1993 or	On Land	Tank Failure	Flammable Not Hazardous
137	CH44	Chevron	Chevron Willbridge	CH	44	Base Oil	771264	835393	Fixed Roof	1920	2612.55	28.8375	181.19135	42.745998	-122.7423	45.563518	Category 1	No	Pre-1993 or	On Land	Tank Failure	Flammable Not Hazardous
155	CH76	Chevron	Chevron Willbridge	CH	76	Base Oil	467832	498258	Fixed Roof	1960	1426.89	21.3118	133.90599	46.680302	-122.7415	45.564182	Category 1	No	Pre-1993 or	On Land	Tank Failure	Flammable Not Hazardous
221	KMW117	Kinder Morgan	Kinder Morgan Willbridge Terminal	KMW	117	Biodiesel	340200	567000	Internal floa	1951	2115.3501	25.9487	163.04049	35.832001	-122.7457	45.566373	Category 3	No	Pre-1993 or	On Land	Tank Failure	Flammable Not Hazardous
346	MC10	McCall	McCall Portland Terminal	MC	10	Biodiesel	157248	469392	Internal floa	1974	1780.05	23.803499	149.5618	35.251099	-122.7357	45.564053	Category 3	No	Pre-1993 or	Material in Water	Tank Failure	Flammable Not Hazardous
366	MC5	McCall	McCall Portland Terminal	MC	5	Biodiesel	5000	27216	Cone roof	1974	402.138	11.3139	71.08733	9.0473003	-122.7339	45.563564	Category 3	No	Pre-1993 or	Material in Water	Tank Failure	Flammable Not Hazardous
367	MC6	McCall	McCall Portland Terminal	MC	6	Biodiesel	5000	27216	Cone roof	1974	402.138	11.3139	71.08733	9.0473003	-122.7339	45.56346	Category 3	No	Pre-1993 or	Material in Water	Tank Failure	Flammable Not Hazardous
370	MC9	McCall	McCall Portland Terminal	MC	9	Biodiesel	140658	473004	Cone roof	1979	1604.5699	22.5998	141.99873	39.4072	-122.7341	45.563637	Category 3	No	Pre-1993 or	Material in Water	Tank Failure	Flammable Not Hazardous
383	NU2113	NuStar	Nustar Portland Terminal	NU	2113	Biodiesel	698922	865857	Internal floa	1938	2293.6799	27.020399	169.77417	50.464199	-122.7783	45.593108	Category 3	No	Pre-1993 or	Material in Water	Tank Failure	Flammable Not Hazardous
467	PH4254	Phillips 66	Phillips 66	PH	4254	PS 300	Not listed	459312	Welded Ste	1968	2444.3701	27.8939	175.26254	25.119499	-122.7392	45.560389	Category 1	No	Pre-1993 or	On Land	Tank Failure	Flammable Not Hazardous
468	PH4255	Phillips 66	Phillips 66	PH	4255	Biodiesel	Not listed	404250	Welded Ste	1968	2445.21	27.898701	175.29271	22.100599	-122.739	45.560238	Category 3	No	Pre-1993 or	On Land	Tank Failure	Flammable Not Hazardous
487	PH4332	Phillips 66	Phillips 66	PH	4332	Super ATF	Not listed	17500	Welded Ste	1973	114.719	6.04287	37.968472	20.392599	-122.7406	45.560507	Category 1	No	Pre-1993 or	On Land	Tank Failure	Flammable Not Hazardous
136	CH43	Chevron	Chevron Willbridge	CH	43	Base Oil	770334	837085	Fixed Roof	1993	2761.1101	29.646099	186.27193	40.528	-122.7421	45.563801	Category 1	No	1993 - 2004	On Land	No Tank Failure	Flammable Not Hazardous

Exhibit List 811

Liquefaction

Contents

Soil **liquefaction** is a phenomenon in which the strength and stiffness of a soil is reduced by earthquake shaking or other rapid loading. During strong shaking, water-logged sediments at the Earth's surface temporarily behave like a liquid, causing structures and other objects to shift or sustain major damage. Liquefaction and related phenomena have been responsible for tremendous amounts of damage in historical earthquakes around the world.



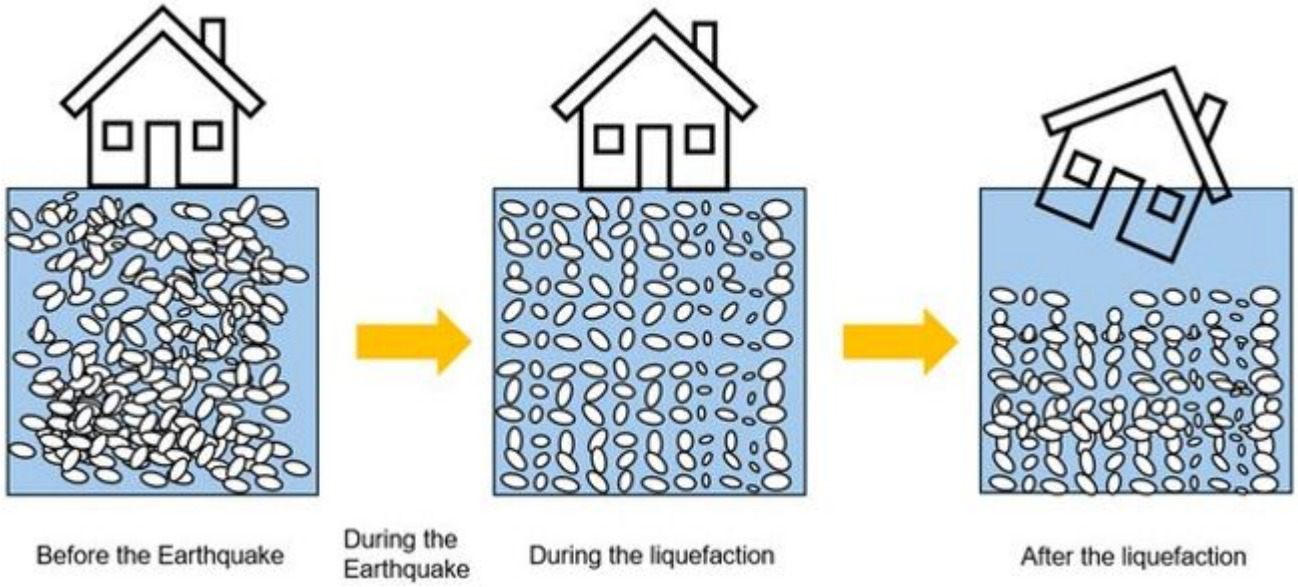
Effects of liquefaction during the 2010 Canterbury earthquake sequence in New Zealand. *Photo from Brett Maurer.*

