CHAPTER 4 ENVIRONMENTAL HEALTH AND RISK

During the public scoping process for the proposed project, many concerns were raised about the potential for spills, fires, and explosions that could occur during crude-by-rail transport from the mid-continent area to the Shell Puget Sound Refinery (PSR) (Skagit County and Ecology 2015). This chapter investigates the likelihood and potential consequences related to a release of oil into the environment. The intent of this chapter is to inform the public and decision makers about the probabilities and potential impacts of an oil release, and provide information for use in planning and response efforts to minimize impacts.

INTRODUCTION

This chapter presents an analysis of the probability of accidents in Washington State that could result in releases, fires, or explosions from trains transporting crude oil to or from the proposed Shell Puget Sound Refinery (PSR) rail unloading facility. Although the probability of a *rail accident* is low, such an event could occur. Therefore, this chapter also describes the potential consequences of spills, fires, or explosions at various locations along the proposed rail transportation routes.

Rail accidents include derailments, collisions, fire or explosion events, highway-rail incidents, and miscellaneous accidents (e.g., trains striking objects on the track and other impacts). These categories are based on accident reporting data from the Federal Railway Administration (FRA). As used in this EIS, the term "rail accident" follows the FRA definition of an accident, which is a safety-related event involving on-track rail equipment causing monetary damages above a prescribed amount (currently $10,500). The term "accident" is not meant to convey lack of liability or culpability for the event occurring.

The information presented in the following sections is summarized from the detailed analyses provided in Appendix G, Rail Spill Probability and Volume Analysis; Appendix H, Evaluation of Hydrocarbon Releases from Crude-by-Rail Incidents Using Trajectory, Fate, and Effects Modeling; and Appendix I, Dispersion, Fire, and Explosion Analysis. These analyses are intended to inform the public and decision makers about the probabilities and potential impacts of an oil release, and to provide meaningful information for use in planning and response efforts that can minimize impacts.

This chapter focuses on answering the four questions listed below regarding an accident in Washington State. The co-leads chose to limit the probability analysis to Washington State based on two primary considerations: the transfer of track responsibility between BNSF Railway and Montana Rail Link occurs just east of the state border at Sandpoint Junction, Idaho; and the regulatory authority of Washington State.

The analyses of the consequences of a spill, fire, or explosion focus on three locations in the Puget Sound region. These sites were selected to provide a range of scenarios that could occur elsewhere along the rail corridor.

1. *What is the probability of an accident and release of oil from a proposed project train?*

This question focuses on the *probability* of a crude-by-rail accident occurring in Washington State, the likelihood that an accident would result in a release of oil from tank cars or locomotives, and the *frequency* at which releases would be anticipated. A detailed explanation of the methodology and results of the probability analysis conducted for this environmental impact statement (EIS) are presented in Appendix G.

The probability of an accident is a measure of the likelihood that such an event will happen in a given year. The frequency of an accident is the anticipated number of times that such an event will happen over a given period.

2. *What are the potential consequences following an oil spill?*

This question focuses on the *potential consequences* of a release of oil into the environment. The detailed explanation of the methodology and analyses of potential spills prepared for this EIS are provided in Appendix G.

The potential consequences were modeled at three representative locations along the proposed rail transportation route to the Shell PSR: the Swinomish Channel Swing Bridge, the Skagit River Crossing, and the Edmonds Ferry Terminal.

The Swinomish Channel Swing Bridge site was chosen as a representative location for releases into relatively confined saltwater environments with extensive tidal flats and marshy areas. The location is adjacent to the Swinomish Reservation and is in an area with sensitive aquatic receptors such as crabs harvested for human consumption and migratory bird populations).

The Skagit River Crossing site was chosen as a representative location for releases into a freshwater environment with a high potential for extensive oiling of shorelines before entering Skagit Bay. The site also has the potential for oil to sink due to oil interactions with suspended particulate matter and is upstream of a municipal water intake that could be affected.

The potential consequences described in this chapter were estimated by using a computer model to analyze hypothetical, unmitigated releases of oil into the environment. An unmitigated release is one in which no response measures are taken. The consequence analyses for all release scenarios intentionally ignore the potential for emergency response, which would limit the overall impacts to the environment. The estimated potential impacts presented in this chapter are therefore conservatively high.

As described in Chapter 3.17 – Public Services and Incident Response, and outlined below, numerous plans are in place at local, state, and federal levels to respond to oil spills. In the event of an actual release, many of the impacts described in this chapter would be minimized through the use of the procedures outlined in those plans.

The Edmonds Ferry Terminal site was selected as a representative location for releases onto land and into less confined areas within Puget Sound with a high potential for transport of surface oil due to currents, winds, and larger "open water" areas compared with the other sites. The ferry terminal was also chosen for modeling because of its proximity to residential areas, high ferry traffic, and the large influx of tourists during the summer months. These sites were not selected

based on any increased potential for risk, but for their diversity of physical, natural, and social characteristics and due to concerns raised during the EIS scoping process.

The investigation included modeling the variability of environmental conditions that could affect oil trajectory, fate, and potential effects including tides, river flow, and wind conditions. At the Swinomish Channel Swing Bridge, scenarios were modeled in the summer with spring tide conditions, and in the winter with neap tide conditions. The scenarios modeled at the Skagit River Bridge Crossing targeted high river flow (summer) and low river flow (winter) for seasonal conditions. The Skagit River Bridge Crossing was also considered to evaluate a release over freshwater. Factors considered at the Edmonds Ferry Terminal included the summer (low-wind speeds) and the winter (high-wind speeds).

The scenarios modeled at the Skagit River Bridge Crossing used high river flow conditions during the freshet (the flood of a river from heavy rain or snow melt; modeled here during summer) and average low river flow conditions during the winter.

While the variability in certain environmental parameters was targeted for each scenario, it is important to note that seasonally appropriate corresponding values for all modeled environmental parameters (e.g., hydrodynamics, winds, temperature, and concentration of total suspended solids) were characterized at each location based on the identified season. Therefore, seasonally appropriate hydrodynamics would include variability in general circulation, river flows, and tidal fluctuations. For each scenario, this would be coupled with the appropriate temperature, wind speed and direction, and other values for all of the other environmental parameters. Data inputs for the modeling efforts were obtained from independent sources with rigorous quality standards.

The potential consequences of an unmitigated oil release at any one of these locations are intended to be representative of the impacts that could occur if a release were to happen at any point along the proposed train routes. The modeled spill scenarios for each location included two potential release volumes:

- 5,700 barrels (239,400 gallons). The 5,700-barrel release volume corresponds with seven to eight cars rupturing and is slightly above the average release volume from 16 observed crude-by-rail releases that have occurred in the U.S. and Canada between 2013 and 2015.
- 20,000 barrels (840,000 gallons). The 20,000-barrel release volume corresponds with 28 to 30 cars rupturing and is roughly twice the size of the largest observed U.S. crude-by-rail release in Casselton, North Dakota, and about 60 percent of the volume of the largest crude-by-rail release in North America in Lac-Mégantic, Quebec.

These volumes were chosen based on concerns raised during the public scoping process about the potential for a high volume, high consequence release. See Appendix G for a detailed explanation of how distributions of release volumes were modeled. The model results are intended to demonstrate the potential range of impacts that could occur if there were a spill. In addition, the analysis considers the potential consequences of a spill in urban and rural environments. It also looks at potential consequences of a higher probability, lower volume release accident.

3. *What is the probability and what are the potential consequences of a release that results in a fire or explosion?*

A third question focuses on the frequency and potential consequences of a release that results in a fire or explosion. The potential consequences are discussed in detail in Appendix I. Unmitigated accidents resulting in fire and explosions were modeled at the same three locations as the spill analysis to determine the potential consequences. In addition, the analysis considers the potential consequences of a fire and explosion in urban and rural environments, as well as the potential consequences of a higher probability, lower volume release accident.

4. *What are the potential economic consequences of an oil release, fire, or explosion?*

The final question focuses on the potential economic consequences of an oil release, fire, or explosion. The potential consequences are meant to encompass the types of impacts that could occur, rather than offer a complete accounting of all the potential impacts.

Select Laws, Regulations, and Guidance

Select laws, regulations, and guidance applicable to environmental health and risk are summarized in Table 4-1.

Table 4-1 Laws, Regulations, and Guidance for Environmental Health and Risk

Laws, Regulations, and Guidance	Description
Federal	
U.S. Environmental Protection Agency Spill Prevention, Control, and Countermeasure Plan and Facility Response Plan (40 CFR 112)	Provides guidelines for the prevention and response plans for accidental discharges of oils and hazardous substances into the waters of the United States.
U.S. Coast Guard Facility Operations Manual (33 CFR 154, Subpart F)	Establishes oil spill response plan requirements for all marine transportation-related facilities that could reasonably be expected to cause substantial harm or significant and substantial harm to the environment by discharging oil into or on the navigable waters.
Federal Railroad Administration (FRA) General Regulations (49 CFR Parts 200 299)	Established the Surface Transportation Board—an independent adjudicatory and economic-regulatory agency charged by Congress with resolving railroad rate and service disputes and reviewing proposed railroad mergers.
Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (42 USC)	Establishes prohibitions and requirements concerning closed and abandoned hazardous waste sites, provides for liability of persons responsible for releases of hazardous waste at these sites, and establishes a trust fund to provide for cleanup when no responsible party can be identified.

Laws, Regulations, and Guidance	Description
Superfund Amendment and Reauthorization Act (SARA) (40 CFR 302)	Amended CERCLA to stress the importance of permanent remedies and innovative treatment technologies in cleaning up hazardous waste sites. Requires actions to consider the standards and requirements found in other state and federal environmental laws and regulations; provides new enforcement authorities and settlement tools, increases state involvement in every phase of the program and the focus on human health problems posed by hazardous waste sites; encourages greater citizen participation in making decisions on how sites should be cleaned up; and increases the size of the trust fund.
Resource Conservation and Recovery Act (RCRA) (42 USC 6901 et seq.)	Gives the U.S. Environmental Protection Agency (USEPA) the authority to control hazardous waste from the "cradle-to-grave." This includes the generation, transportation, treatment, storage, and disposal of hazardous waste. Also sets forth a framework for the management of non-hazardous solid wastes. This is a delegated Washington State program under the Washington Hazardous Waste Management Act.
Toxic Substances Control Act (15 USC 2601–2629)	Provides USEPA with authority to require reporting, record-keeping and testing requirements, and restrictions relating to chemical substances and/or mixtures.
Occupational Safety and Health Act (OSHA) (29 USC 651 et seq.)	Enacted to "assure safe and healthful working conditions for working men and women." Sets standards and enforces inspections to ensure that employers are providing safe and healthful workplaces.
State	
State Environmental Policy Act (SEPA) (RCW 43.21c; WAC 197-11)	Helps state and local agencies in Washington identify possible environmental impacts that could result from a proposed action, alternatives to the proposed action, and potential impact minimization and mitigation measures. Information learned through the review process can be used to change a proposal to reduce likely impacts and inform permitting decisions at the state and local levels.
Water Pollution Control Act and Water Quality Standards for Groundwaters of the State of Washington (RCW 90.48; WAC-173-200	Maintains the highest possible standards to ensure the purity of all waters of Washington State are consistent with public health and public enjoyment, the propagation and protection of wildlife, birds, game, fish, and other aquatic life and industrial development of the state. To that end, requires the use of all known available and reasonable methods by industries and others to prevent and control the pollution of state waters. Establishes and implements policies to maintain the highest quality of the state's groundwaters and protects existing and future beneficial uses of the groundwater through the reduction or elimination of the discharge of contaminants.

Laws, Regulations, and Guidance	Description
Washington State Oil and Hazardous Substance Spill Prevention and Response (RCW 90.56)	Establishes a comprehensive prevention and response program to protect Washington's waters and natural resources from oil spills. Anyone responsible for spilling oil into state waters is liable for damages resulting from injuries to public resources.
Oil Movement by Rail and Pipeline Notification Rule (WAC 173-185) (Effective October 1, 2016)	Oil Movement by Rail and Pipeline Notification to enhance oil spill preparedness and response in Washington State. It establishes reporting standards for facilities that receive crude oil by rail, and pipelines that transport crude oil in or through the state. Additionally, the rule identifies reporting standards for Ecology to share information with emergency responders, local governments, tribes, and the public.
Oil Spill Contingency Plan – Railroad Rule (WAC 173-186) (Effective October 1, 2016)	These regulations establish oil spill contingency plan, drill and equipment verification requirements, and provisions for inspection of records for owners and operators of railroad required to submit oil spill contingency plans under chapter 90.56 RCW, and for the response contractors that support the implementation of the railroad plans. The rule requires railroads to develop and maintain contingency plans approved by Ecology.
Washington State Hazardous Waste Management Act (RCW 70.105, and WAC 173–303)	Establishes and implements a comprehensive statewide framework for the planning, regulation, control, and management of hazardous waste that will prevent land, air, and water pollution and conserve the natural, economic, and energy resources of the state.
Model Toxics Control Act (MTCA) and Cleanup Regulation (RCW 70.105D; WAC 173-340)	Sets cleanup standards to ensure that the quality of cleanup and protection of human health and the environment are not compromised and requires potentially liable persons to assume responsibility for cleaning up contaminated sites.
Washington State Solid Waste Handling Standards (WAC 173–350)	Sets standards for the proper handling and disposal of solid waste.
Washington State Hazardous Waste Operations (WAC 296–843)	Applies to facilities that have workers handling hazardous waste at a treatment, storage, or disposal facility and are required to have a permit under RCRA. The Shell Puget Sound Refinery has RCRA Permit: WAD 009 276 197.
Oil Spill Natural Resource Damage Assessment (WAC 173-183)	Establishes procedures for convening a resource damage assessment committee, pre-assessment screening of resource damages resulting from oil spills to determine which damage assessment methods to use, and determines damages in cases where the compensation schedule is selected as the damage assessment methodology to apply.

Laws, Regulations, and Guidance	Description
Industry Agreements	
Mutual Aid Agreement for Rail Emergency Response	In 2015, Shell and the other Washington refineries entered into a Mutual Aid Agreement with BNSF Railway to share personnel and resources in the event of a rail accident involving crude oil in Washington State.

PROBABILITY OF AN ACCIDENT AND RELEASE

The probability analysis quantified the likelihood and frequency of a release in Washington State associated with the transport of crude oil by rail for the proposed project, as well as the likelihood of different volumes of oil being released. The probability of a release was calculated for unit trains traveling to and from the Shell PSR considering three possibilities: a release of crude oil from tank cars, a release of diesel fuel from locomotives on a loaded train, and a release of diesel fuel from locomotives transporting unloaded (empty) tank cars.

Typically, crude-by-rail accidents are thought of as releases of crude oil from tank cars. However, smaller spills from locomotives may also occur. The co-lead agencies chose to include analyses of potential spills of diesel from locomotives to address these additional lower volume releases.

The release probability analysis followed the steps presented in Figure 4-1. For each train traveling to or from the Shell PSR, there either would or would not be an accident, and that accident either would or would not result in a release of oil. The geographic area covered in the probability analysis included all BNSF Railway main line routes that would most likely carry crude oil from Sandpoint Junction, Idaho, into Washington State, through the Columbia River corridor, and north to the Shell PSR. Return routes would most likely travel through Stampede Pass, as shown in Figure 4-2.

The probability and spill volume analyses were conducted by performing a Monte Carlo simulation. A Monte Carlo simulation is one that produces distributions of possible outcomes based on variable inputs. It is named after the casino in Monte Carlo because, figuratively speaking, there is a lot of virtual "dice-rolling" involved in its application. A Monte Carlo simulation models the effects of a variety of different probabilities and uncertainties to provide predictions of outcomes. In the case of this analysis, the approach is used to incorporate uncertainties and randomness in input values and probabilities that affect both accident and spill rates to derive predictions of outcomes.

For this analysis, Monte Carlo simulations were conducted using computer models for 100,000 simulations. Each simulation randomly selected values for the variables input into the model. This determines the probability that there will be a rail accident, the probability that the accident will result in a spill, and estimates the number of tank cars (or locomotives) involved, which determines the likelihood of spills of various sizes.

Generally, for a release of crude oil to occur during rail transport, three events need to take place:

- Tank cars on a unit train in transit must be loaded with crude oil.
- An accident (Table 4-2) must occur.
- A breach must occur in at least one tank car.