Liquefaction occurs in saturated soils, where the space between individual soil particles is completely filled with water. Prior to an earthquake, the water pressure within t
relatively low and the weight of the buried soil rests on the framework of grai

Feedback

Exhibit List 812

comprise it. However, earthquake shaking can disrupt the soil structure, so that the soil particles no longer support all the weight and the groundwater pressure begins to rise. The soil particles can move farther, become entrained in the water, and the “liquefied” soil begins to flow. Liquefied soil will force open ground cracks in order to escape to the surface. The ejected material often results in sand boils or flooding and may leave cavities in the soil. Once shaking stops, the soil re-solidifies, locking tilted structures into place.



Liquefaction results from the reorganization of water-logged sediments during an earthquake. *From Cong and Inazumi (2024).*

Whether and where liquefaction will take place depends on many factors. These include: the degree of soil saturation; local grain size distribution and consistency at a site; the strength, duration, and frequency content of the shaking; and even the grain shape and depth of soil. Liquefaction susceptibility is generally highest in places where the soil is less consolidated or more highly saturated, such as reclaimed land (landfill) or river valleys.

Liquefaction Susceptibility Maps

Areas with a high to moderate susceptibility to liquefaction are often mapped in urban areas. This mapping has been done by various agencies in the Pacific Northwest. Relevant links can be found below.

WASHINGTON: Liquefaction susceptibility maps are available for Washington through the Washington Geologic Survey's Geologic Information Portal, under Earthquakes > Ground

Exhibit List 813

Response > Liquefaction Susceptibility.

OREGON: Liquefaction susceptibility maps are available for Oregon through the Oregon Department of Geology and Mineral Industries (DOGAMI) through their Statewide Geohazards Viewer, under Earthquake Hazard > Liquefaction Susceptibility Map.

Video Examples of Liquefaction

The following videos show examples of liquefaction and resulting damage from the magnitude 6.2 Christchurch, NZ, earthquake on February 22, 2011.



Exhibit List 814

Christchurch Earthquake (22.02.2011) - Liquefaction & Road Dam

VideoMasterNZ

Watch on



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DATA QuickShake Station Map Station List

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Exhibit List 815

pnsn@uw.edu 2066858180

Exhibit List 816

The Wayback Machine - https://web.archive.org/web/20260713193055/https://swap.oregon.gov/conservation-opportunity-area/colum...

COA ID: 006



Geographic boundaries of the COAs () were updated for the 2026 State Wildlife Action Plan and the associated COA () profiles are intended to provide additional information. Content of each COA () profile is being refined and will be updated to reflect current conditions when feasible. Please help us by submitting information on Local Conservation Actions, Plans, or Potential Partners () to: OCS.revision@odfw.oregon.gov (https://web.archive.org/web/20260713193055/mailto:OCS.revision@odfw.oregon.gov).

The Columbia River – Blind Slough Swamp COA () (144 mi^2) is an large area on the lower Columbia River Estuary which extends from just east of Tongue Point upstream to Crims Island. The area includes many islands on the Oregon side of the Columbia River, as well as the Lewis and Clark National Wildlife Refuge and portions of the Julia B. Hanson Refuge for The Columbian White-tailed Deer. This COA () also includes the Blind Slough Swamp Preserve, which has some of the only remaining Sitka spruce swamplands in Oregon. In addition, there are many important tributary streams flowing into the Columbia in this area, including Mary's Creek, Gnat Creek and Big Creek. This area provides critical habitat for many fish and wildlife species including migratory and wintering waterfowl, coho salmon, Columbian white-tailed deer, and many more.

Exhibit List 817

This COA () creates a contiguous chunk of habitat along with the Clatsop State Forest-Jewel Meadows Area and Clatskanie River COAs ().

RECOMMENDED CONSERVATION ACTIONS ()

- Maintain and restore floodplain wetlands, tidal wetlands and bottomland forests.
- Improve fish passage and riparian vegetation in tributary streams.
- Maintain and restore existing habitat and ecological function, ensuring sufficient habitat complexity for wildlife.
- Manage public use and recreation to minimize disturbance to sensitive wildlife.