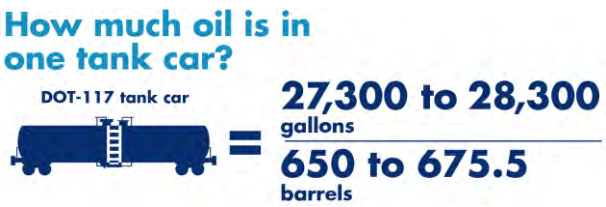
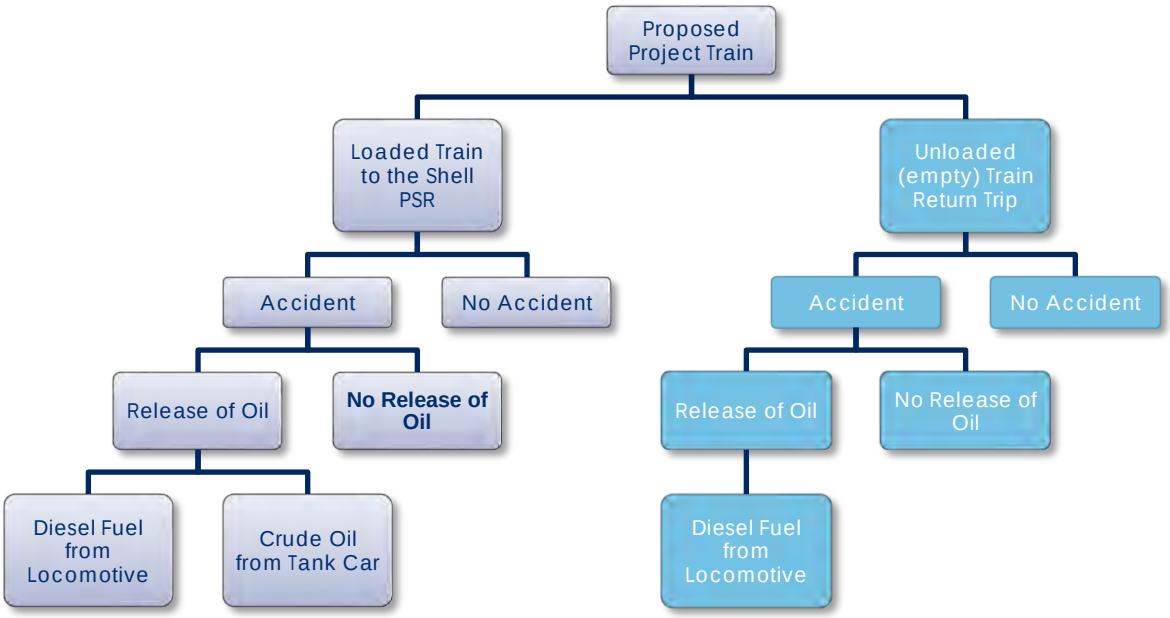


Figure 4-1 Shell PSR Crude-by-Rail Train Event Tree



Diesel fuel could also be released from one or more locomotives that derail or are otherwise damaged in an accident while transporting loaded or unloaded (empty) tank cars.

This analysis considered five different types of rail accidents: derailments, collisions, fire or explosions, highway-rail crossing incidents, and other miscellaneous accidents. There are many causes of different accident types. For example, one of the primary causes of derailments is track conditions, including broken track or welds; one of the primary causes of collisions is human error; and, one of the primary causes of fire and explosion accidents is mechanical or electrical failures. Table 4-2 outlines the accident types and their primary causes.

To determine the probability of an oil release from a proposed project unit train, the analysis considered the following questions:

- What is the probability that an accident could occur?
- If there were an accident, what is the probability of a release of oil?

- If there was a release of oil, how much oil would likely be released?

As described in more detail in Appendix G, to evaluate the potential range of probabilities that may occur from a rail accident and release, the analysis considers:

- High Estimate Evaluation of Accident and Release Rates (High Estimate).
- Low Estimate Evaluation of Accident and Release Rates (Low Estimate).

Table 4-2 Accident Types and their Primary Causes

Accident Type	Description	Primary Causes
Derailment	A derailment occurs when a train runs off of its rails.	Track conditions and mechanical/ electrical failures.
Collision	A collision occurs when a train hits another train or a structure.	Human error.
Fire or Explosion Events	Fire or explosion events include fires, violent ruptures, or detonations resulting in an accident, but do not include accidents in which a spill ignites or explodes after such an occurrence (i.e., a fire that results after a derailment, collision, highway-rail crossing or miscellaneous accident).	Mechanical/ electrical failures.
Highway-Rail Crossing Incidents	A highway-rail incident occurs when a train collides with a highway vehicle at an at-grade crossing.	A vehicle on the tracks at an at-grade crossing.
Miscellaneous Accidents	Miscellaneous accidents include obstruction accidents that occur when a train hits an object on a train right of way, and other accidents that cannot be captured under the other categories.	Human error and mechanical/ electrical failures.

Source: FRA 2016.

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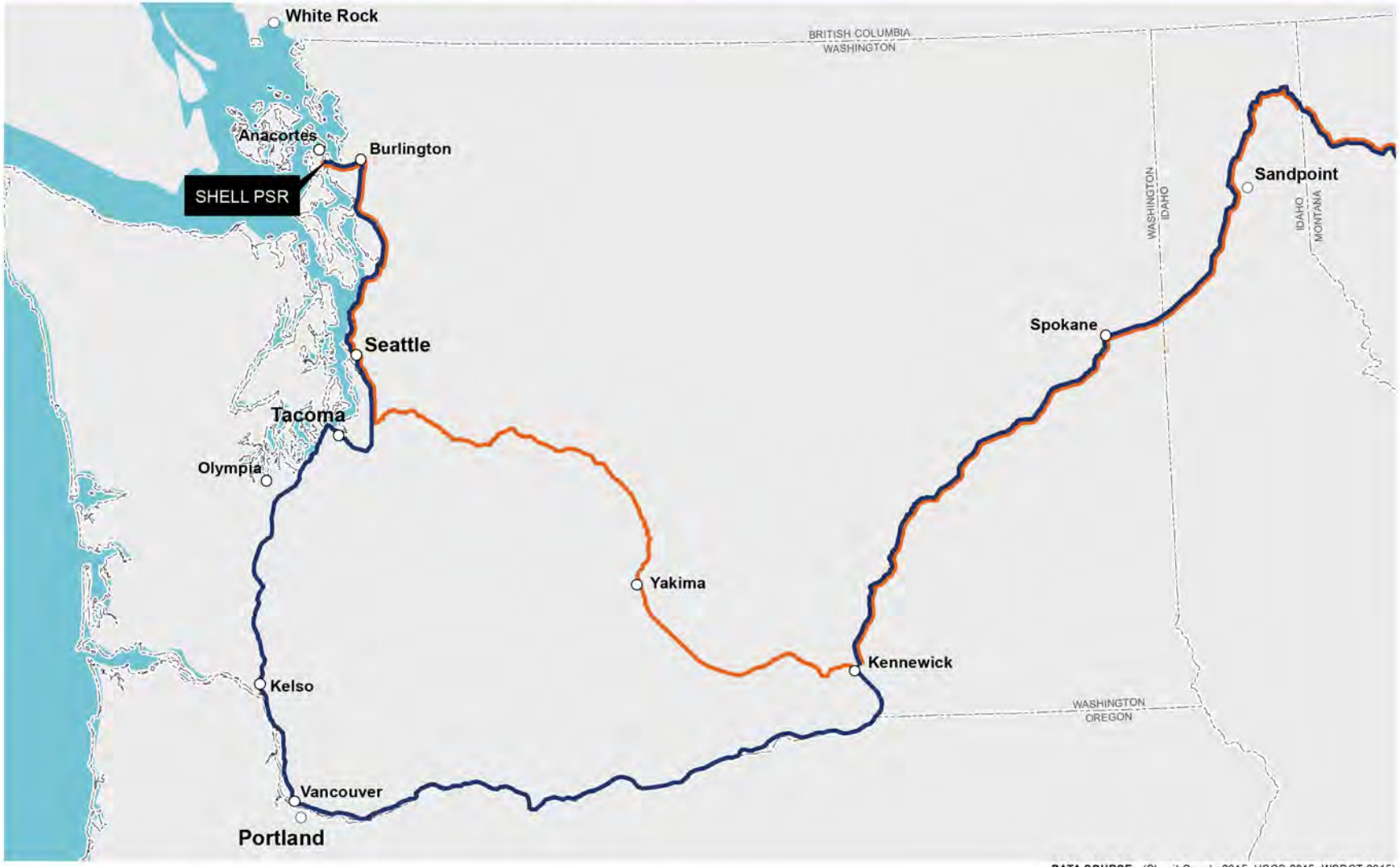


DATA SOURCE: (Skagit County 2015, USGS 2015, WSDOT 2015)

Representative Train Route to Shell PSR
Representative Train Route from Shell PSR
State/Provincial/International Boundary

N

0 25 50 Mile

Figure 4-2
PROPOSED PROJECT RAIL ROUTE THROUGH WASHINGTON STATE

The High Estimate is a purposefully conservative evaluation of the probability of an accident and release occurring based on historic rates of accidents and releases. This conservative estimate includes adjustments to the accident rate based on factors specific to crude-by-rail trains that would increase the likelihood of an accident over historic rates. These adjustments consider increased accident rates associated with sloshing and longer train length. The High Estimate assumes that safety measures (i.e., accident and release reduction measures) would not be in place or would be ineffective. These include some safety measures that are already in place, such as wayside detectors, and some measures that are expected to be implemented within the next year or two, such as positive train control.

The Low Estimate incorporates the various measures specific to crude-by-rail unit trains and for freight traffic in general that have been, or are anticipated to be, implemented to make train transport safer. These include positive train control, enhanced braking, wayside detectors, and track upgrades. Several of these measures would need to be sustained over time for the release rate probabilities to remain constant (e.g., improved track maintenance).

An Introduction to Probability

The probability of an accident occurring is a measure of the likelihood that an event will happen in a given year. The result is reported as either a frequency or a return period. The frequency is the anticipated number of times that that accident will occur over a given period of time.

The return period for a release is directly related to the probability of an accident occurring. The return period is the amount of time, on average, that passes between consecutive accidents of a similar magnitude. Return periods are frequently used with low probability events.

As an example, if an individual were to toss a coin once a minute hoping for "heads," the average frequency of a heads would be one in two tosses or 50 percent. The average return period for "heads" would be the inverse of 1/2, which is 2/1, or 2 minutes.

It is important to note that probabilities are estimates of likelihood and not a true prediction of an event occurring at a specific point in time. While there is a 50/50 chance that "heads" will be thrown with each toss of the coin, it is impossible to predict if the next toss will, in fact, be "heads." It is quite possible to toss 2, 3, or even more "tails" in a row. Furthermore, the likelihood of throwing "heads" on the 4th toss or subsequent tosses would still be 50 percent.

Therefore, when speaking of the frequency or return period, the word "average" is used to describe probability rather than certainty. To clarify, a return period of two years does not mean that an accident will happen every two years. The accident could happen tomorrow, in five years, or, possibly, not at all. However, on average and given a long enough period of time, the frequency of occurrence would average every two years.

When considering extremely low probability events, return periods help frame the likelihood of events with time. For example, it is estimated that more than 100 lightning bolts strike the Earth every second. Even with so many lightning strikes, the odds of being struck by lightning in the U.S. in any one year are roughly 1 in 700,000 years. However, we know that individual people do not live for 700,000 years and that some individuals are unfortunate enough to be struck by lightning. This statistic helps explain that while an event could occur, it is not likely.

In the following sections of this chapter, an overview of the probability analysis and results is presented. Overall, the probability of an accident involving a Shell PSR unit train in Washington State resulting in a release of oil is low. However, should such an accident occur, the consequences could be substantial. Tables 4-3 and 4-4 and Figures 4-3 and 4-4 present a summary of the anticipated release frequencies and return periods (average years between releases) for loaded proposed project trains. These tables also presents the cumulative release frequencies and return periods when project trains are grouped with current and reasonably foreseeable future crude-by-rail train traffic. Because the proposed project would add one train each direction per day in Washington, the probability of an accident and release involving a Shell unit train is low. However, when considered with all other existing and planned crude-by-rail traffic, the overall probability of an accident and release in Washington would be higher.

Table 4-3 Projected Release Frequencies for Loaded Proposed Project Trains in Washington

	Release Size (Barrels [gallons]	Frequency (Releases/Year)	Average Return Period (Years)	**Probability ("Odds") of** a Release in any Given Year
High Estimate Evaluation of Accident and Release Rates	250 (10,500)	0.046	22	1 in 22
	5,700 (239,400)	0.032	31	1 in 31
	20,000 (840,000)	0.0069	140	1 in 140
Low Estimate Evaluation of Accident and Release Rates	250 (10,500)	0.0055	180	1 in 180
	5,700 (239,400)	0.0036	280	1 in 280
	20,000 (840,000)	0.00055	1,800	1 in 1,800

Figure 4-3 Projected Release Frequencies for Loaded Proposed Project Trains in Washington

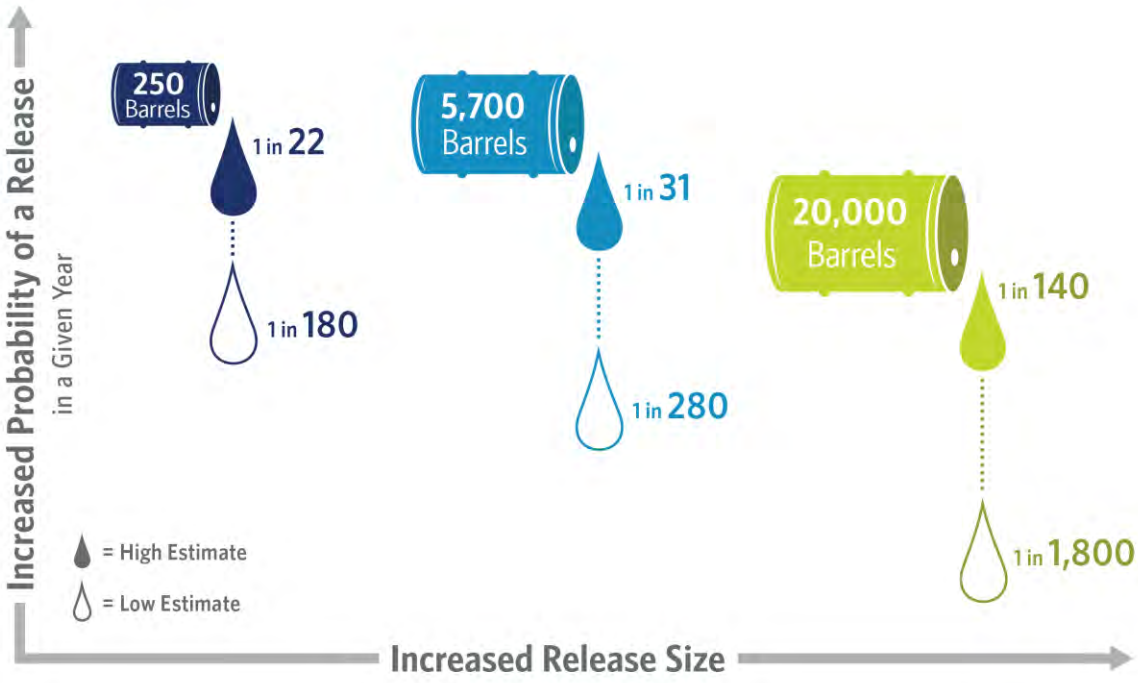
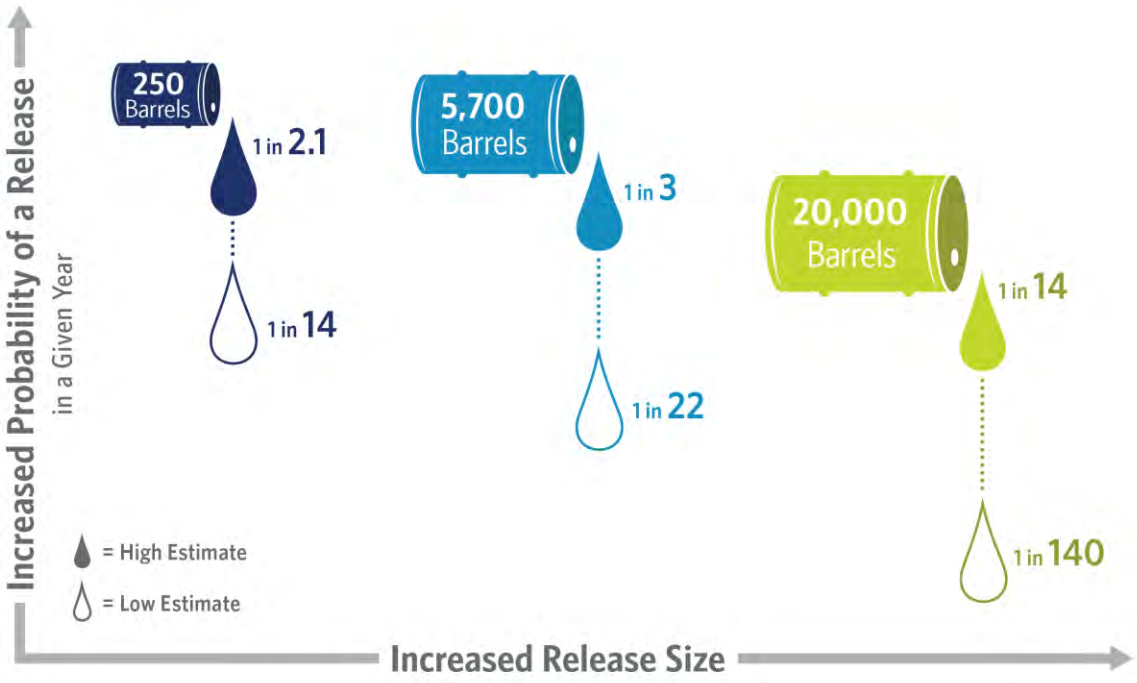


Table 4-4 Projected Cumulative Release Frequencies for Past, Present, and Future Loaded Crude Oil Trains in Washington

	Release Size (Barrels [gallons])	Frequency (Releases/Year)	Average Return Period (Years)	**Probability ("Odds") of** a Release in any Given Year
Cumulative High Estimate Evaluation of Accident and Release Rates	250 (10,500)	0.48	2.1	1 in 2.1
	5,700 (239,400)	0.34	3	1 in 3
	20,000 (840,000)	0.072	14	1 in 14
Cumulative Low Estimate Evaluation of Accident and Release Rates	250 (10,500)	0.069	14	1 in 14
	5,700 (239,400)	0.045	22	1 in 22
	20,000 (840,000)	0.0069	140	1 in 140

Note:
The cumulative low and high estimates assume that all planned crude-by-rail projects in Washington State would be constructed and that currently operating facilities continue to operate at the same level. This would increase the number of weekly crude-by-rail trains in the state from about 21 currently to about 70.