LOCAL CONSERVATION ACTIONS AND PLANS ()

- **Coastal Multi-Species Conservation and Management Plan**
  (https://web.archive.org/web/20260713193055/https://www.dfw.state.or.us/fish/crp/coastal_multispecies.asp)
- **Important Bird Areas**
  (https://web.archive.org/web/20260713193055/http://netapp.audubon.org/IBA/State/US-OR)
- **National Wildlife Refuge Comprehensive Conservation Plan**
  (https://web.archive.org/web/20260713193055/http://www.fws.gov/pacific/planning/main/docs/WA/docsjbhlc.htm)
- **Oregon Coast Coho Conservation Plan**
  (https://web.archive.org/web/20260713193055/https://www.dfw.state.or.us/fish/crp/coastal_coho_conservation_plan.asp)
- **Oregon Department of Forestry Habitat Conservation Plan**
  (https://web.archive.org/web/20260713193055/https://www.oregon.gov/odf/aboutodf/pages/hcp-initiative.aspx)
- **Private Forest Accord**
  (https://web.archive.org/web/20260713193055/https://www.dfw.state.or.us/habitat/PFA/)
- **Recovery Plan for Lower Columbia River Coho Salmon, Lower Columbia River Chinook Salmon, Columbia River Chum Salmon, and Lower Columbia River Steelhead**
  (https://web.archive.org/web/20260713193055/https://www.fisheries.noaa.gov/resource/document/recovery-plan-lower-columbia-river-coho-salmon-lower-columbia-river-chinook)

POTENTIAL PARTNERS ()

- **Center for Natural Lands Management**
  (https://web.archive.org/web/20260713193055/http://www.spk.usace.army.mil/Portals/12/documents/regulatory/pdf/LandManagement_CostAnalysis.pdf)
- **Columbia Land Trust**
  (https://web.archive.org/web/20260713193055/https://www.columbialandtrust.org/project/columbia-river-the-lower-80/)

Exhibit List 818

- **Columbia River Estuary Study Taskforce**
  (https://web.archive.org/web/20260713193055/https://www.columbiaestuary.org/)
- **Columbia River Inter-Tribal Fish Commission**
  (https://web.archive.org/web/20260713193055/http://www.critfc.org/)
- **Columbia River Keeper**
  (https://web.archive.org/web/20260713193055/http://columbiariverkeeper.org/)
- **Ducks Unlimited**
  (https://web.archive.org/web/20260713193055/http://www.ducks.org/resources/media/Conservation/Reports/State%20Conservation%20Reports/master/oregon.pdf)
- **Lower Columbia Estuary Partnership**
  (https://web.archive.org/web/20260713193055/http://www.estuarypartnership.org/restorationsite/308)
- **National Marine Fisheries Service**
  (https://web.archive.org/web/20260713193055/https://www.fisheries.noaa.gov/contact/west-coast-region)
- **Oregon Department of Forestry**
  (https://web.archive.org/web/20260713193055/https://www.oregon.gov/odf/pages/index.aspx)
- **Oregon Department of State Land**
  (https://web.archive.org/web/20260713193055/https://www.oregon.gov/dsl/pages/default.aspx)
- **Oregon Habitat Joint Venture**
  (https://web.archive.org/web/20260713193055/http://www.pacificbirds.org/PACIFIC-BIRDS-HABITAT-JOINT-VENTURE-PLANS/)
- **Oregon Parks and Recreation Department**
  (https://web.archive.org/web/20260713193055/https://www.oregon.gov/oprd/pages/index.aspx)
- **The Nature Conservancy**
  (https://web.archive.org/web/20260713193055/http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/oregon/placesweprotect/blind-slough-swamp.xml)
- **U.S. Army Corps of Engineers**
  (https://web.archive.org/web/20260713193055/https://www.nwp.usace.army.mil/)
- **U.S. Fish and Wildlife Service**
  (https://web.archive.org/web/20260713193055/https://www.fws.gov/oregonfwo/)

SPECIAL FEATURES ()

General

- This area has some of the only populations of the federally threatened Columbian white-tailed deer (*Odocoileus virginianus leucurus*) in Oregon. This subspecies occurs in small numbers along the Columbia River, utilizing fragmented pockets of lowland and floodplain habitat. Due to the small and isolated nature of the population, this species is extremely vulnerable to population declines from disease, climate change, and continued habitat loss.
- The islands along the Lower Columbia River provide critical habitat for a variety of bird species. These islands provide protected areas for breeding birds during the nesting season, from colonial species such as the

Exhibit List 819

Caspian Tern (*Hydroprogne caspia*) to the federally endangered Streaked horned lark (*Eremophila alpestris strigata*). The Streaked horned lark requires large expanses of open grassland for nesting – habitat which is created post-dredging on many of the Lower Columbia River Estuary islands.

- Many waterfowl and shorebird species rely on the resources available within this COA () during migration and while overwintering. The islands along the Lower Columbia River can host thousands of waterfowl during the fall and winter months, taking advantage of the optimal habitat and food resources available.
- The Blind Swamp Slough (preserved by the North Coast Land Conservancy) contains some incredibly unique habitat, with Sitka spruce swamplands that are over 400-years-old. This is some of the highest quality remaining swampland of its kind in Oregon, and provides critical habitat for a huge variety of fish and wildlife species.
- There has been an emphasis on chum salmon reintroduction/recovery in this area in recent years.
- Land ownership along the Lower Columbia River is largely federal, while inland it is primarily Clatsop State Forest. There are smaller parcels of commercial timber and small private ownership dispersed throughout as well.

Protected Areas

- Blind Slough Swamp Habitat Preserve
- John Day River Marsh Habitat Preserve
- Julia Butler Hansen Refuge for the Columbian White-Tailed Deer
- Lewis and Clark National Wildlife Refuge
- Wolf Bay Habitat Preserve

Previous COA () Associations

- Previously Associated with (2006 COA () IDs)
  - CR ()-02 (Columbia – Clatskanie area)
  - CR ()-03 (Clatskanie River)
- Size Change from 2016 boundaries: – 16.9 mi^2 (11% decrease)

Exhibit List 820

ECOREGIONS



Coast Range

Oregon's Coast Range, known for its dramatic scenery, is extremely diverse, with habitats ranging from open sandy dunes to lush forests and from tidepools to headwater streams. It follows the coastline and extends east through coastal forest to the border of the Willamette Valley and Klamath Mountains ecoregions (https://web.archive.org/web/20260713193055/https://swap.oregon.gov/ecoregion/coast-range/)

KEY HABITATS

Exhibit List 821



Estuaries

Estuaries are broadly defined as partially enclosed coastal bodies of tidally influenced water with one or more inputs of freshwater, and with a free or intermittent connection to the open sea. Estuaries typically occur at locations where freshwater from rivers, streams, or creeks meets saltwater from the nearshore ocean, creating a tidal basin that experiences frequent …

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/key-habitat/estuaries/)



Grasslands

Grasslands include a variety of upland grass-dominated habitats, such as upland prairies, coastal bluffs, and montane grasslands.

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/key-habitat/grasslands/)



Late Successional Mixed Conifer Forests

Late successional mixed conifer forests provide a multi-layered tree canopy, including large-diameter trees, shade-tolerant tree species in the understory, and a high volume of dead wood, such as snags and logs.

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/key-habitat/late-successional-mixed-conifer-forests/)

Exhibit List 822



Natural Lakes

Natural lakes are relatively large bodies of freshwater surrounded by land that were formed through geological processes, such as glacial scouring, tectonic movements, volcanic activity and river meander cutoffs. In Oregon, natural lakes are defined as standing water bodies larger than 20 acres, including some seasonal lakes. Depth is not a reference for characterization of …
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/key-habitat/natural-lakes/)



Flowing Water and Riparian Habitats

Flowing Water and Riparian Habitats include all naturally occurring flowing freshwater streams and rivers throughout Oregon as well as the adjacent riparian habitat.
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/key-habitat/riparian-habitats-and-flowing-water/)



Wetlands

Wetlands are habitats that are inundated or saturated by surface water or ground water at a frequency and duration sufficient to support vegetation typically adapted for life in sodden soil conditions. While dominated by periods of inundation, the natural ecological cycle may also include dry intervals. Permanently wet habitats include backwater sloughs, oxbow lakes, peatlands, …
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/key-habitat/wetlands/)

SPECIES OF GREATEST CONSERVATION NEED

Exhibit List 823



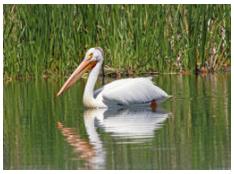
American Avocet (Observed)

Recurvirostra americana (https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/american-avocet/)



American Goshawk (Observed and Modeled)

Astur atricapillus (https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/american-goshawk/)



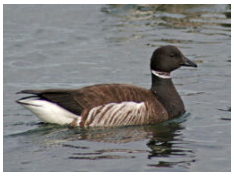
American White Pelican (Observed and Modeled)

Pelecanus erythrorhynchos (https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/american-white-pelican/)



Black Oystercatcher (Modeled)

Haematopus bachmani (https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/black-oystercatcher/)



Brant (Modeled)

Branta bernicla (https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/brant/)



California Brown Pelican (Modeled)

Pelecanus occidentalis californicus (https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/california-brown-pelican/)



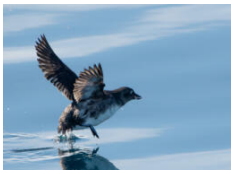
California Myotis (Modeled)

Myotis californicus (https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/california-myotis/)



Caspian Tern (Observed and Modeled)

Hydroprogne caspia (https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/caspian-tern/)



Cassin's Auklet (Modeled)

Ptychoramphus aleuticus (https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/cassins-auklet/)



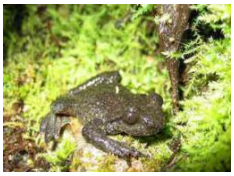
Chipping Sparrow (Observed)

Spizella passerina (https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/chipping-sparrow/)



Coastal Cutthroat Trout (Modeled)

Oncorhynchus clarki clarki (https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/coastal-cutthroat-trout/)



Coastal Tailed Frog (Observed and Modeled)

Ascaphus truei (https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/coastal-tailed-frog/)

Exhibit List 824



Columbia Pebblesnail **(Observed)**

Fluminicola fuscus

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/columbia-pebblesnail/)



Columbia Torrent Salamander **(Observed and Modeled)**

Rhyacotriton kezeri

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/columbia-torrent-salamander/)



Columbian White-tailed Deer **(Observed and Modeled)**

Odocoileus virginianus leucurus

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/columbia-white-tailed-deer/)



Common Nighthawk **(Observed and Modeled)**

Chordeiles minor

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/common-nighthawk/)



Cope's Giant Salamander **(Modeled)**

Dicamptodon copei

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/copes-giant-salamander/)



Eulachon **(Observed and Modeled)**

Thaleichthys pacificus

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/eulachon-southern-dps/)



Ferruginous Hawk **(Observed)**

Buteo regalis

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/ferruginous-hawk/)



Fork-tailed Storm-Petrel **(Modeled)**

Hydrobates furcatus

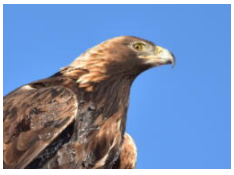
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/fork-tailed-storm-petrel/)



Fringed Myotis **(Modeled)**

Myotis thysanodes

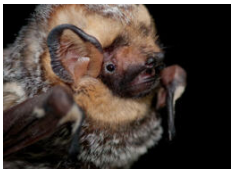
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/fringed-myotis/)



Golden Eagle **(Observed and Modeled)**

Aquila chrysaetos

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/golden-eagle/)



Hoary Bat **(Modeled)**

Lasiurus cinereus

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/hoary-bat/)