Figure 4-4 Projected Cumulative Release Frequencies for Past, Present, and Future Crude-by-Rail Projects in Washington



High Estimate Evaluation of Accident and Release Rates

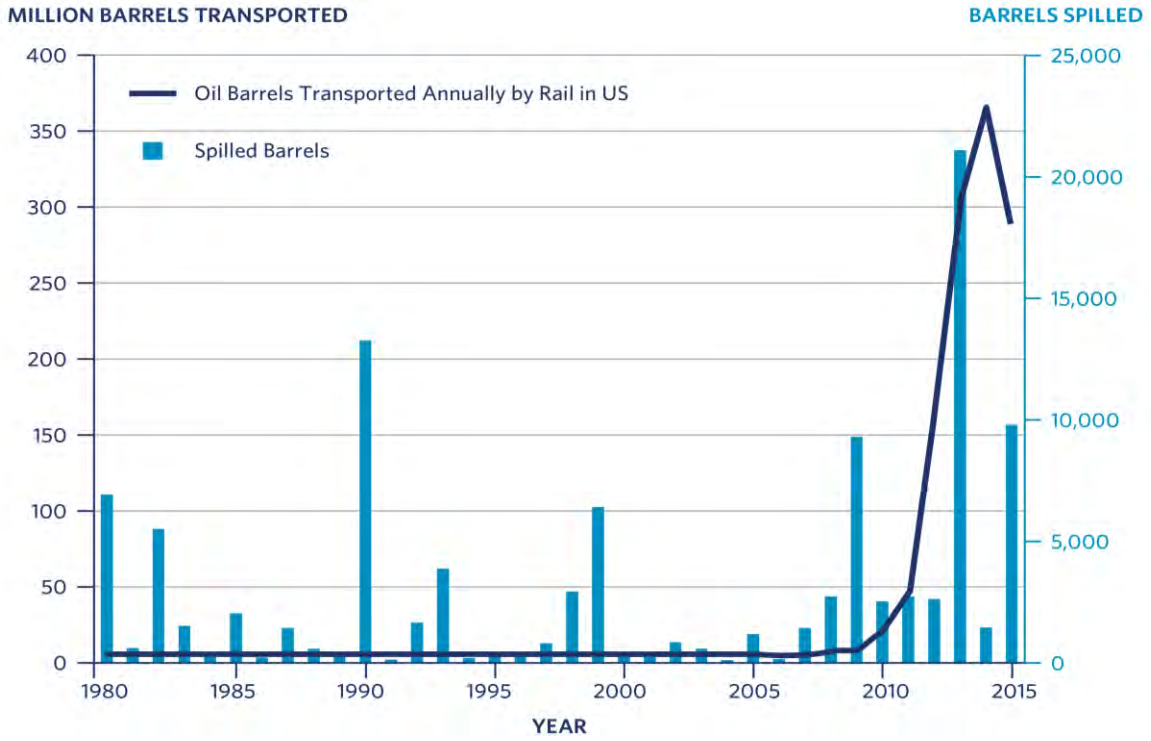
The High Estimate evaluation is based on historic accident data from 1985 to 2004, for freight trains and historic release data from 1985 to 2015, for hazardous materials rail cars. The reason that the 1985 to 2004 accident data time frame was selected is that it provided the higher, most conservative accident rates, while eliminating the much higher accident rates that occurred during 1975 to 1984, when railroad operations were considerably different. The accident rate in the time period for 2005 to 2015 was lower than the previous decades due to the incorporation of some safety measures. However, the time period for release rates (i.e., the probability of a tank car spilling some or all of its contents) was based on a larger time frame because having a larger data set provides a more statistically accurate analysis. The release rate from hazardous materials tank cars was not dependent on any changes in rail operations.

High Estimate Evaluation of a Rail Accident

The widespread transport of crude oil by rail is a relatively recent development, with shipments at the national level increasing from about 25 million barrels in 2010, to more than 350 million barrels in 2014 (Figure 4-5) (AAR 2016). This rapid expansion has led to an increase in the number of accidents that have occurred involving crude-by-rail trains. From 2010 to the present, there have been 36 accidents in North America (25 in the United States) (Figure 4-6), including the June 2016 derailment of a crude-by-rail train in Mosier, Oregon. However, as shown in

Figure 4-7, the number of accidents along the main lines nationwide for all freight traffic (of which crude by rail is only a small subset) has decreased over the past 30 years.

Figure 4-5 Oil Barrel Shipments by Rail 1980–2015



Source: AAR 2016.

Figure 4-6 North American Crude-by-Rail Accidents from 2010 to Present

Note:
The accidents depicted in Figure 4-6 are based on a review of the Pipeline and Hazardous Materials Safety Administration (PHMSA) database of accidents involving crude-by-rail shipments (USDOT 2016). Only those accidents that occurred along the rail line were included (i.e., if a crude-by-rail accident occurred at a receiving facility, it was not included). Further, the PHMSA database includes accidents that were not classified as accidents in the Federal Railway Administration (FRA) database because they did not exceed the monetary damages threshold or did not result in a release of oil. These data are included here to illustrate that crude-by-rail trains can be involved in accidents that do not result in a release of oil; many of these events did not result in a release as further illustrated in Figures 4-8 and 4-9.

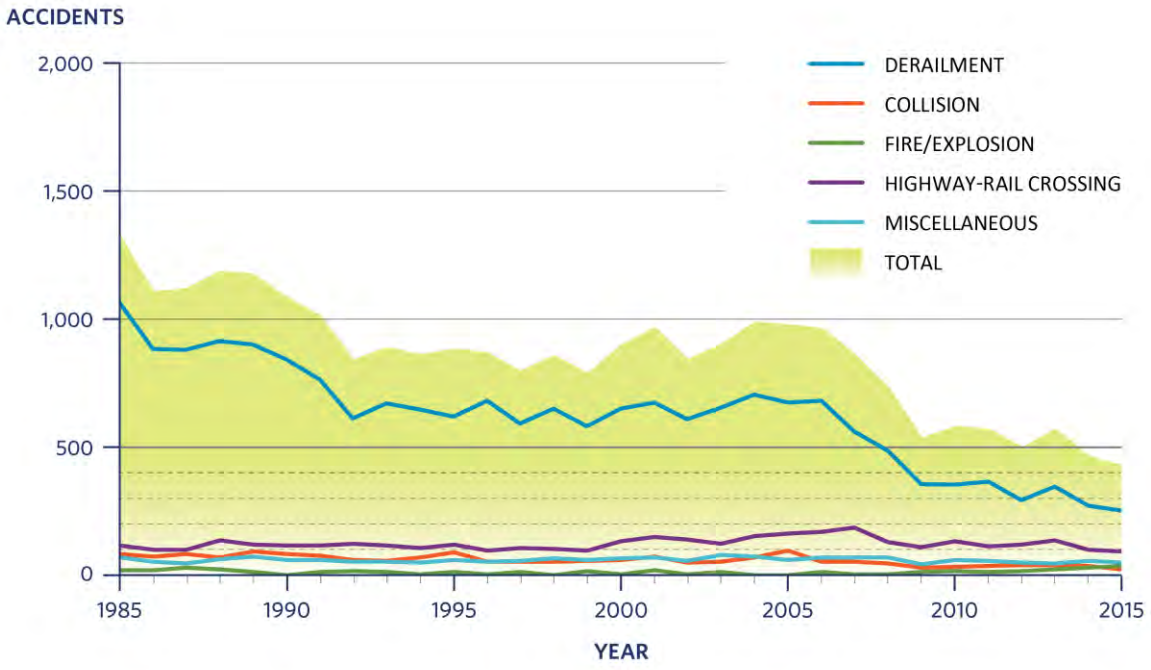
Conducting a statistically meaningful probability analysis requires a large enough sample size to minimize the margin of error in the results. In other words, if the sample size is too small, the results will not be reliable. In this case, because crude-by-rail transport did not become widespread until around 2010, there is not enough data across a long enough period of time to determine a statistically valid likelihood of an accident involving crude-by-rail unit trains. The crude-by-rail data from 2010 to the present provide a snapshot of the potential risk; however, it was necessary to use broader Federal Railway Administration (FRA) freight train accident data to create a statistically accurate analysis. Therefore, 20 years (1985 to 2004)

A train mile is one mile traversed by one train. For example, 100 trains traveling 50 miles each would be 5,000 train miles.

of freight train accident data from the FRA were analyzed to determine the frequency of rail accidents per *train mile* at the national level (FRA 2016).

The approach of using freight train data to assess risk has been applied in several other studies, including the risk analyses conducted at the University of Illinois at Urbana-Champaign Rail Transportation and Engineering Center, which is the leading center for rail transportation research in the United States. For most rail accidents (e.g., derailments, collisions) the cause of the accident is independent of the cargo being transported; therefore, it was appropriate and necessary to use the freight train accident data for this comparative analysis.

Figure 4-7 U.S. (Nationwide) Main Line Freight Accidents 1985–2015



Source: FRA 2016.

Evaluating the FRA train accident data relative to the number of freight train miles in any given year across the United States revealed the per-train mile rates at which different accident types would be anticipated. As described further in Appendix G, the accident rates were then adjusted to account for differences between general freight traffic and crude-by-rail traffic, including the greater likelihood of an accident due to increased train length and the potential effects of sloshing (longitudinal [front to back] liquid movement during transit within tank cars that are only partially loaded). With these adjustments, the following values were used as the rates of an accident involving a crude-by-rail unit train:

- Derailment: 0.9096 to 1.5251 accidents per million train miles.
- Collision: 0.0841 to 0.1763 accidents per million train miles.

- Fire/Explosion: 0.0000 to 0.0464 accidents per million train miles.
- Highway-Rail Crossing: 0.0743 to 0.2065 accidents per million train miles.
- Miscellaneous: 0.0878 to 0.1764 accidents per million train miles.

For context, proposed project trains would be expected to travel approximately 650 miles in Washington State to the Shell PSR facility, and 530 miles in Washington State on return trips. Annually, this would equate to about 372,000 miles traveled for proposed project trains both coming into and leaving the state.

High Estimate Evaluation of an Oil Release

When an accident occurs, it does not necessarily lead to a release of oil. Between 2010 and 2015, more than 1 billion barrels of oil were transported via crude-by-rail trains in the United States (Figure 4-5). In North America between 2010 and the present, 36 accidents occurred involving crude-by-rail trains, and 22 of those accidents resulted in a release of oil (Figure 4-8 for the U.S. and Figure 4-9 for Canada). The outcomes from these accidents varied widely. Some did not result in a release of any oil (e.g., Seattle and Philadelphia). At the low end of accidents resulting in oil releases, the February 2014 accident in Portage, Wisconsin resulted in a release of 179 barrels (7,500 gallons) of oil, and the June 2016 accident in Mosier, Oregon resulted in a release of 1,119 barrels (47,000 gallons) of oil. In contrast, at the high end, the July 2013 Lac-Mégantic, Quebec accident resulted in a release of 37,739 barrels (1.59 million gallons) of oil.

As depicted in Figure 4-9, the volume of oil released during the Lac-Mégantic accident is much higher when compared with the amount of oil released in other accidents. The approximately 38,000 barrels of oil that were released at Lac-Mégantic would fall near the 97th percentile in the spill volume distribution modeling. In other words, only three percent of releases would be expected to be more than 38,000 barrels. The Lac-Mégantic accident in Canada was the largest crude-by-rail accident to occur to date. In its Railway Investigation Report, the Transportation Safety Board of Canada concluded that "[operating railroad] did not have a functioning Safety Management System," which contributed directly to the accident (TSB of Canada 2016).

As described in the preceding discussion, although there have been numerous accidents resulting in releases from crude-by-rail trains, there are not enough data regarding crude-by-rail accidents across a long enough time period to inform a statistically meaningful release probability analysis. In addition, there are no reliable national train-mileage data for crude-by-rail transport, or even an accurate record of crude-by-rail accidents available from FRA or other sources, upon which a per-train-mile analysis could then be applied to the projections for the Shell PSR and Washington State as a whole. Therefore, for this analysis, release data from accidents associated with hazardous materials and petroleum (primarily refined products, but also some crude oil) tank car shipments served as a substitute for crude-by-rail trains. Historically, hazardous materials, refined petroleum products, and crude oil have been shipped in smaller, overall volumes in tank cars such as the DOT-111 or earlier models. Releases from these tank cars occurred independent of the materials that were being carried (e.g., ethanol is no more or less likely to spill than crude oil); therefore, it was appropriate to use the historic hazardous materials release data for this analysis.

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Figure 4-8 U.S. Historic Accidents Involving Crude-by-Rail Unit Trains and Amount of Crude Oil Released 2013–2015