Leach's Storm-Petrel **(Modeled)**

Hydrobates

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/leachs-storm-petrel/)

Exhibit List 825



Leatherback Sea Turtle (Modeled)

Dermochelys coriacea

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/leatherback-sea-turtle/)



Little Brown Myotis (Modeled)

Myotis lucifugus

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/little-brown-myotis/)



Loggerhead Shrike (Observed)

Lanius ludovicianus

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/loggerhead-shrike/)

Long-billed Curlew (Modeled)

Numenius americanus

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/long-billed-curlew/)

Long-legged Myotis (Modeled)

Myotis volans

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/long-legged-myotis/)

Marbled Murrelet (Modeled)

Brachyramphus

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/marbled-murrelet/)

North American Porcupine (Modeled)

Erethizon dorsatum

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/north-american-porcupine/)

Northern Red-legged Frog (Observed and Modeled)

Rana aurora

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/northern-red-legged-frog/)

Northern Spotted Owl (Modeled)

Strix occidentalis caurina

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/northern-spotted-owl/)



Northwestern Pond Turtle (Observed and Modeled)

Actinemys marmorata

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/northwestern-pond-turtle/)

Olive-sided Flycatcher (Observed and Modeled)

Contopus cooperi

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/olive-sided-flycatcher/)

Oregon Floater Mussel (Observed)

Anodonta oregonensis

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/oregon-floater-mussel/)

Exhibit List 826



Oregon Vesper Sparrow (Modeled)

Pooecetes gramineus affinis (https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/oregon-vesper-sparrow/)

Pacific Brook Lamprey (Modeled)

Occidentis pacifica (https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/pacific-brook-lamprey/)

Pacific Lamprey (Modeled)

Entosphenus tridentatus (https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/pacific-lamprey/)

Pallid Bat (Modeled)

Antrozous pallidus (https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/pallid-bat/)

Red-necked Grebe (Holboell) (Modeled)

Podiceps grisegena holbollii (https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/red-necked-grebe/)

Rhinoceros Auklet (Modeled)

Cerorhinca monocerata (https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/rhinoceros-auklet/)

Rock Sandpiper (Modeled)

Calidris ptilocnemis tschuktschorum (https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/rock-sandpiper/)

Short-eared Owl (Observed and Modeled)

Asio flammeus flammeus (https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/short-eared-owl/)

Silver-haired Bat (Modeled)

Lasionycteris noctivagans (https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/silver-haired-bat/)



Sockeye Salmon (Modeled)

Oncorhynchus nerka (https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/sockeye-salmon/)

Townsend's Big-eared Bat (Modeled)

Corynorhinus townsendii (https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/townsends-big-eared-bat/)

Trumpeter Swan (Observed and Modeled)

Cygnus buccinator (https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/trumpeter-swan/)

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Tufted Puffin (Modeled)

Fratercula cirrhata

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/tufted-puffin/)

Western Bluebird (Observed)

Sialia mexicana occidentalis

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/western-bluebird/)

Western Grebe (Observed and Modeled)

Aechmophorus occidentalis

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/western-grebe/)



Western Long-eared Myotis (Modeled)

Myotis evotis

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/western-long-eared-myotis/)

Western Meadowlark (Observed and Modeled)

Sturnella neglecta

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/western-meadowlark/)

Western Painted Turtle (Observed and Modeled)

Chrysemys picta belli

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/western-painted-turtle/)



Western Pearlshell Mussel (Observed)

Margaritifera falcata

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/western-pearlshell-mussel/)

Western Purple Martin (Modeled)

Progne subis arboricola

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/western-purple-martin/)

Western River Lamprey (Modeled)

Occidentis ayresii

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/western-

Western Snowy Plover (Modeled)

Anarhynchus nivosus nivosus

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/western-snowy-plover/)

White-breasted Nuthatch (Pacific) (Modeled)

Sitta carolinensis aculeata

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/white-breasted-nuthatch/)

Willet (Modeled)

Tringa semipalmata inornata

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/willet/)

Exhibit List 828

Willow Flycatcher (Observed and Modeled)

Empidonax traillii (https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/willow-flycatcher/)

Winged Floater Mussel (Observed)

Anodonta nuttalliana (https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/winged-floater-mussel/)

Wrentit (Observed and Modeled)

Chamaea fasciata (https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/wrentit/)



Yuma Myotis (Modeled)

Myotis yumanensis (https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/yuma-myotis/)

Exhibit List 829

The Wayback Machine - https://web.archive.org/web/20260713193055/https://swap.oregon.gov/conservation-opportunity-area/colum...

COA ID: 006



Geographic boundaries of the COAs () were updated for the 2026 State Wildlife Action Plan and the associated COA () profiles are intended to provide additional information. Content of each COA () profile is being refined and will be updated to reflect current conditions when feasible. Please help us by submitting information on Local Conservation Actions, Plans, or Potential Partners () to: OCS.revision@odfw.oregon.gov (https://web.archive.org/web/20260713193055/mailto:OCS.revision@odfw.oregon.gov).

The Columbia River – Blind Slough Swamp COA () (144 mi^2) is an large area on the lower Columbia River Estuary which extends from just east of Tongue Point upstream to Crims Island. The area includes many islands on the Oregon side of the Columbia River, as well as the Lewis and Clark National Wildlife Refuge and portions of the Julia B. Hanson Refuge for The Columbian White-tailed Deer. This COA () also includes the Blind Slough Swamp Preserve, which has some of the only remaining Sitka spruce swamplands in Oregon. In addition, there are many important tributary streams flowing into the Columbia in this area, including Mary's Creek, Gnat Creek and Big Creek. This area provides critical habitat for many fish and wildlife species including migratory and wintering waterfowl, coho salmon, Columbian white-tailed deer, and many more.

Exhibit List 830

This COA () creates a contiguous chunk of habitat along with the Clatsop State Forest-Jewel Meadows Area and Clatskanie River COAs ().

RECOMMENDED CONSERVATION ACTIONS ()

- Maintain and restore floodplain wetlands, tidal wetlands and bottomland forests.
- Improve fish passage and riparian vegetation in tributary streams.
- Maintain and restore existing habitat and ecological function, ensuring sufficient habitat complexity for wildlife.
- Manage public use and recreation to minimize disturbance to sensitive wildlife.

LOCAL CONSERVATION ACTIONS AND PLANS ()

- **Coastal Multi-Species Conservation and Management Plan**
  (https://web.archive.org/web/20260713193055/https://www.dfw.state.or.us/fish/crp/coastal_multispecies.asp)
- **Important Bird Areas**
  (https://web.archive.org/web/20260713193055/http://netapp.audubon.org/IBA/State/US-OR)
- **National Wildlife Refuge Comprehensive Conservation Plan**
  (https://web.archive.org/web/20260713193055/http://www.fws.gov/pacific/planning/main/docs/WA/docsjbhlc.htm)
- **Oregon Coast Coho Conservation Plan**
  (https://web.archive.org/web/20260713193055/https://www.dfw.state.or.us/fish/crp/coastal_coho_conservation_plan.asp)
- **Oregon Department of Forestry Habitat Conservation Plan**
  (https://web.archive.org/web/20260713193055/https://www.oregon.gov/odf/aboutodf/pages/hcp-initiative.aspx)
- **Private Forest Accord**
  (https://web.archive.org/web/20260713193055/https://www.dfw.state.or.us/habitat/PFA/)
- **Recovery Plan for Lower Columbia River Coho Salmon, Lower Columbia River Chinook Salmon, Columbia River Chum Salmon, and Lower Columbia River Steelhead**
  (https://web.archive.org/web/20260713193055/https://www.fisheries.noaa.gov/resource/document/recovery-plan-lower-columbia-river-coho-salmon-lower-columbia-river-chinook)

POTENTIAL PARTNERS ()

- **Center for Natural Lands Management**
  (https://web.archive.org/web/20260713193055/http://www.spk.usace.army.mil/Portals/12/documents/regulatory/pdf/LandManagement_CostAnalysis.pdf)
- **Columbia Land Trust**
  (https://web.archive.org/web/20260713193055/https://www.columbialandtrust.org/project/columbia-river-the-lower-80/)

Exhibit List 831

- **Columbia River Estuary Study Taskforce**
  (https://web.archive.org/web/20260713193055/https://www.columbiaestuary.org/)
- **Columbia River Inter-Tribal Fish Commission**
  (https://web.archive.org/web/20260713193055/http://www.critfc.org/)
- **Columbia River Keeper**
  (https://web.archive.org/web/20260713193055/http://columbiariverkeeper.org/)
- **Ducks Unlimited**
  (https://web.archive.org/web/20260713193055/http://www.ducks.org/resources/media/Conservation/Reports/State%20Conservation%20Reports/master/oregon.pdf)
- **Lower Columbia Estuary Partnership**
  (https://web.archive.org/web/20260713193055/http://www.estuarypartnership.org/restorationsite/308)
- **National Marine Fisheries Service**
  (https://web.archive.org/web/20260713193055/https://www.fisheries.noaa.gov/contact/west-coast-region)
- **Oregon Department of Forestry**
  (https://web.archive.org/web/20260713193055/https://www.oregon.gov/odf/pages/index.aspx)
- **Oregon Department of State Land**
  (https://web.archive.org/web/20260713193055/https://www.oregon.gov/dsl/pages/default.aspx)
- **Oregon Habitat Joint Venture**
  (https://web.archive.org/web/20260713193055/http://www.pacificbirds.org/PACIFIC-BIRDS-HABITAT-JOINT-VENTURE-PLANS/)
- **Oregon Parks and Recreation Department**
  (https://web.archive.org/web/20260713193055/https://www.oregon.gov/oprd/pages/index.aspx)
- **The Nature Conservancy**
  (https://web.archive.org/web/20260713193055/http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/oregon/placesweprotect/blind-slough-swamp.xml)
- **U.S. Army Corps of Engineers**
  (https://web.archive.org/web/20260713193055/https://www.nwp.usace.army.mil/)
- **U.S. Fish and Wildlife Service**
  (https://web.archive.org/web/20260713193055/https://www.fws.gov/oregonfwo/)

SPECIAL FEATURES ()

General

- This area has some of the only populations of the federally threatened Columbian white-tailed deer (*Odocoileus virginianus leucurus*) in Oregon. This subspecies occurs in small numbers along the Columbia River, utilizing fragmented pockets of lowland and floodplain habitat. Due to the small and isolated nature of the population, this species is extremely vulnerable to population declines from disease, climate change, and continued habitat loss.
- The islands along the Lower Columbia River provide critical habitat for a variety of bird species. These islands provide protected areas for breeding birds during the nesting season, from colonial species such as the

Exhibit List 832

Caspian Tern (*Hydroprogne caspia*) to the federally endangered Streaked horned lark (*Eremophila alpestris strigata*). The Streaked horned lark requires large expanses of open grassland for nesting – habitat which is created post-dredging on many of the Lower Columbia River Estuary islands.