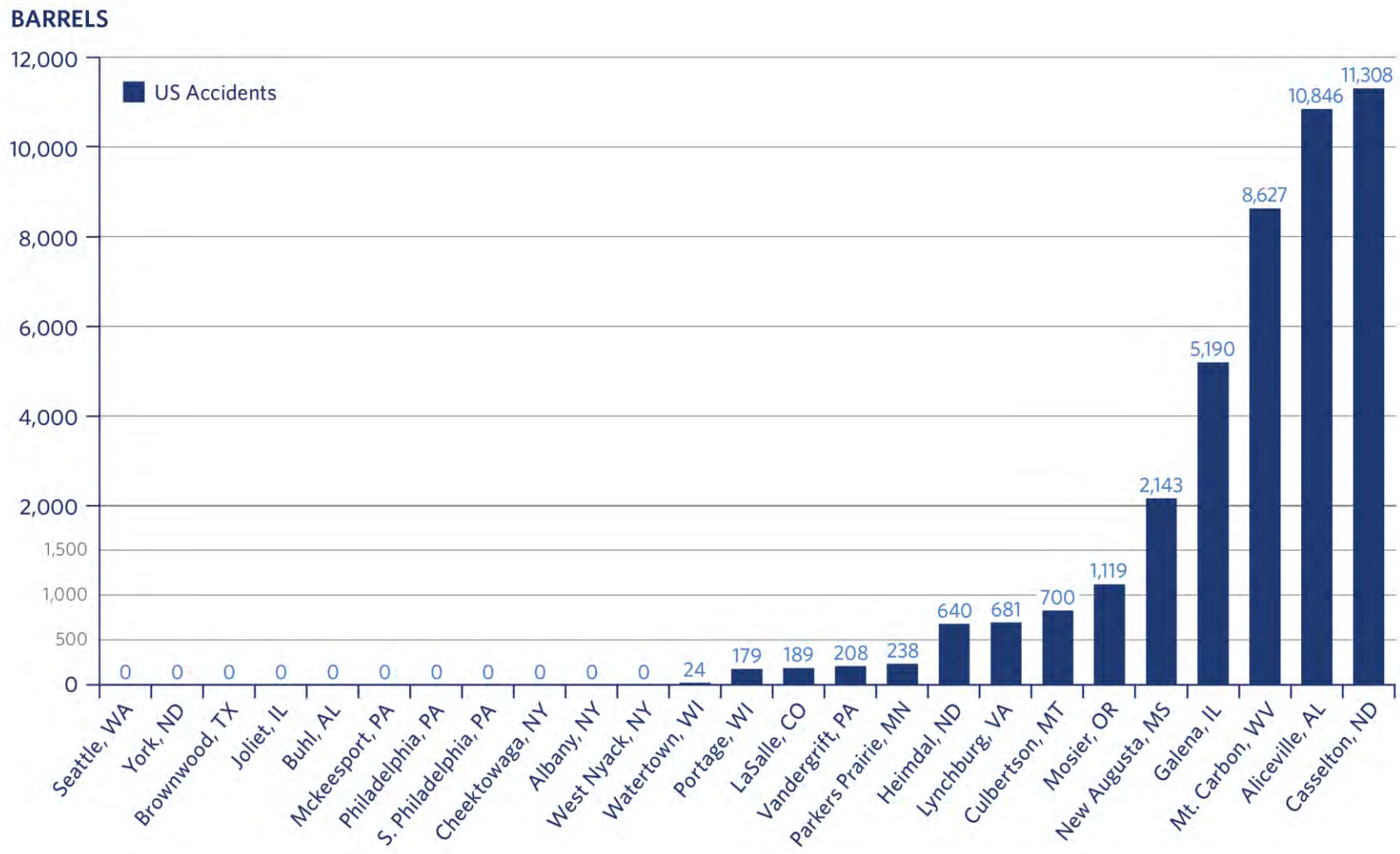

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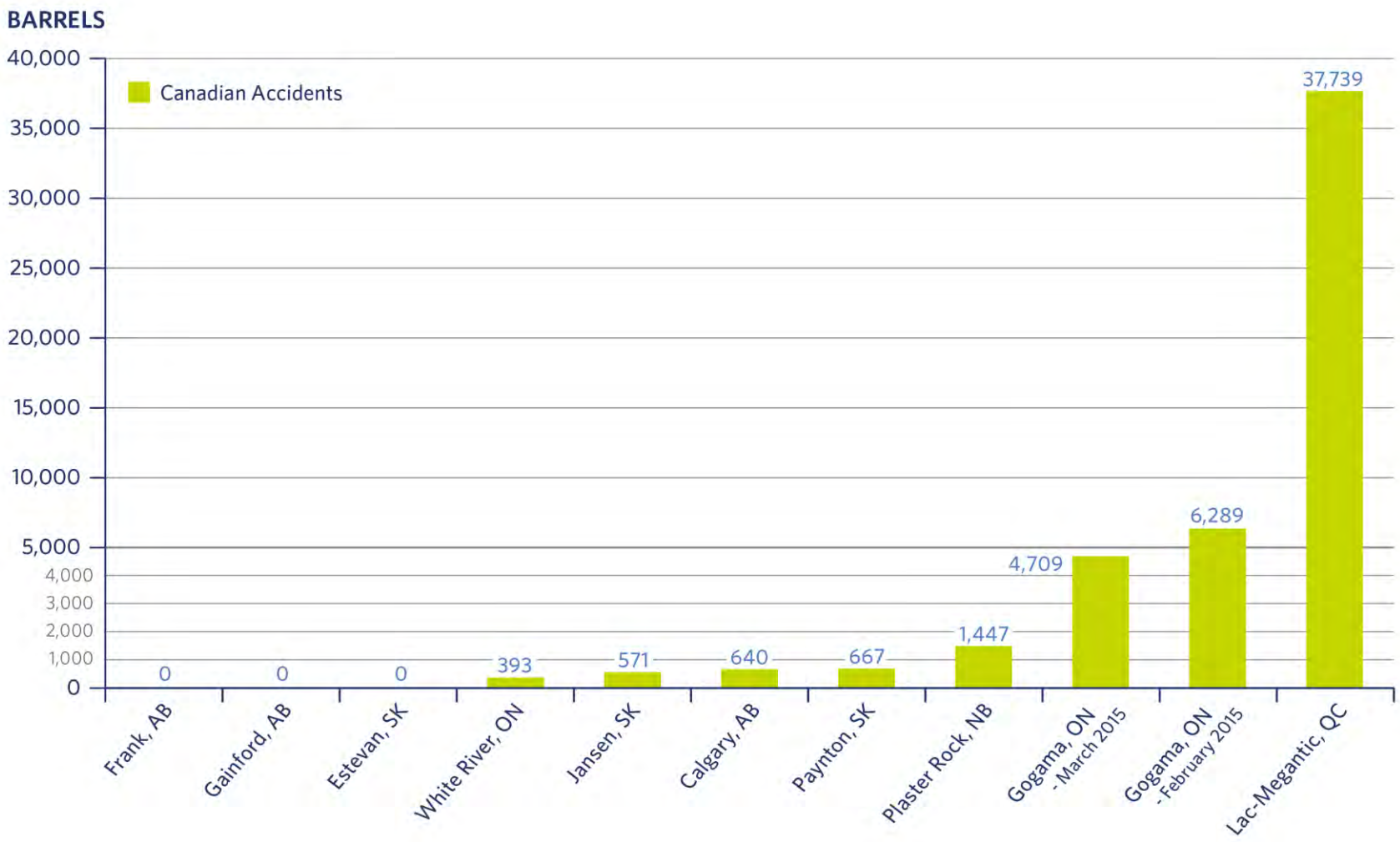
Figure 4-9 Canadian Historic Release Accidents Involving Crude-by-Rail Unit Trains and Amount of Crude Oil Released 2013–2015



Rail accidents involving hazardous materials tank cars, such as those used to transport crude oil, do not necessarily result in a release. An analysis of the FRA accident data from 1975 to 2015 in the United States showed that there were 3,589 accidents involving a total 0f 11,352 tank cars carrying hazardous materials that were either damaged or derailed. Of the 11,352 cars, 2,418 (21.3 percent) released hazardous materials. Over time, the release rate has been changing, with 22.6 percent of accidents resulting in a release between 1985 and 1994, 14.6 percent between 1995 and 2004, and 19.0 percent between 2005 and 2015.

As described in Appendix G, the probability that an accident would result in a release is dependent on the accident type. Historically, accidents involving hazardous materials freight traffic have resulted in the following likelihoods of a release occurring:

- Derailment: 21.5 percent.
- Collision: 19.5 percent.
- Fire/Explosion: 60.0 percent.
- Highway-Rail Crossing: 17.0 percent.
- Miscellaneous: 19.1 percent.

In other words, if a derailment occurred, there is a 21.5 percent chance that it would result in a release. Similarly, if there were a fire or explosion, it could result in a release 60 percent of the time.

The results presented in this chapter are given as averages; however, the statistical modeling that was conducted resulted in a wide range of outputs. For a full discussion of the analysis conducted, please refer to Appendix G.

Based on these percentages, the High Estimate evaluation average annual number of releases of any size was calculated to be 0.222 releases per million train miles. The likelihood of a release from one or more tank cars (or locomotives) as a result of an accident was considered along with the number of train miles that proposed project trains would be expected to travel and the probability of any of the accident types occurring. This determined the frequency (releases per year) and return period (average years between releases) of a release of any size.

For proposed project trains, the average frequency of a release of any size would be 0.046 releases per year, or one release every 22 years. This does not mean it would take 22 years for another release of any size to occur, rather that there is a 1 in 22 chance that a release of any size could occur from an accident in any given year.

If a release of oil were to take place, there would be a range of potential release volumes that could occur. As described in Appendix G, the amount of oil released would depend on:

- The total number of tank cars in the unit train (up to 102 tank cars for proposed project trains).
- The number of tank cars involved in the accident (up to all of the tank cars on a train).
- The volume of oil contained and released within each tank car (650 to 675.5 barrels per DOT-117 tank cars, and 690 barrels per DOT-111 tank cars).

How many tank cars per proposed project train?

1 unit train = 102 tank cars

The results indicated that for an accident involving a proposed project train, the average release volume would be 11,144 barrels (468,000 gallons), or the equivalent of 16.2 tank cars. As shown in Figure 4-10, the potential distribution of release volumes trended toward smaller releases. In other words, 10 percent of the accidents would be expected to involve more than 20,000 barrels (840,000 gallons).

Overall, releases from the proposed project trains are not anticipated to occur with great frequency. However, the potential volumes released would be at different average frequencies. As indicated by the modeling results in Table 4-5, smaller releases from proposed unit trains are expected to occur more frequently than larger ones. The return period for all modeled releases from proposed project trains varied from one 250-barrel release every 22 years, to one 50,000-barrel release every 22,000 years. This does not mean it would take 22 years for another 250-barrel release to occur, rather, that there is a 1 in 22 chance a 250-barrel release could occur in any given year.

Figure 4-10 Distribution of Release Volumes

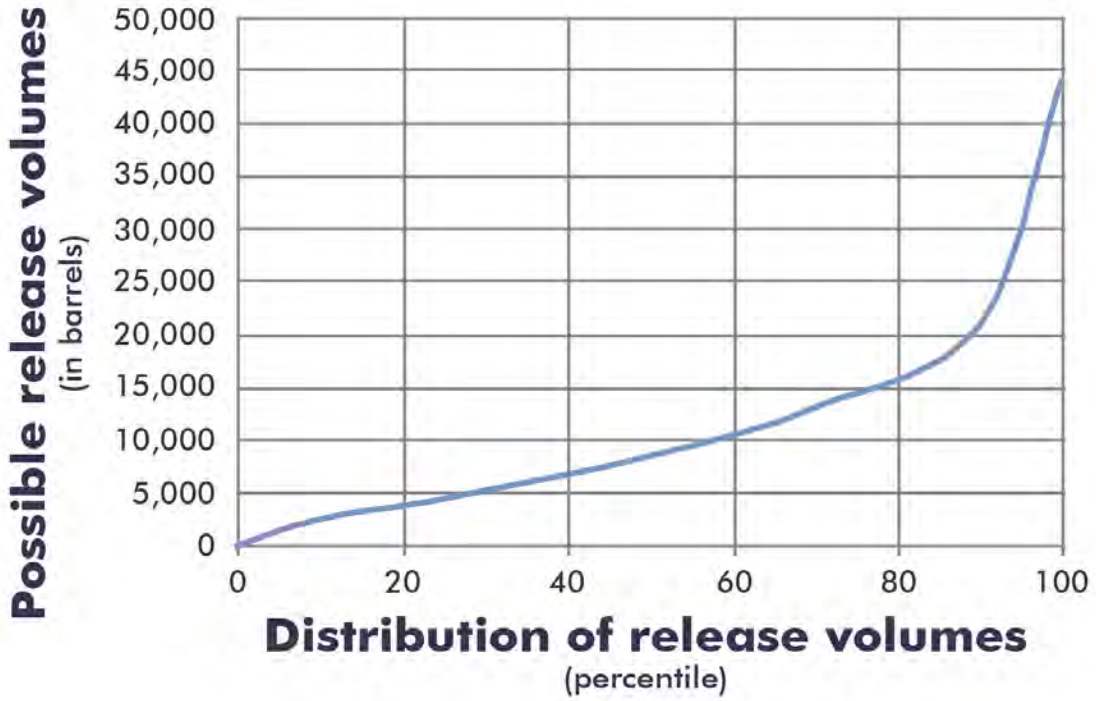


Table 4-5 High Estimate Evaluation – Expected Average Frequency of Releases by Volume for Shell PSR Trains

Release Volume (Barrels [gallons])	Average Frequency (Releases/Year)	Average Return Period (Years)	Probability ("Odds") of a Release in any Given Year
250 (10,500)	0.046	22	1 in 22
2,500 (105,000)	0.041	24	1 in 24
4,000 (168,000)	0.037	27	1 in 27
5,700 (239,400)	0.032	31	1 in 31
8,000 (333,600)	0.025	40	1 in 40
10,000 (420,000)	0.016	62	1 in 62
15,000 (630,000)	0.012	87	1 in 87
20,000 (840,000)	0.0069	140	1 in 140
40,000 (1,680,000)	0.00092	1,100	1 in 1,100
50,000 (2,100,000)	0.00005	22,000	1 in 22,000

From 201o to 2014, there was an 84-fold increase in the number of crude-by-rail trains traveling nationally (though the number of shipments has been decreasing since late 2014) (Figure 4-5). The increase in the overall number of crude-by-rail trains has led to an overall higher rate of accidents. When there were no, or only few, crude-by-rail trains, there were limited opportunities for such accidents and releases. Prior to 2010, when oil spilled from rail tank cars, it was usually fuel oil from a locomotive or refined petroleum from a small number of tank cars. Occasionally, crude oil was transported in rail tank cars in small volumes. Despite the rise in the absolute number, accident rates on a per-mile basis are lower today because of improved operations (e.g., more routine track maintenance) (see Figure 4-7).

Currently, there are approximately 21 crude-by-rail trains traveling in Washington per week. Because the proposed project would add one unit train per day, on average, the probability of an accident and release involving a Shell unit train is low. However, when considered with all other existing and planned crude-by-rail traffic (which would increase traffic to approximately 70 crude-by-rail trains per week), the overall probability of an accident and release involving any crude-by-rail train in Washington would be higher. This probability is discussed below under Cumulative Impacts.

Low Estimate Evaluation of Accident and Release Rates

The Low Estimate accounts for the reductions in the probability of an accident or release that could occur from the various measures specific to crude-by-rail unit trains that have been, or are anticipated to be, implemented to make trains safer. These include positive train control,

enhanced braking, wayside detectors, track upgrades, and safer tank cars (Table 4-6). Several of these measures would need to be sustained over time for the release rate probabilities to remain constant (e.g., improved track maintenance).

Low Estimate Evaluation of a Rail Accident

As described in Appendix G and Chapter 3-15 – Rail Traffic and Transportation, there are a number of industry practices and policies that are designed to minimize the likelihood of accidents involving crude-by-rail trains (Table 4-6). These factors include safety improvements to the rail line, such as wayside detection systems, positive train control, and track upgrades; and unit train operating parameters, including enhanced braking. The Low Estimate also accounts for the increased train length, which increases accident probability, associated with Shell PSR unit trains.

Many of these factors, especially positive train control, track upgrades, and wayside detectors, would work together to prevent rail accidents. The net result of the analysis showed that accidents associated with crude-by-rail trains were assumed to be 25.1 to 71.3 percent less likely to occur than indicated by the historic accident data for all freight rail traffic based on safety enhancements that are or will shortly be in place. A review of technical engineering studies determined that lateral sloshing (side-to-side liquid movement within tank cars during transit) and changes in lateral stability associated with crude-by-rail trains, were not likely to have an effect on the likelihood of an accident.

The adjustment rate is based on a review of technical engineering, industry studies, and other evaluations of the potential changes to the accident rate. These adjustments were only applied to the probability of an accident of the type that lead to spillage. The adjustments were assumed to be independent of, and therefore did not apply to, the probability of a release of oil to the environment that could occur during an accident. When the 25.1 to 71.3 percent reduction in the likelihood of an accident occurring was applied to the historic rates, the following accident rates for different accident types would be expected:

- Derailment: 0.1264 to 0.5255 accidents per million train miles.
- Collision: 0.0035 to 0.0709 accidents per million train miles.
- Fire/Explosion: 0.0000 to 0.0087 accidents per million train miles.
- Highway-Rail Crossing: 0.0155 to 0.1002 accidents per million train miles.
- Miscellaneous: 0.0156 to 0.0962 accidents per million train miles.

For context, proposed project trains would be expected to travel approximately 650 miles in Washington State to the Shell PSR facility, and 530 miles in Washington State on return trips. Annually, this would equate to about 372,000 miles traveled for proposed project trains both coming into and leaving the state.

Table 4-6 Adjustments to Accident Rates for Crude-by-Rail Trains for the Low Estimate Evaluation

Adjustment	Description
Wayside Detectors	Wayside detection systems monitor the wheels of passing trains and alert rail car operators about potential defects. In Washington State, acoustic-bearing detectors, wheel impact load detectors, hot box detectors, and dragging detectors are currently in use.
Track Upgrades	Track improvements and upgrades are likely to prevent or reduce the occurrence of certain types of track-related derailment accidents.
Positive Train Control	The FRA has mandated the use of positive train control for all railroads. Positive train control is designed to automatically stop a train before certain accidents, including train-to-train collisions, derailments caused by excessive speed, and movement of trains on tracks where they are not supposed to be. This directive was originally mandated to be in effect by the end of 2015, but was extended to the end of 2018.
Enhanced Braking	The U.S. Department of Transportation (USDOT) Final Rule requires that crude-by-rail trains have in place a functioning end-of-train device or a distributive power braking system. It further requires that by January 1, 2021, all unit trains comprised of 70 or more loaded tank cars traveling at more than 30 mph be operated with an electronically controlled pneumatic braking system.
Lateral Stability	Unit trains carrying crude by rail are assumed to have greater lateral stability because all of the tank cars are relatively identical in size and shape. However, studies conducted have not shown a net change to the accident rate.
Sloshing	Sloshing (the movement of oil in partially filled tank cars) has been raised as a stability concern for the transport of crude by rail. However, studies have shown that lateral liquid sloshing actually has a dampening effect and reduces lateral movement of oil in the tank car. Any changed probability due to longitudinal sloshing (in the direction of the track) was considered to be negligible as there are no specific data that support the hypothesis that longitudinal sloshing increases accident rates.
Train Length	Train length changes the probability of accidents. As train length increases, the probability of an accident also increases.