- Many waterfowl and shorebird species rely on the resources available within this COA () during migration and while overwintering. The islands along the Lower Columbia River can host thousands of waterfowl during the fall and winter months, taking advantage of the optimal habitat and food resources available.
- The Blind Swamp Slough (preserved by the North Coast Land Conservancy) contains some incredibly unique habitat, with Sitka spruce swamplands that are over 400-years-old. This is some of the highest quality remaining swampland of its kind in Oregon, and provides critical habitat for a huge variety of fish and wildlife species.
- There has been an emphasis on chum salmon reintroduction/recovery in this area in recent years.
- Land ownership along the Lower Columbia River is largely federal, while inland it is primarily Clatsop State Forest. There are smaller parcels of commercial timber and small private ownership dispersed throughout as well.

Protected Areas

- Blind Slough Swamp Habitat Preserve
- John Day River Marsh Habitat Preserve
- Julia Butler Hansen Refuge for the Columbian White-Tailed Deer
- Lewis and Clark National Wildlife Refuge
- Wolf Bay Habitat Preserve

Previous COA () Associations

- Previously Associated with (2006 COA () IDs)
    - CR ()-02 (Columbia – Clatskanie area)
    - CR ()-03 (Clatskanie River)
- Size Change from 2016 boundaries: – 16.9 mi^2 (11% decrease)

Exhibit List 833

ECOREGIONS



Coast Range

Oregon's Coast Range, known for its dramatic scenery, is extremely diverse, with habitats ranging from open sandy dunes to lush forests and from tidepools to headwater streams. It follows the coastline and extends east through coastal forest to the border of the Willamette Valley and Klamath Mountains ecoregions (https://web.archive.org/web/20260713193055/https://swap.oregon.gov/ecoregion/coast-range/)

KEY HABITATS

Exhibit List 834



Estuaries

Estuaries are broadly defined as partially enclosed coastal bodies of tidally influenced water with one or more inputs of freshwater, and with a free or intermittent connection to the open sea. Estuaries typically occur at locations where freshwater from rivers, streams, or creeks meets saltwater from the nearshore ocean, creating a tidal basin that experiences frequent …

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/key-habitat/estuaries/)



Grasslands

Grasslands include a variety of upland grass-dominated habitats, such as upland prairies, coastal bluffs, and montane grasslands.

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/key-habitat/grasslands/)



Late Successional Mixed Conifer Forests

Late successional mixed conifer forests provide a multi-layered tree canopy, including large-diameter trees, shade-tolerant tree species in the understory, and a high volume of dead wood, such as snags and logs.

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/key-habitat/late-successional-mixed-conifer-forests/)

Exhibit List 835



Natural Lakes

Natural lakes are relatively large bodies of freshwater surrounded by land that were formed through geological processes, such as glacial scouring, tectonic movements, volcanic activity and river meander cutoffs. In Oregon, natural lakes are defined as standing water bodies larger than 20 acres, including some seasonal lakes. Depth is not a reference for characterization of …
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/key-habitat/natural-lakes/)



Flowing Water and Riparian Habitats

Flowing Water and Riparian Habitats include all naturally occurring flowing freshwater streams and rivers throughout Oregon as well as the adjacent riparian habitat.
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/key-habitat/riparian-habitats-and-flowing-water/)



Wetlands

Wetlands are habitats that are inundated or saturated by surface water or ground water at a frequency and duration sufficient to support vegetation typically adapted for life in sodden soil conditions. While dominated by periods of inundation, the natural ecological cycle may also include dry intervals. Permanently wet habitats include backwater sloughs, oxbow lakes, peatlands, …
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/key-habitat/wetlands/)

SPECIES OF GREATEST CONSERVATION NEED

Exhibit List 836



American Avocet (Observed)

Recurvirostra americana

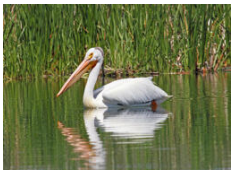
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/american-avocet/)



American Goshawk (Observed and Modeled)

Astur atricapillus

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/american-goshawk/)



American White Pelican (Observed and Modeled)

Pelecanus erythrorhynchos

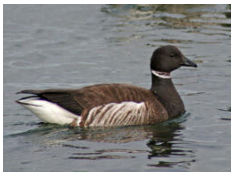
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/american-white-pelican/)



Black Oystercatcher (Modeled)

Haematopus bachmani

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/black-oystercatcher/)



Brant (Modeled)

Branta bernicla

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/brant/)



California Brown Pelican (Modeled)

Pelecanus occidentalis californicus

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/california-brown-pelican/)



California Myotis (Modeled)

Myotis californicus

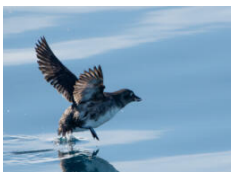
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/california-myotis/)



Caspian Tern (Observed and Modeled)

Hydroprogne caspia

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/caspian-tern/)



Cassin's Auklet (Modeled)

Ptychoramphus aleuticus

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/cassins-auklet/)



Chipping Sparrow (Observed)

Spizella passerina

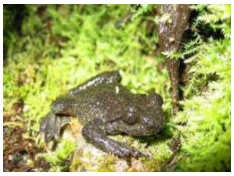
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/chipping-sparrow/)



Coastal Cutthroat Trout (Modeled)

Oncorhynchus clarki clarki

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/coastal-cutthroat-trout/)



Coastal Tailed Frog (Observed and Modeled)

Ascaphus truei

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/coastal-tailed-frog/)

Exhibit List 837



Columbia Pebblesnail **(Observed)**

Fluminicola fuscus

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/columbia-pebblesnail/)



Columbia Torrent Salamander **(Observed and Modeled)**

Rhyacotriton kezeri

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/columbia-torrent-salamander/)



Columbian White-tailed Deer **(Observed and Modeled)**

Odocoileus virginianus leucurus

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/columbia-white-tailed-deer/)



Common Nighthawk **(Observed and Modeled)**

Chordeiles minor

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/common-nighthawk/)