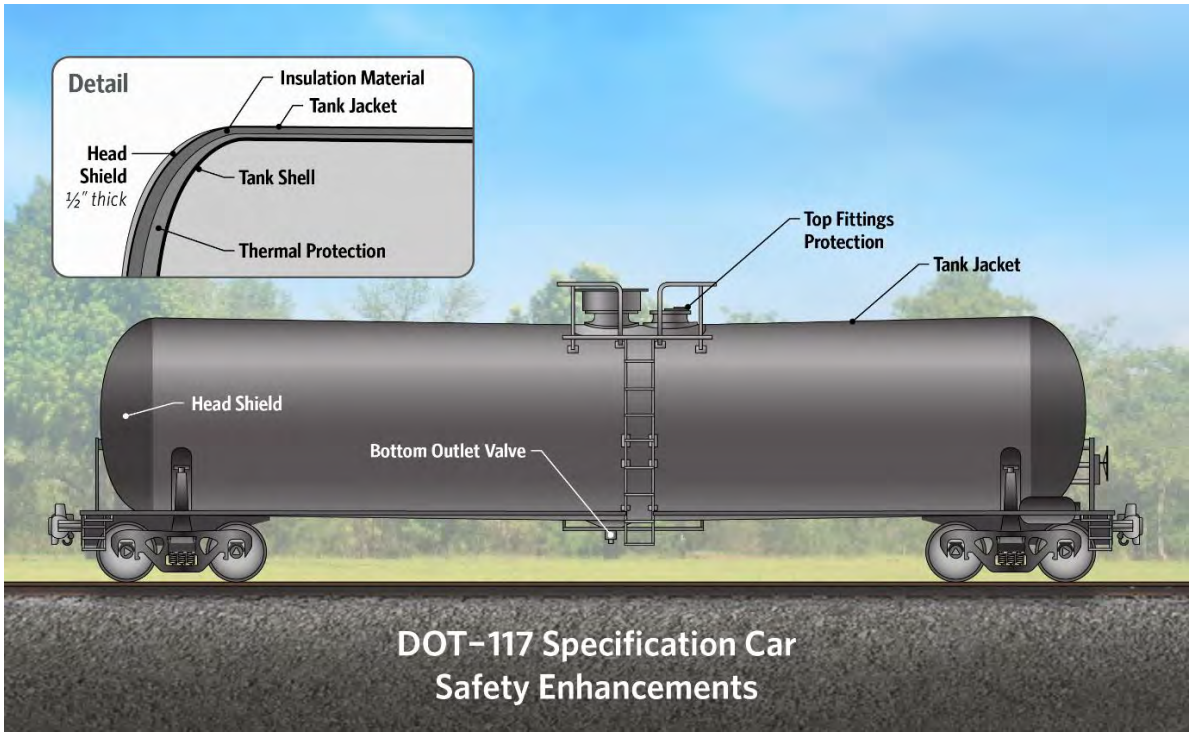
Note: For additional information and citations for all information please refer to Appendix G.

Low Estimate Evaluation of an Oil Release

As described in Appendix G, there are a number of factors specific to the transport of crude oil by rail such as the use of DOT-117 Specification tank cars and reduced crude-by-rail train traveling speeds (see below), both of which would reduce the probability of a release. Shell would use only tank cars that meet or exceed the specifications of DOT-117 tank cars to transport crude oil as part of the proposed project (Figure 4-11). This would be included as a condition of approval and would be enforced through state and local permitting requirements. These tank cars are considered safer and less likely to rupture and release oil in the event of an accident. Their safety

features are attributed to the increase in wall thickness, thermal protective measures, and other mechanical improvements such as fittings, valves, and brakes, when compared with the previously used DOT-111 tank cars (USDOT 2014).

Figure 4-11 DOT-117 Specification Tank Car Safety Enhancements



Source: adapted from USDOT 2016.

In accordance with the USDOT Final Rule issued on May 1, 2015, crude-by-rail trains are restricted to operating at less than 50 miles per hour (mph), which reduces the likelihood of an accident and may reduce the likelihood of a release in the event of an accident. The effects of this rule are not reflected in the historic release probabilities as the rule does not apply to general hazardous materials shipments and has only been in place for a little over a year.

As described in Appendix G, when combined, speed reductions and the use of DOT-117 tank cars, which include thermal protection, reduce the probability of releases in the case of all accident types except fire/explosions by 43 to 72.2 percent. Reductions associated with speed and the use of DOT-117 tank cars do not effect releases due to fire/explosions; therefore, releases from tank cars because of fire/explosions would be reduced by 12 percent because of the thermal protection measures incorporated into the DOT-117 tank cars. With these adjustments, the following average release probabilities for different accident types would be anticipated:

- Derailment: 6.0 to 12.3 percent.
- Collision: 5.5 to 11.1 percent.
- Fire/Explosion: 52.8 percent.

- Highway-Rail Crossing: 4.8 to 9.7 percent.
- Miscellaneous: 5.4 to 10.9 percent.

In other words, the probability that a derailment would result in a release would be reduced by 43 to 72.2 percent from the historic probability of 21.5 percent to 6.0 to 12.3 percent.

Based on these percentages, the average number of releases of any size was calculated to be 0.027 releases per million train miles. The likelihood of a release in the event of an accident was considered along with the number of train miles that proposed project trains would be expected to travel and the probability of any of the accident types occurring. This calculation determined the average frequency (average releases per year) and average return period (average years between releases) of a release of any size. For proposed project trains, the average frequency of a release of any size would be 0.0055 releases per year, or one release every 180 years. That means there is a 1 in 180 chance that a release of any size could occur in any given year.

A range of potential release volumes could occur if a release were to take place. As described in Appendix G, the results indicated for an accident involving a proposed project train, the average release volume would be 10,498 barrels (441,000 gallons), or the equivalent of 16.2 tank cars.

The potential volume released would be at different average frequencies. As indicated by the modeling results in Table 4-7, smaller releases from proposed unit trains are anticipated to occur more frequently than larger ones. The return period, on average, for all modeled releases varied from one 250-barrel release every 180 years, to one 50,000-barrel release every 180,000 years. This does not mean it would take 180 years for another 250-barrel release to occur; rather, that there is a 1 in 180 chance a 250-barrel release could occur in any given year.

Table 4-7 Low Estimate Evaluation – Expected Average Frequency of Releases by Volume for Shell PSR Trains

Release Volume (Barrels [gallons])	Average Frequency (Releases/Year)	Average Return Period (Years)	Probability **("Odds") of a** Release in any Given Year
250 (10,500)	0.0055	180	1 in 180
2,500 (105,000)	0.005	200	1 in 200
4,000 (168,000)	0.0044	230	1 in 230
5,700 (239,400)	0.0036	280	1 in 280
8,000 (333,600)	0.003	330	1 in 330
10,000 (420,000)	0.0022	450	1 in 450
15,000 (630,000)	0.0014	730	1 in 730
20,000 (840,000)	0.0055	1,800	1 in 1,800

Release Volume (Barrels [gallons])	Average Frequency (Releases/Year)	Average Return Period (Years)	Probability **("Odds") of a** Release in any Given Year
40,000 (1,680,000)	0.000055	18,000	1 in 18,000
50,000 (2,100,000)	0.0000055	180,000	1 in 180,000

Probability of Release from an Unloaded Train

Both loaded and unloaded (empty) proposed project trains could be involved in an accident that releases crude oil or diesel fuel. For a loaded train, there could be a release of crude oil from the tank cars and/or diesel fuel from the locomotives. For an unloaded train, the primary concern would be the release of diesel fuel from the locomotives because the residual crude oil content in the tank cars after unloading is considered too small to have an effect. The analysis of the probability of a release for unloaded project unit trains followed the same methodology for loaded trains under the High and Low Estimate evaluations, as described in Appendix G.

For the proposed project, each unit train is anticipated to have between four and six locomotives. Each locomotive would be carrying between 65 and 131 barrels of diesel fuel. During an accident, it is anticipated that 20 to 60 percent of the locomotives would be involved. Locomotives are typically placed in groups, with two or three positioned at both the front and back of the train. It is unlikely that both ends of the train would be involved in an accident. For analysis, it was assumed that the range of diesel fuel released from each locomotive would be between 1 to 100 percent.

The expected average frequency of a release would vary depending on the volume of diesel fuel released. As indicated by the modeling results in Table 4-8, smaller releases are anticipated to occur more frequently than larger ones. The return period, on average, for all modeled releases from a proposed project locomotive varied from a single, five-barrel release every 260 years under the High Estimate evaluation, to one 300-barrel release every 26,000 years. Under the Low Estimate evaluation, the return period ranged from a single, five-barrel release every 1,000 years, to one 300-barrel release every 100,000 years.

Table 4-8 Expected Average Frequency of Releases by Volume for Unloaded Shell PSR Trains

Release Volume of Diesel Fuel (Barrels [gallons])	High Estimate Evaluation			Low Estimate Evaluation		
	Frequency (Releases/ Year)	Average Return Period (Years)	Probability **("Odds")** of a Release in any Given Year	Frequency (Releases/ Year)	Average Return Period (Years)	Probability **("Odds")** of a Release in any Given Year
5 (210)	0.0038	260	1 in 260	0.00098	1,000	1 in 1,000
25 (1,050)	0.0034	290	1 in 290	0.00088	1,100	1 in 1,100
40 (1,680)	0.0027	380	1 in 380	0.00069	1,500	1 in 1,500
50 (2,100)	0.0021	480	1 in 480	0.00054	1,900	1 in 1,900
60 (2,520)	0.0015	660	1 in 660	0.00039	2,600	1 in 2,600
70 (2,940)	0.0011	880	1 in 880	0.00029	3,400	1 in 3,400
100 (4,200)	0.00038	2,600	1 in 2,600	0.000098	10,000	1 in 10,000
250 (10,500)	0.00019	5,300	1 in 5,300	0.000049	20,000	1 in 20,000
300 (12,600)	0.00006	26,000	1 in 26,000	0.000001	100,000	1 in 100,000

Cumulative Probability of an Accident and Release

As described in Chapter 1 – Introduction, four refineries in Washington currently receive crude by rail from the mid-continent area. Cumulative impacts for studied resources are described in Chapters 3.1 through 3.17 and include the reasonably foreseeable crude-by-rail projects that are currently proposed in Washington State. If all facilities, including the proposed project, were approved and implemented, weekly trainloads of crude oil would increase to approximately 70 trains from the current level of about 21 trains (Table 4-9). Shell PSR unit trains would constitute 8.7 percent of this statewide traffic. For train traffic in Northwest Washington—from King County to Whatcom County—the Shell PSR would constitute 19.6 percent of crude-by-rail traffic.

Table 4-9 State of Washington Crude-by-Rail Facilities and Expected Weekly Traffic

Washington Refinery	Facility Status	Weekly Trains
BP Refinery/ Cherry Point	Operating	7
Tesoro Refinery/Anacortes	Operating	14
Phillips 66 Refinery/Ferndale	Changes under construction	3.5
U.S. Oil Refinery/Tacoma	Changes under construction	3.5
NuStar Terminal/ Vancouver	Changes under construction	2
Imperium Terminal/Grays Harbor	Proposed changes to existing facility	2
Shell PSR/Anacortes	Proposed changes to existing facility	6
Grays Harbor Rail Terminal	Proposed new facility	3.5
Vancouver Energy/Vancouver	Proposed new facility	28

Cumulative High Estimate Evaluation of an Accident and Release

The cumulative High Estimate evaluation for the 70 possible weekly trains followed the same methodology that was used to calculate the High Estimate probability for loaded and unloaded proposed project trains, as described starting on page 4-14 and in Appendix G.

The High Estimate cumulative probability that an accident would result in a release would also be the same as described above and in Appendix G. The likelihood of a release in the event of an accident was considered along with the number of train miles that the 70 possible weekly trains would be expected to travel, and the probability of any of the accident types occurring. This determined the frequency (releases per year) and return period (average years between releases) of a release of any size.

The results indicated that the High Estimate cumulative average frequency of a release of any size from loaded existing crude-by-rail trains, loaded proposed project trains, and reasonably foreseeable future projects would be 0.48, or one release every 2.1 years (Table 4-10). In other words, there is a 1 in 2.1 chance that a release of any size would occur in any given year. This compares with an average frequency of a release of any size from a proposed project train of 0.046 releases per year or, on average, one release every 22 years.

If an accident from the 70 possible weekly trains were to occur, there is a range of potential volumes that could be released. These releases would be expected to occur at different average frequencies. As indicated by the modeling results in Table 4-11, smaller releases from the 70 possible weekly trains are anticipated to occur more frequently than larger ones. The return period for all modeled releases from the 70 possible weekly trains varied from one 250-barrel release every 2.1 years, to one 50,000-barrel release every 2,100 years. This does not mean it would take 2.1 years for another 250-barrel release to occur, rather that there is a 1 in 2.1 chance a 250-barrel release could occur in any given year. The frequency distribution of releases from locomotives by volume is presented in Table 4-12.

Table 4-10 Cumulative High Estimate Evaluation – Crude-by-Rail Release Frequencies and Return Periods for a Release of any Size from Loaded and Unloaded Trains

	Current Facilities (21 Trains/Week)		Proposed Project Trains (6 Trains/Week)		Reasonably Foreseeable Future Crude-by-Rail Projects (43 Trains/Week)		Total (70 Trains/Week)	
	Loaded Train	Unloaded Train	Loaded Train	Unloaded Train	Loaded Train	Unloaded Train	Loaded Train	Unloaded Train
Frequency (Releases/ Year)	0.17	0.013	0.046	0.0038	0.26	0.029	0.48	0.046
Average Return Period (Years)	6	76	22	260	4	34	2.1	22
Probability **("Odds")** of a Release in any Given Year	1 in 6	1 in 76	1 in 22	1 in 260	1 in 4	1 in 34	1 in 2	1 in 22

Table 4-11 Cumulative High Estimate Evaluation – Expected Average Frequency of Crude Oil Releases by Volume – Loaded Trains

Release Volume (Barrels [gallons])	Current Facilities (21 Trains/Week)		Proposed Project Trains (6 Trains/Week)		Reasonably Foreseeable Future Crude-by-Rail Projects (43 Trains/Week)		Total (70 Trains/Week)		
	Number Per Year	Return Years	Number Per Year	Return Years	Number Per Year	Return Years	Number Per Year	Return Years	Probability **("Odds")** of a Release in any Given Year
250 (10,500)	0.17	6	0.046	22	0.26	3.9	0.48	2.1	1 in 2.1
2,500 (105,000)	0.15	6.5	0.041	24	0.23	4.3	0.43	2.3	1 in 2.3
4,000 (168,000)	0.14	7.4	0.037	27	0.21	4.8	0.38	2.6	1 in 2.6
5,700 (239,400)	0.12	8.4	0.032	31	0.18	5.5	0.34	3	1 in 3
8,000 (333,600)	0.094	11	0.025	40	0.14	7	0.26	3.8	1 in 3.8
10,000 (420,000)	0.060	17	0.016	62	0.091	11	0.17	6	1 in 6
15,000 (630,000)	0.043	24	0.012	87	0.065	15	0.12	8.3	1 in 8.3
20,000 (840,000)	0.026	39	0.0069	140	0.039	26	0.072	14	1 in 14
40,000 (1,680,000)	0.0034	290	0.00092	1,100	0.0052	190	0.0096	100	1 in 100
50,000 (2,100,000)	0.00017	5,900	0.00005	22,000	0.00026	3,800	0.00048	2,100	1 in 2,100

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Table 4-12 Cumulative High Estimate Evaluation – Expected Average Frequency of Diesel Fuel Releases by Volume – Unloaded Trains

Diesel Fuel Release Volume (Barrels [gallons])	Current Facilities (21 Trains/Week)		Proposed Project Trains (6 Trains/Week)		Reasonably Foreseeable Future Crude-by-Rail Projects (43 Trains/Week)		Total (70 Trains/Week)		
	Number Per Year	Return Years	Number Per Year	Return Years	Number Per Year	Return Years	Number Per Year	Return Years	Probability **("Odds") of** a Release in any Given Year
5 (210)	0.013	76	0.0038	260	0.029	34	0.046	22	1 in 22
25 (1,050)	0.012	85	0.0034	290	0.026	38	0.041	24	1 in 24
40 (1,680)	0.0091	110	0.0027	380	0.02	49	0.032	31	1 in 31
50 (2,100)	0.0072	140	0.0021	480	0.016	63	0.025	40	1 in 40
60 (2,520)	0.0052	190	0.0015	660	0.012	86	0.018	54	1 in 54
70 (2,940)	0.0039	260	0.0011	880	0.0087	120	0.014	72	1 in 72
100 (4,200)	0.0013	770	0.00038	2,600	0.0029	340	0.0046	220	1 in 220
250 (10,500)	0.00065	1,500	0.00019	5,300	0.0015	690	0.0023	440	1 in 440
300 (12,600)	0.00013	7,700	0.00006	26,000	0.00029	3,400	0.00046	2,200	1 in 2,200

Cumulative Low Estimate Evaluation of an Accident and Release

The cumulative Low Estimate evaluation for the 70 possible weekly trains followed the same methodology that was used to calculate the Low Estimate probability for loaded and unloaded proposed project trains, as described above and in Appendix G. The cumulative Low Estimate accounts for the reductions in the probability of an accident or release associated with the policies and regulations designed to minimize the risk of such an event involving a crude-by-rail train.

The assumptions regarding safety adjustments for crude-by-rail trains associated with projects other than that proposed by Shell, would be slightly different. For the purposes of this analysis, it was assumed that crude-by-rail trains associated with other projects would be up to 120 tank cars long, which would increase the probability of an accident relative to the 102 tank cars for the proposed project. Overall, the net result was that accidents associated with non-Shell PSR crude-by-rail trains would be 12.8 to 59.0 percent less likely to occur than with general freight traffic.

The same likelihoods of a release occurring during an accident as described for the Low Estimate evaluation were used for the Low Estimate cumulative analysis. The likelihood of a release during an accident was considered along with the number of train miles that the 70 possible weekly trains would be expected to travel, and the probability of any of the accident types occurring. This calculation determined the frequency (releases per year) and return period (average years between releases) of a release of any size.

The results indicated that the Low Estimate cumulative average frequency of a release of any size from loaded existing crude-by-rail trains, loaded proposed project trains, and reasonably foreseeable future projects would be 0.069, or one release every 14 years (Table 4-13). In other words, there is a 1 in 14 chance that a release of any size could occur in any given year. This compares with an average frequency of a release of any size from a proposed project train of 0.0055 release per year, or one release every 200 years.

Table 4-13 Low Estimate Evaluation – Crude-by-Rail Release Frequencies and Return Periods for a Release of any Size

	Current Facilities (21 Trains/Week)		Proposed Project Trains (6 Trains/Week)		Reasonably Foreseeable Future Crude-by-Rail Projects (43 Trains/Week)		Total (70 Trains/Week)	
	Loaded	Unloaded	Loaded	Unloaded	Loaded	Unloaded	Loaded	Unloaded
Frequency (Releases/ Year)	0.025	0.0050	0.0055	0.001	0.037	0.011	0.069	0.018
Average Return Period (Years)	40	200	180	1,000	27	89	14	56
Probability **("Odds")** of a Release in any Given Year	In 40	1 in 200	1 in 180	1 in 1,000	1 in 27	1 in 89	1 in 14	1 in 56

If an accident from the 70 possible weekly trains were to occur, there is a range of potential volumes that could be released. The releases would be expected to occur at different average frequencies. As indicated by the modeling results in Table 4-14, smaller releases from the 70 possible weekly trains are anticipated to occur more frequently than larger ones. The return period for all modeled releases from the 70 possible weekly trains varied from one 250-barrel release every 14 years, to one 50,000-barrel release every 14,000 years. This does not mean it would take 14 years for another 250-barrel release to occur, rather that there is a 1 in 14 chance a 250-barrel release could occur in any given year. The frequency distribution of releases from locomotives by volume is presented in Table 4-15.

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Table 4-14 Cumulative Low Estimate Evaluation – Expected Average Frequency of Crude Oil Releases by Volume – Loaded Trains

Release Volume (Barrels [gallons])	Current Facilities (21 Trains/Week)		Proposed Project Trains (6 Trains/Week)		Reasonably Foreseeable Future Crude-by-Rail Projects (43 Trains/Week)		Total (70 Trains/Week)		
	Number Per Year	Return Years	Number Per Year	Return Years	Number Per Year	Return Years	Number Per Year	Return Years	Probability **("Odds") of** a Release in any Given Year
250 (10,500)	0.025	40	0.0055	180	0.037	27	0.069	14	1 in 14
2,500 (105,000)	0.023	44	0.005	200	0.033	30	0.062	16	1 in 16
4,000 (168,000)	0.02	50	0.0044	230	0.03	34	0.055	18	1 in 18
5,700 (239,400)	0.016	62	0.0036	280	0.024	42	0.045	22	1 in 22
8,000 (333,600)	0.014	73	0.003	330	0.02	49	0.038	26	1 in 26
10,000 (420,000)	0.01	100	0.0022	450	0.015	68	0.028	36	1 in 36
15,000 (630,000)	0.063	160	0.0014	730	0.0093	110	0.017	58	1 in 58
20,000 (840,000)	0.0025	400	0.00055	1,800	0.0037	270	0.0069	140	1 in 140
40,000 (1,680,000)	0.00025	4,000	0.000055	18,000	0.00037	2,700	0.00069	1,400	1 in 1,400
50,000 (2,100,000)	0.000025	40,000	0.0000055	180,000	0.000037	27,000	0.000069	14,000	1 in 14,000

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Table 4-15 Cumulative Low Estimate Evaluation – Expected Average Frequency of Diesel Fuel Releases by Volume – Unloaded Trains

Diesel Fuel Release Volume (Barrels [gallons])	Current Facilities (21 Trains/Week)		Proposed Project Trains (6 Trains/Week)		Reasonably Foreseeable Future Crude-by-Rail Projects (43 Trains/Week)		Total (70 Trains/Week)		
	Number Per Year	Return Years	Number Per Year	Return Years	Number Per Year	Return Years	Number Per Year	Return Years	Probability **("Odds")** of a Release in any Given Year
5 (210)	0.005	198	0.00098	1,000	0.011	89	0.018	56	1 in 56
25 (1,050)	0.0045	220	0.00088	1,100	0.0099	100	0.016	62	1 in 62
40 (1,680)	0.0035	290	0.00069	1,500	0.0077	130	0.013	79	1 in 79
50 (2,100)	0.0028	360	0.00054	1,900	0.0061	170	0.0099	100	1 in 100
60 (2,520)	0.002	500	0.00039	2,600	0.0044	230	0.0072	140	1 in 140
70 (2,940)	0.0015	670	0.00029	3,400	0.0033	300	0.0054	190	1 in 190
100 (4,200)	0.0005	2,000	0.000098	10,000	0.0011	910	0.0018	560	1 in 560
250 (10,500)	0.00025	4,000	0.000049	20,000	0.00055	1,800	0.0009	1,100	1 in 1,100
300 (12,600)	0.00005	20,000	0.000001	100,000	0.00011	9,100	0.00018	5,600	1 in 5,600

POTENTIAL OIL RELEASE CONSEQUENCES

Oil spill trajectory, fate, and effects modeling and analyses were performed to evaluate risks and impacts from potential releases of crude oil into aquatic environments from proposed project trains. The analysis predicted where oil released into those environments could move and how it could impact resources within the modeled area.

Analyses of oil spill trajectory, fate, and effects are modeled using the SIMAP and OILMAP Land modeling packages developed by RPS ASA (previously Applied Science Associates). Both models are used extensively by industry and government (French-McCay 2004, Horn and French-McCay, 2015).

The analysis focused primarily on aquatic environments as the area affected and the potential consequences of a release into water are typically greater than releases onto land. While a crude oil release into the environment is very unlikely, the analysis assumed a release had occurred and offered a reference point for contingency planning and response efforts. It also provided a range of expected impacts based on varying geographic and environmental conditions. The ecological and human health impacts identified from the modeled release scenarios were considered in the discussion of economic risks and potential cumulative impacts. Detailed methods, results, and discussion of the oil release consequence analysis are presented in Appendix H.

The *trajectory* and *fate* modeling, in combination with the fire and explosion analysis below, provided a detailed accounting of the potential consequences or impacts following an unmitigated release of oil. The lower probability, larger volume release accidents have been investigated to provide the upper range of anticipated effects should a release occur into the environment. In the event of a smaller volume release, the predicted areas, volumes of water, and potential effects are predicted to be lower. .

The trajectory of a release describes the movement of oil within the environment and includes the spatial extent of the release over time. The fate of a release describes the way in which the oil will interact with the environment and includes processes such as evaporation, dissolution, and degradation.

The representative locations chosen for this assessment included a wide range of environments that are typical along the rail corridor. A range of aquatic ecosystems within both urban and rural settings were selected for assessment. This included open waters and urban settings (Edmonds), more confined embayment with mud flats and a channel (Swinomish Channel and Padilla Bay), and a freshwater river (Skagit River). The intent was to target locations around water, which can increase both the extent and magnitude of potential effects. Trajectory and fate modeling and fire and explosion modeling were not provided for a purely terrestrial release location such as a downtown setting.

During the public scoping process, many commenters expressed concerns about the potential impacts of a rail accident occurring in the Columbia River Gorge, as well as a wide range of other locations along the rail corridor (Skagit County and Ecology 2015). The co-lead agencies considered these comments when selecting the study locations. The locations evaluated in this EIS are intended to capture the various types of environments that could be affected by an accident (e.g., fresh water or marine environments; rural or urban areas).

In the event of a release in a highly populated center, there are some qualitative predictions that may assist in understanding the potential effects. First and foremost, the population density in an urban center can increase the potential for significantly negative effects to people. This includes the inhalation hazards of volatilized compounds from released crude oil, as well as the increased risk of fire and explosion in more confined areas. Both factors may increase the potential consequences following a release in an urban environment.

There are also factors that may reduce potential effects in highly populated areas. Rail speeds through urban centers are typically much lower, which would reduce the likelihood of a derailment or rupture. For example, the USDOT Final Rule issued on May 1, 2015, requires that crude-by-rail trains operate at less than 50 mph in all areas, and less than 40 mph in all high-threat urban areas (i.e., Seattle and Bellevue, WA). Ecology also recently developed *two new rules* related to the shipment of crude oil by rail in Washington State that would improve preparation for and response to accidents and spills. Both rules would help to minimize the potential effects of shipments through highly populated areas.

The first rule, WAC 173-185, created notification requirements for facilities receiving crude oil by rail and established procedures for Ecology to disclose crude oil movement to the public.

The second rule, WAC 173-186, established contingency plan requirements for railroads transporting oil by rail.

Urban areas are complex in nature with certain aspects that can both increase and decrease the potential risks (probability and consequence) associated with a release of crude oil. Urban areas have a large number of first responders, which should reduce response times for emergency personnel when compared with some of the more remote and less accessible locations along the rail corridor. However, a release in an urban center may also cut power, sever transportation routes for citizens and emergency personnel (e.g. roads and bridges), and otherwise compromise safety. In addition, urban areas have stormwater management systems, which may assist in the containment and cleanup of released oil, or potentially convey drainage and spills directly to surface waters. It is important to note that every spill is unique, dependent on the site-specific characteristics and the accident itself.

If a release were to occur in a tunnel, there are a number of different outcomes that could result. The spill would be confined to a smaller area, which could aid in containment and cleanup. However, there is the possibility that volatile concentrations in the atmosphere within the confined space would be much higher, as compared with a release in the open. This could lead to an increased risk of fire or explosion due to the increased concentration of gases in the confined space.

Approach to Analysis of Oil Release

Oil spill release scenarios were developed to characterize the range of potential impacts from a number of environmental and oil spill release conditions. Understanding the potential trajectory of crude oil within the environment and its ultimate fate was necessary to identify the potential impacts. Results can also be used to inform planning and response efforts. Oil spill release scenarios were defined by release location, release volume, and environmental conditions.

Release Scenario Locations

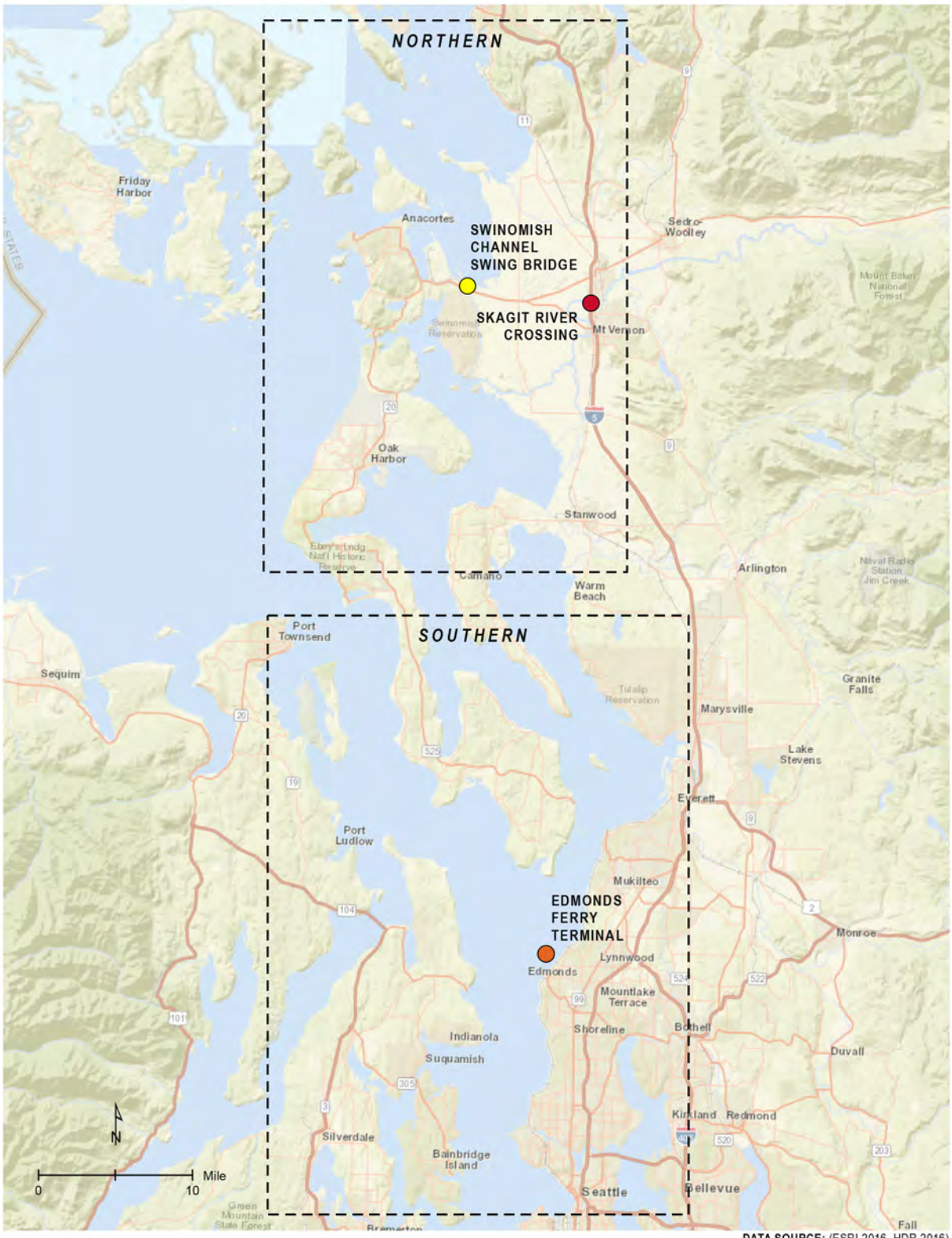
Potential releases of oil from unit trains were modeled at three locations along the rail transport route in western Washington (Figure 4-12). Several criteria were used to select locations along the rail corridor, including proximity to the corridor, proximity to populated areas and sensitive aquatic ecosystems, general geographic and environmental conditions, and the presence of variable environmental conditions. The locations were also chosen because they were identified as areas of interest by the public during scoping (Skagit County and Ecology 2015). Areas specifically identified included potential spills over waterbodies (such as the Skagit River and Padilla Bay), rivers, streams, nonmarine waterways, and wetlands. However, an oil spill is no more likely to occur in these locations than anywhere else along the rail transport route.

The release locations that were selected for analysis (Figure 4-12) are:

- Swing Bridge over the Swinomish Channel.
- Skagit River Bridge Crossing.
- Edmonds Ferry Terminal.

The co-leads modeled relatively low probability, high-impact accidents (i.e., large volume releases) to better understand the maximum potential consequences of a more extreme accident. These results provide the upper range of estimates of consequence in the unlikely event that there is a large volume release of oil. It is important to understand that lower volume oil spill release scenarios are more probable.

The co-leads did not specifically model the consequences of higher probability, low-impact accidents. Similarly, the co-leads did not model the consequences of low-probability, high-consequence scenarios in densely urbanized areas, such as the Seattle Tunnel, because such scenarios have a very low probability of occurring. Further, the Seattle Tunnel is fairly well-contained and, in terms of fate modeling, would not represent a potential movement of oil into water bodies.



DATA SOURCE: (ESRI 2016, HDR 2016)

Swinomish Channel Swing Bridge

Skagit River Crossing

Edmonds Ferry Terminal

Modeling Extents

Figure 4-12

MAP OF THE THREE HYPOTHETICAL RELEASE LOCATIONS

Release Scenario Volumes

The scenarios for each of the three selected sites included two potential release volumes of *conditioned* Bakken crude oil, identified as the 30th- and 90th-percentile release volumes:

- A 5,700-barrel release, which corresponds with a 30th-percentile discharge (30PD).
- A 20,000-barrel release, which corresponds with a 90th-percentile discharge (90PD).

Effective April, 1 2015, Bakken crude oil must be conditioned before being transported by rail to reduce volatility and to meet state crude oil safety standards (State of North Dakota Industrial Commission 2014). The intent was to reduce the vapor pressure of Bakken to levels below that of crude oil to decrease the likelihood and potential consequence (i.e., fire and explosion) following a release.

Both release volumes were modeled for 48 hours. Releases were modeled as "unmitigated," meaning that no response actions occurred during the entire 48 hours. An unmitigated release is extremely unlikely given local and regional response capabilities, including the Washington State Emergency Response System, the National Response System, and Shell and BNSF Railway's corporate policies regarding how to respond to accidents and regulatory requirements.

As detailed in Chapter 3.17 – Public Services and Incident Response, the local fire department typically acts as a first responder to such accidents. Normally, response times are on the order of minutes. In addition, Washington State's Spill Response Program is considered a national leader and the State Legislature recently passed new rules to strengthen preparedness and response capabilities. These include measures to require contingency plans for railroads transporting crude oil by rail and notification requirements for the movement of crude by rail through Washington State. The railroads are currently working with the State to implement these programs; however, there is the possibility that the applicability of the programs to the railroads could be challenged in court due to the commerce clause and/or federal preemption.

Unmitigated release scenarios were used to estimate the maximum theoretical extent of impacts. Spill response measures would alter the trajectory and fate of the released oil, depending on the timing of the response, the types of strategies used, and their effectiveness.

Release Scenario Environmental Conditions

The oil release analysis included modeling the seasonal variability of environmental conditions that could affect oil trajectory, fate, and potential impacts.