Cope's Giant Salamander **(Modeled)**

Dicamptodon copei

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/copes-giant-salamander/)



Eulachon **(Observed and Modeled)**

Thaleichthys pacificus

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/eulachon-southern-dps/)



Ferruginous Hawk **(Observed)**

Buteo regalis

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/ferruginous-hawk/)



Fork-tailed Storm-Petrel **(Modeled)**

Hydrobates furcatus

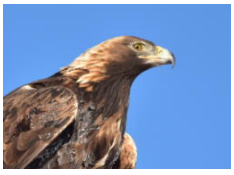
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/fork-tailed-storm-petrel/)



Fringed Myotis **(Modeled)**

Myotis thysanodes

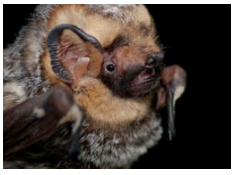
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/fringed-myotis/)



Golden Eagle **(Observed and Modeled)**

Aquila chrysaetos

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/golden-eagle/)



Hoary Bat **(Modeled)**

Lasiurus cinereus

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/hoary-bat/)



Leach's Storm-Petrel **(Modeled)**

Hydrobates leucorhoa

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/leachs-storm-petrel/)

Exhibit List 838



Leatherback Sea Turtle (Modeled)

Dermochelys coriacea

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/leatherback-sea-turtle/)



Little Brown Myotis (Modeled)

Myotis lucifugus

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/little-brown-myotis/)



Loggerhead Shrike (Observed)

Lanius ludovicianus

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/loggerhead-shrike/)



Long-billed Curlew (Modeled)

Numenius americanus

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/long-billed-curlew/)



Long-legged Myotis (Modeled)

Myotis volans

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/long-legged-myotis/)

Marbled Murrelet (Modeled)

Brachyramphus

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/marbled-murrelet/)



North American Porcupine (Modeled)

Erethizon dorsatum

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/north-american-porcupine/)



Northern Red-legged Frog (Observed and Modeled)

Rana aurora

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/northern-red-legged-frog/)



Northern Spotted Owl (Modeled)

Strix occidentalis caurina

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/northern-spotted-owl/)



Northwestern Pond Turtle (Observed and Modeled)

Actinemys marmorata

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/northwestern-pond-turtle/)



Olive-sided Flycatcher (Observed and Modeled)

Contopus cooperi

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/olive-sided-flycatcher/)



Oregon Floater Mussel (Observed)

Anodonta oregonensis

(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/oregon-floater-mussel/)

Exhibit List 839



Oregon Vesper Sparrow (Modeled)

Pooecetes gramineus affinis
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/oregon-vesper-sparrow/)



Pacific Brook Lamprey (Modeled)

Occidentis pacifica
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/pacific-brook-lamprey/)



Pacific Lamprey (Modeled)

Entosphenus tridentatus
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/pacific-lamprey/)



Pallid Bat (Modeled)

Antrozous pallidus
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/pallid-bat/)



Red-necked Grebe (Holboell) (Modeled)

Podiceps grisegena holbollii
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/red-necked-grebe/)



Rhinoceros Auklet (Modeled)

Cerorhinca monocerata
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/rhinoceros-auklet/)



Rock Sandpiper (Modeled)

Calidris ptilocnemis tschuktschorum
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/rock-sandpiper/)



Short-eared Owl (Observed and Modeled)

Asio flammeus
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/short-eared-owl/)



Silver-haired Bat (Modeled)

Lasionycteris noctivagans
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/silver-haired-bat/)



Sockeye Salmon (Modeled)

Oncorhynchus nerka
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/sockeye-salmon/)



Townsend's Big-eared Bat (Modeled)

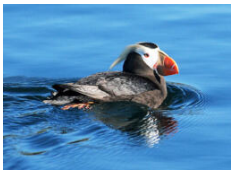
Corynorhinus townsendii
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/townsends-big-eared-bat/)



Trumpeter Swan (Observed and Modeled)

Cygnus buccinator
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/trumpeter-swan/)

Exhibit List 840



Tufted Puffin (Modeled)

Fratercula cirrhata
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/tufted-puffin/)



Western Bluebird (Observed)

Sialia mexicana occidentalis
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/western-bluebird/)



Western Grebe (Observed and Modeled)

Aechmophorus occidentalis
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/western-grebe/)



Western Long-eared Myotis (Modeled)

Myotis evotis
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/western-long-eared-myotis/)



Western Meadowlark (Observed and Modeled)

Sturnella neglecta
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/western-meadowlark/)



Western Painted Turtle (Observed and Modeled)

Chrysemys picta belli
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/western-painted-turtle/)



Western Pearlshell Mussel (Observed)

Margaritifera falcata
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/western-pearlshell-mussel/)



Western Purple Martin (Modeled)

Progne subis arboricola
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/western-purple-martin/)



Western River Lamprey (Modeled)

Occidentis ayresii
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/western-



Western Snowy Plover (Modeled)

Anarhynchus nivosus nivosus
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/western-snowy-plover/)



White-breasted Nuthatch (Pacific) (Modeled)

Sitta carolinensis aculeata
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/white-breasted-nuthatch/)



Willet (Modeled)

Tringa semipalmata inornata
(https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/willet/)

Exhibit List 841



Willow Flycatcher (Observed and Modeled)

Empidonax traillii (https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/willow-flycatcher/)



Winged Floater Mussel (Observed)

Anodonta nuttalliana (https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/winged-floater-mussel/)



Wrentit (Observed and Modeled)

Chamaea fasciata (https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/wrentit/)



Yuma Myotis (Modeled)

Myotis yumanensis (https://web.archive.org/web/20260713193055/https://swap.oregon.gov/sgcn/yuma-myotis/)