This analysis included high and low *tides*, river flow, and wind speed conditions. To provide a range of impacts, the single environmental parameter believed to be the most dominant seasonal forcing characteristic (i.e., natural processes driving the movement of oil) for each of the three scenario locations was selected.

For example, at the Swinomish Channel, scenarios were modeled in the summer with a *spring tide* condition and in the winter with a *neap tide* condition. The scenarios modeled at the Skagit River Bridge Crossing used high river flow conditions during the freshet (the flood of a river from heavy rain or snow melt; modeled here during summer) and average low river flow conditions during the winter.

The tides are controlled by the gravitational pull from the sun and the moon. When the sun, Earth, and moon are in alignment, the gravitational pull from the sun and the moon are also aligned. This results in the greatest difference between high and low tide (i.e., high tides are very high and low tides are very low) known as spring tide. When the sun and moon are at a right angle relative to Earth, the gravitational pull from each competes. This results in a smaller difference between high and low tide, known as neap tide.

Factors considered at the Edmonds Ferry Terminal included low-wind speeds (summer) and high-wind speeds (winter). The combination of three potential release locations, two release volumes, and two variations in the dominant seasonal environmental parameter resulted in a total of 12 modeling scenarios (Table 4-16).

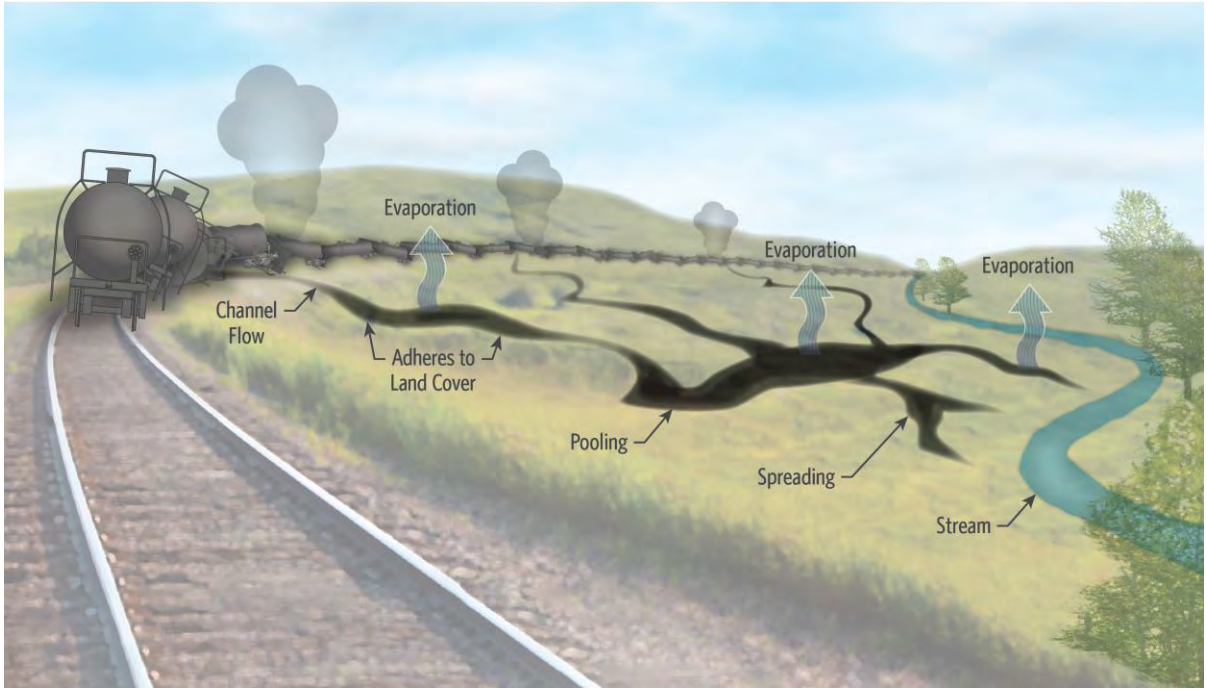
Table 4-16 Release Scenarios and Environmental Conditions

Scenario	Release Location	Seasonal/Environmental Condition	Release Volume (Barrels)
1	Swinomish Channel Swing Bridge	Summer – Spring Tide	20,000 (840,000 gallons)
2			5,700 (239,400 gallons)
3		Winter – Neap Tide	20,000 (840,000 gallons)
4			5,700 (239,400 gallons)
5	Skagit River Crossing	Summer – High River Flow	20,000 (840,000 gallons)
6			5,700 (239,400 gallons)
7		Winter – Low River Flow	20,000 (840,000 gallons)
8			5,700 (239,400 gallons)
9	Edmonds Ferry Terminal	Summer – Low Wind	20,000 (840,000 gallons)
10			5,700 (239,400 gallons)
11		Winter – High Wind	20,000 (840,000 gallons)
12			5,700 (239,400 gallons)

Release Scenario Trajectory and Fate Modeling Methods

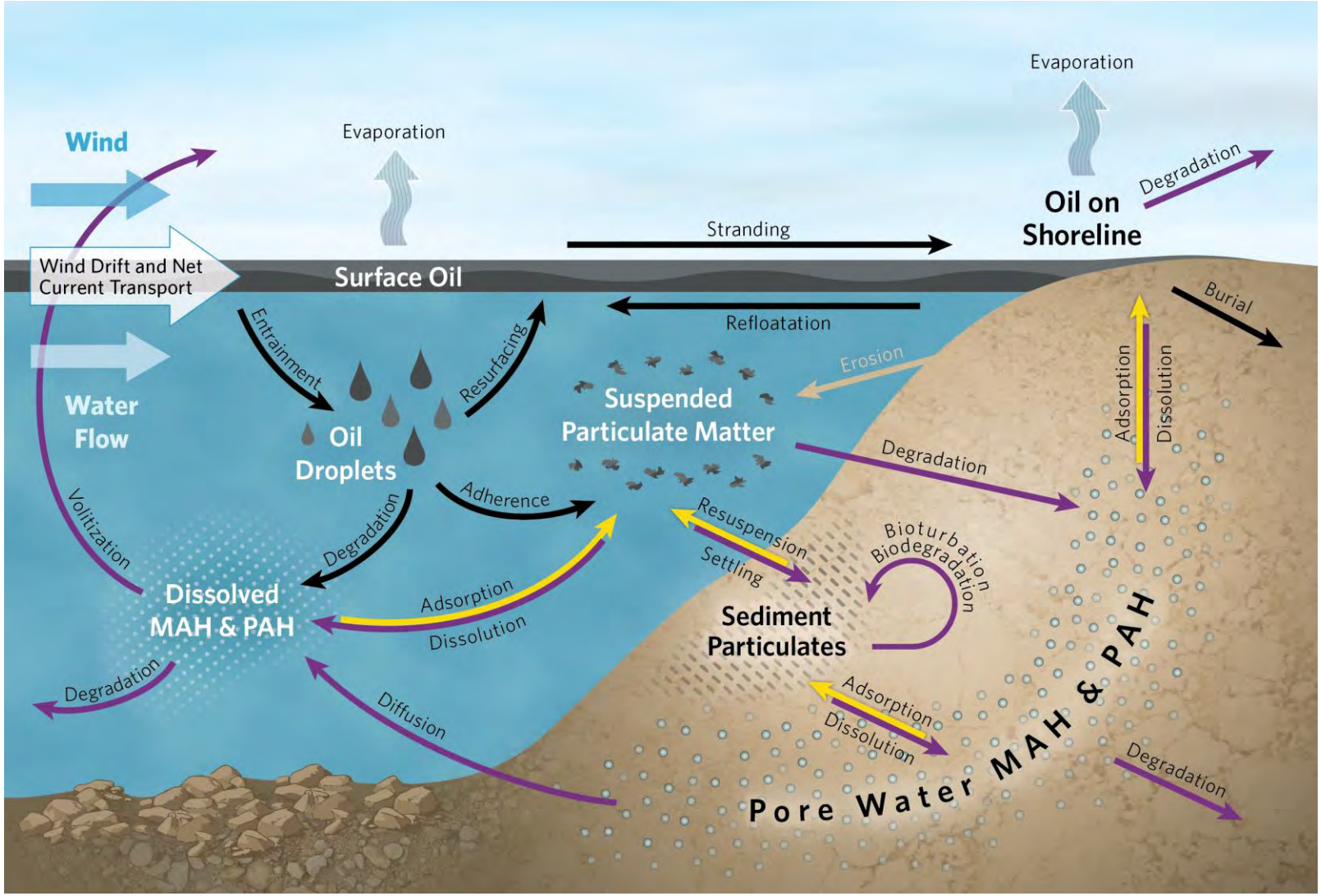
The OILMAP Land and SIMAP models that were used for the proposed project included separate applications for understanding trajectories for oil releases occurring on the land and in the water. OILMAP Land was used at the Edmonds Ferry Terminal scenario to determine how much oil adhered to land, pooled, and evaporated before reaching water (Figure 4-13).

Figure 4-13 Conceptual Diagram of the OILMAP Land Transport Model Depicting the Possible Fate of Oil as it Moves over the Land Surface



The SIMAP model was used at the Swinomish Channel Swing Bridge, Skagit River Crossing, and the Edmonds Ferry Terminal scenarios for the marine and river environments. It provided trajectory and fate information such as shoreline stranding, surface oiling, evaporation, entrainment, emulsification, dissolution, volatilization from the water column, adsorption and sedimentation, and degradation (See Appendix H for definitions). Additionally, this information was used to determine the potential biological impacts (Figure 4-14).

Figure 4-14 Conceptual Model of Oil Fate Processes in Water that are Simulated in the SIMAP Model



Refer to callout box on the next page and Appendix H for a detailed explanation of the technical terms provided in this figure.

The modeling results provided predictions of trajectory and fate for each of the 12 scenarios over the 48-hour release simulation. The results were presented in terms of:

- Mass balance of released oil. Estimates the oil's fate over time, including the amount of oil on the water surface, in the water column, on shorelines, evaporated to the atmosphere, on sediments, and oil that had decayed by natural weathering processes.
- Trajectory. Tracks the movement of each individual particle of released oil in both space and time as droplets of oil in the water column, *dissolved aromatics*, floating surface oil, stranded shoreline oil, and the amount on sediments.
- Surface oil thickness. Predicts floating surface oil and associated thicknesses over space and time.
- Water column concentration. Predicts maximum water column concentrations of dissolved aromatics over space and time. Dissolved aromatics are the portion of the oil having the greatest potential to affect water column animal and plant life.
- Shoreline and sediment impact. Predicts the total mass of oil deposited onto the shoreline and on sediments.

Hydrocarbons are organic compounds that comprise the main components of crude oil. Total hydrocarbons is a measure of the mixture of all different hydrocarbons found in a particular crude oil (i.e., total amount). There are several thousand different hydrocarbons. Whole oil is a combination of tens to hundreds of thousands of hydrocarbon compounds. A portion of these are soluble, meaning they dissolve into the water column. Total dissolved aromatic concentrations include both mono-cyclic aromatic hydrocarbons (MAHs), poly-cyclic aromatic hydrocarbons (PAHs), and others. Approximately 9 percent of Bakken crude oil can dissolve in the water column. Those compounds are typically responsible for biological impacts. The mass balance presents the fate of the oil released in an event (e.g., on shorelines, in/on the water, or evaporated).

Potential Impacts Overlay Analysis and Biological Impacts Assessment Methods

Resource Overlay Analysis

The trajectory and fate results were used to determine the potentially affected resources located within the oil spill footprint for each scenario. Potentially affected resources were compiled on a Geographical Information System (GIS) platform from the National Oceanic Atmospheric Association (NOAA 2016), Washington State Department of Ecology (Ecology 2016), Washington Department of Health (DOH 2016), and the Washington Department of Fish and Wildlife (WDFW 2016). A detailed list of spatial resource data and attributes is provided in Appendix H. Resources were mapped and the trajectory of the modeled release of oil was overlaid onto the resource maps.

Affected resources included the following categories of environmentally sensitive areas:

- Socioeconomic resources: Parks, management areas, public access points, fishing areas, and tribal resources.

- Marine and freshwater resources: Shellfish locations, fish spawning areas, and seal haulout points.
- Avian and terrestrial resources: Bird colonies, nesting areas, wetlands, biodiversity corridors, and wildlife observations.

This overlay analysis was strictly a count of resources that were intersected by the oil trajectory. The counts of affected resources may overstate a portion of the resources potentially affected. That means the counts should be used only to compare the relative impacts from one modeled release to another, rather than as a quantified number of affected resources.

Biological Impacts Assessment

The trajectory and fate modeling results were also used in a biological impacts assessment. The assessment estimated the potential short-term (acute) exposure of organisms to floating oil and subsurface oil contamination (in-water and on sediments), and predicted the resulting percent mortality. The acute exposure level to floating oil was defined as oil on the water surface with a thickness greater than 10 microns (µm). As a point of reference, a piece of regular copy paper is about 100 µm thick and a rainbow sheen of oil on a puddle of water is approximately 0.1 to 1 µm. The acute exposure level for organisms in the water column (i.e., exposure to dissolved aromatics) and sediment varied depending on the specific environment, season, and life stage of each species. For example, an egg or juvenile life stage may be more sensitive to habitat disruption or toxicity than older life stages. To bound this range of potential variations, two sensitivity thresholds for dissolved aromatics were used:

- High sensitivity species: Biological impacts were evaluated assuming these organisms were highly sensitive to dissolved aromatics (5 micrograms per liter [µg/L]), which is protective of 97.5 percent of species.
- Average sensitivity species: Biological impacts were evaluated assuming these organisms had an average sensitivity to dissolved aromatics (50 µg/L), which is protective of 50 percent of species.

Further definition of high and average sensitivity species is provided in Appendix H. For each of the 12 modeled scenarios provided in Table 4-16, acute toxicity for in-water impacts was calculated for the two sensitivity thresholds, resulting in a total of 24 biological modeling scenarios. These results provided a predicted range of potential acute impacts that could occur following a release of oil to the environment. The acute toxicity to aquatic biota within the water column (pelagic species) and bottom-dwelling species that live within the sediment bottom and up to 1 meter above (demersal species) were evaluated by tracking the exposure of both the high sensitivity and average sensitivity species.

Potential acute impacts following a release can vary greatly by space, time, and percent mortality. In some cases, 100-percent mortality may be experienced in localized regions, while much broader areas may experience only partial impacts (<100 percent mortality [death]). Mortality is calculated as percent loss in specified areas. This is translated into the *equivalent area* of 100-percent loss. This analysis simulates potential direct impacts (i.e., acute mortality) and does not necessarily account for food web or delayed impacts to species and populations. These sublethal impacts (i.e., chronic impacts) may occur over broader areas.

The results of the biological exposure model provide estimates of the equivalent area (in square kilometers [km^2]) of 100-percent mortality by behavior group. Exposure to oil often results in less than 100-percent mortality and the percent mortality often varies by area.

To compare the overall impact among release scenarios, the equivalent areas of 100-percent predicted mortality were estimated. For example, the equivalent area of 100-percent mortality would be the same for a release that resulted in 100-percent mortality over 1 km^2 versus 1-percent mortality over 100 km^2.

Resources potentially impacted by surface and shoreline oiling included waterfowl, aerial and diving birds, wetland and terrestrial wildlife, fur-bearing marine mammals, seals, sea lions, whales, and dolphins. Biota potentially impacted by water column toxicity included mobile and stationary bottom-dwelling fish and invertebrates, small fish and invertebrates, bottom-dwelling organisms, and plankton that drift with the currents. Mortality would only occur if the organism were present in the area predicted to be affected by released oil above the aforementioned thresholds. A full description of the acute biological impacts modeling, including selection of thresholds of concern and validation, are provided in Appendix H.

Release Scenario Trajectory and Fate Modeling Results

Among all release scenarios, common outcomes of trajectory and fate were predicted (Figure 4-15):

- Approximately 50 percent of the released oil was expected to evaporate within the first 48 hours.
- Very little oil decay would occur during the first 48 hours.
- The largest percentage of remaining oil would be deposited on shorelines or form surface slicks during the first 48 hours.

These theoretical release scenarios assumed no response actions (i.e., unmitigated) by the State, federal responders, Shell, BNSF Railway, or local emergency responders. In the Skagit River scenarios, the majority of the total volume of oil released was expected to adhere to the shorelines of the Skagit River. In the more open areas modeled near the Swinomish Channel (Padilla Bay), and Edmonds (Puget Sound), less oil was expected to oil shorelines compared with the Skagit River scenarios, where generally more oil remained on the water surface at the end of the 48-hour modeled simulation.

For each of the modeled scenarios, very little oil was expected to remain in the water column and on the sediments (Figure 4-15). The exception was the Edmonds Ferry Terminal high-wind scenarios. In those cases, high winds produced surface breaking waves that were predicted to force more oil into the water column. This would result in oil settling to the sediments. The extent of surface oiling and dissolved aromatic contamination within the water column is presented for each modeled release scenario (Figure 4-16).

In general, these results are driven by the degree of transport that is expected in each scenario, which is dependent on the season and the modeled environmental parameters. The spatial extent for each modeled component ranged greatly, with dissolved aromatics having more variability than surface oil thickness (Figure 4-16). For example, greater tidal action (i.e., the Swinomish Swing Bridge summer scenarios) and high-wind conditions (i.e., the Edmonds Ferry winter scenarios) acted to increase the area impacted by surface oil. Neap tides (lower tidal currents) and low-wind conditions resulted in less area affected by the oil. Similarly, lower river flow conditions resulted in less area oiled relative to high flow conditions.

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Figure 4-15 Fate of Oil at the End of the 48-hour Simulation

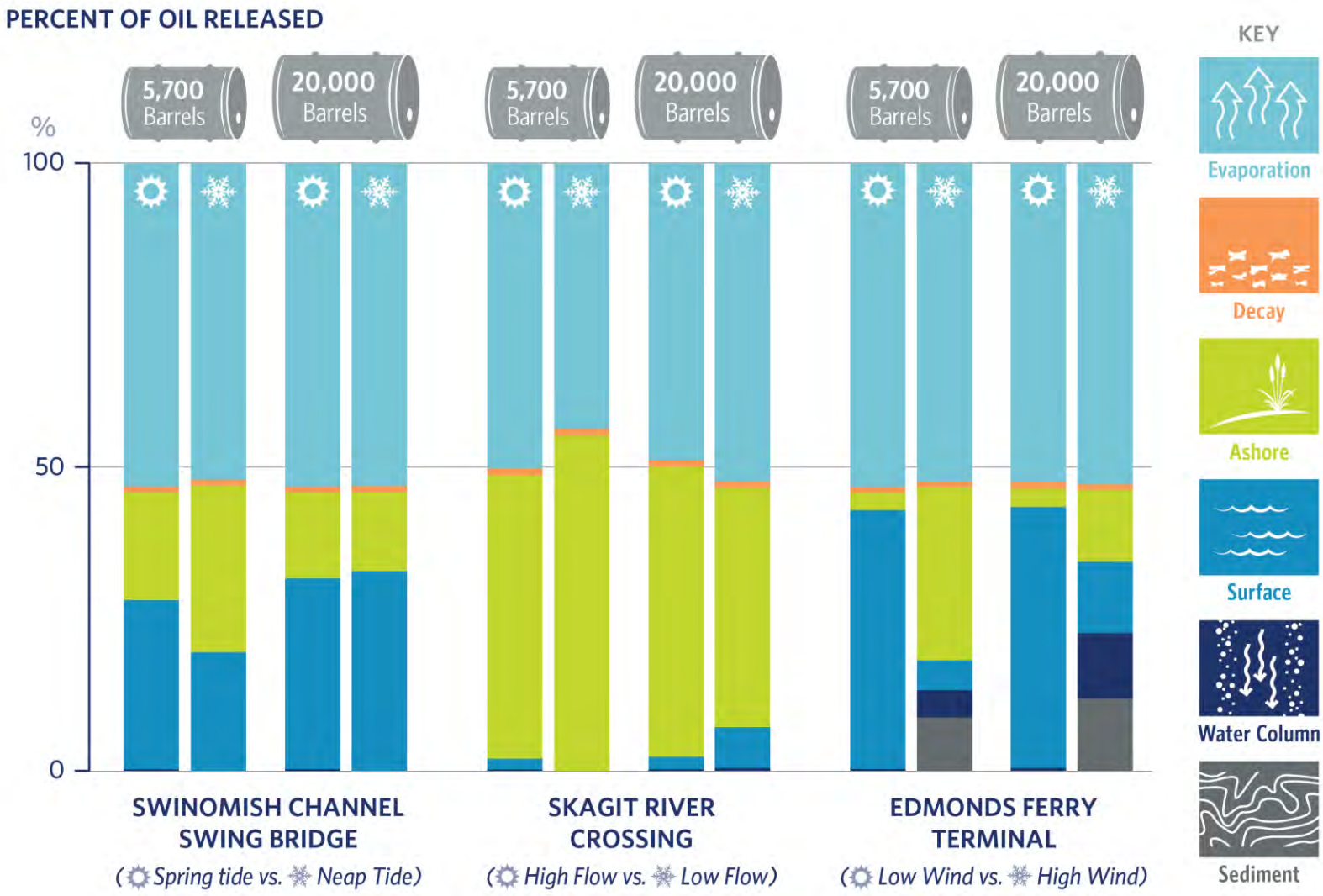

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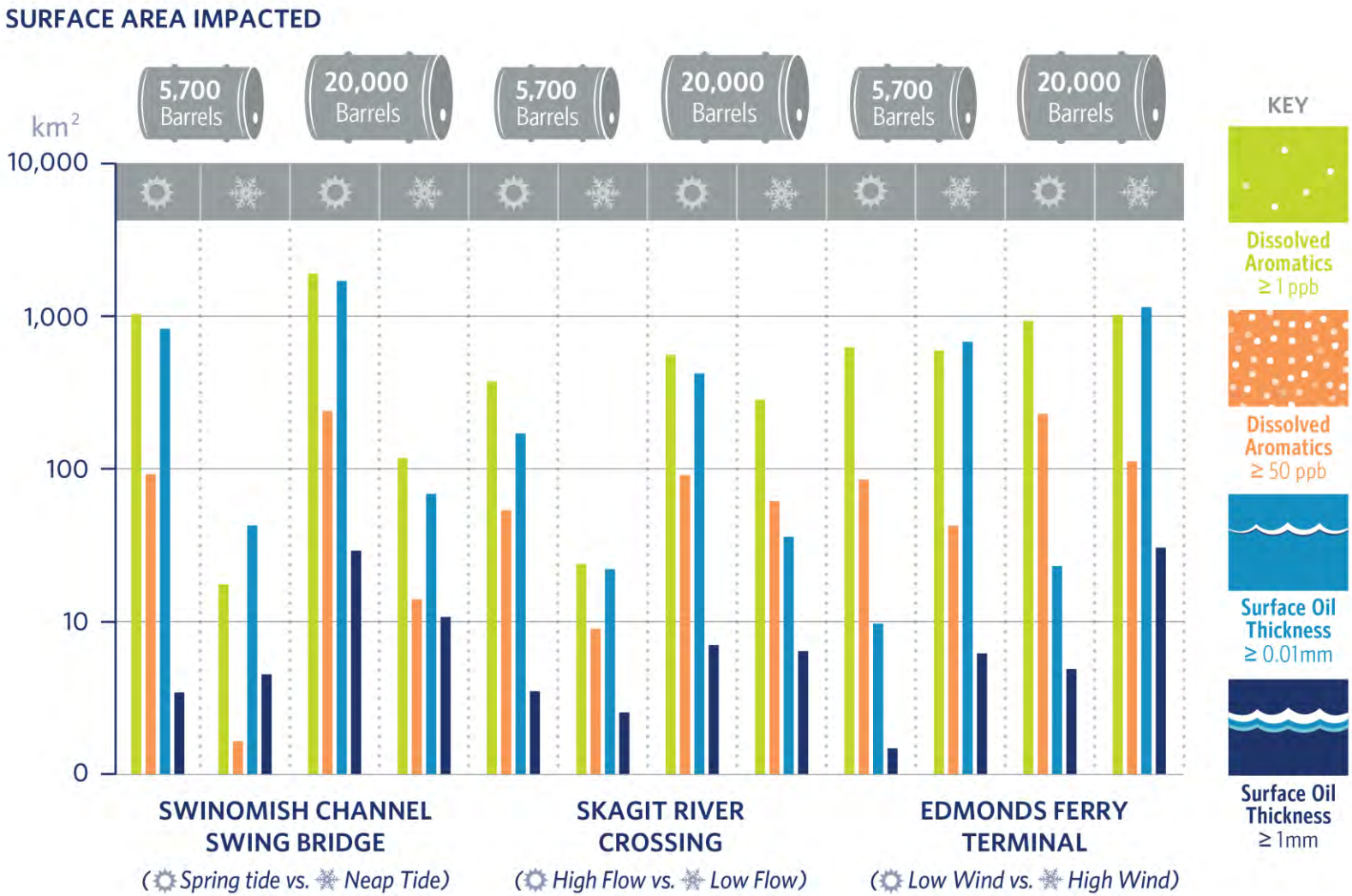
Figure 4-16 Area Experiencing Threshold Exceedance of Dissolved Aromatic Concentration and Surface Oil Thickness for Each of the Modeled Oil Releases



Potential Impacts Overlay Analysis and Biological Impacts Assessment Results

Resource Overlay Analysis

The overlay analysis results included counts of identified resources that could be affected by an oil release. It conservatively assumed that all resources would be present throughout the year for all release scenarios. The results of the overlay analysis provided a general understanding of potentially affected resources including public access, socioeconomic, marine, avian, and terrestrial regions of interest. It also identified sensitive areas that could be affected by released oil. Detailed overlay analysis results are provided in Appendix H.

Oil spill trajectory and fate results in the following sections are summarized in narrative form and in summary tables and figures. Detailed graphics of trajectory and fate results for each release scenario are presented in Appendix H.

For each release scenario, Appendix H presents time series graphics of mass balance depicting where oil would be in the environment from the time of release to the end of the 48-hour simulation.

In addition, Appendix H presents a series of maps depicting aspects of oil release trajectory and fate over the entire 48-hour simulation.

Generally, in the Swinomish Channel Swing Bridge and Skagit River Crossing locations, the summer release scenarios had a broader potential impact to resources than other modeled scenarios. Surf smelt spawning areas, waterfowl areas, and estuarine and marine wetlands were identified as resources that could be affected.

More extensive transport of hydrocarbons was predicted in the following scenarios:

- Edmonds Ferry Terminal high-wind winter scenarios.
- Skagit River high river flow summer scenarios.
- Swinomish Channel summer spring tide scenarios.

This relatively greater transport of hydrocarbons resulted in more potentially affected resources, when compared with their complementary scenarios (e.g., Edmonds Ferry Terminal low-wind scenarios, Skagit River lower river flow winter scenarios, and the Swinomish Channel winter neap tide scenarios).

Biological Impacts Assessment

The biological impacts assessment was used to determine the concentration and duration of exposure that biological receptors (organisms) could experience over the course of the 48-hour modeled release. Impacts were analyzed based on shoreline and surface oiling and in-water concentrations. The magnitude of biological impacts was closely tied to the spatial extent of surface oiling and dissolved aromatics (Figure 4-16).

Among all release scenarios, the greatest impacts from floating oil were on fur-bearing marine mammals, dabbling waterfowl, and surface diving birds. The least impacted groups were the terrestrial wildlife and marine mammals. Maximum in-water impacts were primarily predicted for the sensitive plankton, pelagic fish and invertebrates, and demersal organisms. Potential impacts were much lower for sediment dwelling organisms. By definition, lower impacts were predicted for moderately sensitive species, when compared with high sensitivity species. Detailed biological impacts assessment results are provided in Appendix H.

Among all release scenarios, the greatest impacts from floating oil were on fur-bearing marine mammals, dabbling waterfowl, and surface diving birds. The least impacted groups were the terrestrial wildlife and marine mammals.

Swinomish Channel Swing Bridge

Among the Swinomish Channel Swing Bridge scenarios, the surface and shoreline oil thickness analysis resulted in the largest mortality for all species types investigated within the 20,000-barrel release summer spring tide scenario. This scenario had the largest release volume and maximum spatial extent of surface oiling. Impacts among behavior groups ranged from areas less than 0.05 km^2 to 100.0 km^2.

The resources with the greatest predicted impact were dabbling waterfowl, surface diving birds, and fur-bearing marine mammals. In all release scenarios, there were very small potential areas of 100-percent mortality predicted for whales or dolphins and terrestrial wildlife if they were present in the affected habitat. Exposure of sensitive organisms to oil in the water column or sediment was generally small. Species of moderate sensitivity experienced less potential equivalent areas with 100-percent mortality predicted. Impacts to fish and shellfish may have implications for commercial and recreational harvest.

Skagit River Crossing

Among the Skagit River Crossing scenarios, the surface and shoreline oil thickness analysis indicated that the greatest equivalent areas of 100-percent mortality occurred during the high river flow summer scenarios with the 20,000-barrel release volume. Impacts among behavior groups ranged from areas less than 0.05 km^2 to 94.8 km^2. The resources with the greatest predicted impacts were dabbling waterfowl, surface diving birds, and fur-bearing marine mammals (e.g., otters).

In all release scenarios, there were very limited equivalent areas of 100-percent mortality for whales or dolphins and terrestrial wildlife. Areas of impact for sensitive organisms were generally greatest during the low river flow winter season with the 20,000-barrel release volume.

Impacts to fish and shellfish could affect the operation of both commercial and recreational fisheries.

Edmonds Ferry Terminal

Among the Edmonds Ferry Terminal scenarios, the surface and shoreline oil thickness analysis resulted in the greatest equivalent area of 100-percent mortality during the low-wind summer scenario with the 20,000-barrel release volume. An exception to this general trend included the relatively greater impacts to dabbling waterfowl and nearshore aerial birds during the winter (high-wind) scenarios. Impacts among behavior groups ranged from an area less than 0.05 km^2 to 74.3 km^2. The resources with the greatest predicted impact were aerial seabirds, surface diving birds, and fur-bearing marine mammals. In all release scenarios, the relatively low sensitivity of whales, dolphins, seals and sea lions, and terrestrial wildlife resulted in very limited predicted acute impacts. The greatest exposure was predicted to occur during the high-wind winter scenarios with the 20,000-barrel release volumes.

Potential Cumulative Consequences of a Release

The cumulative frequency of releases from all unit trains would be higher than from proposed project trains alone. As described in Tables 4-3 and 4-4, lower volume releases would be expected to occur with greater frequency than higher volume releases. Crude-by-rail trains associated with the other projects included in the cumulative impacts analysis could be up to 120 tank cars in length (compared with 102 tank cars for proposed project trains). This difference leads to a slightly larger potential release volume than described for the proposed project alone. However, because the volume would only be slightly larger, the analysis of oil spill trajectory, fate, and effects from proposed project trains would apply to the cumulative rail traffic.

FIRE AND EXPLOSION PROBABILITY AND POTENTIAL CONSEQUENCES

This analysis considers the probability and potential consequences of a *fire* and/or *explosion* resulting from an accident during the rail transport of crude oil to the Shell PSR. The probability of a fire or explosion occurring depends on the probability of an accident taking place first. The following types of events could occur and are considered in the analysis:

- Pool Fire. This is a fire that burns from a pool of vaporizing fuel. The primary concern with pool fires is hazards associated with increased temperatures from heat. For crude-by-rail trains, a pool fire could occur if there was an accident leading to a release of crude oil that formed a pool and then caught fire.
- Vapor Cloud Explosion. A vapor cloud explosion is the result of a flammable material that is released into the atmosphere, encounters both congestion and confinement, and ignites. The primary concern with a vapor cloud explosion is overpressure (pressure caused by a *shockwave*). If oil were released during a crude-by-rail accident, light

A fire occurs when fuel combines with oxygen to generate heat, smoke, and light.

An explosion is a sudden, intense release of energy that often produces a loud noise, high temperatures, and a shockwave.

A shockwave is a movement of extremely high pressure air.

hydrocarbons in the oil could evaporate into the air and form a vapor cloud. An explosion would not be immediate, but occur only if the vapor cloud had formed and then ignited.

- Boiling Liquid Expanding Vapor Explosion (BLEVE). A *BLEVE* is an explosion that results when a tank of combustible liquid (in this case, crude oil) is heated by fire and the pressure inside the tank car increases to the point where it weakens the tank and ruptures. The concerns with a BLEVE are the generation of overpressure and projectiles from the explosion. A BLEVE could occur if tank cars containing crude oil were exposed to the flames of a pool fire. This could lead to a sudden explosive rupture and ignition.

DOT-117 Tank Cars (Figure 4-11) are designed to minimize the risk of a BLEVE through improved thermal protection measures incorporated into the design of the tank cars (USDOT 2014).

Although the probability of fire and explosion in association with an accident is low; if a fire or explosion were to occur, the consequences could be substantial.

Approach to Fire and Explosion Analysis

To evaluate the potential consequences associated with fire and explosions, potential events were modeled at the same three scenario locations used for the oil release analysis. At each location, the objective of the analysis was to present areas that could be affected by a pool fire, a vapor cloud explosion, or a BLEVE.

Thermal Radiation (Heat) from a Pool Fire

Thermal radiation is the process by which energy (heat) is emitted from a source, such as the combustion of a flammable material. If a pool of released crude oil ignited, it would emit potentially harmful levels of heat that could cause property damage or human health and safety effects. At each location, the extent of heat generated by a pool fire was modeled by varying:

- The size of the pool (which is dependent on whether the pool forms on land or water and the local topography).
- The quantity of oil released.
- The amount of elapsed time between release and ignition (*early* vs. *late* pool fire).

An early pool fire occurs when the ignition of the pool takes place immediately following the release. During a late pool fire, ignition occurs at a later time.

An early pool fire is generally smaller in area than a late pool fire because it has less time to spread.

The analysis assumed that there were no obstructions, such as existing buildings or structures, to reduce the area affected by thermal radiation; therefore, the results presented are conservative.

The impacts of thermal radiation on the human body depend primarily on the level of heat generated, the duration of exposure, and the ease of escape or finding shelter. Exposure to thermal radiation requires line of sight to the source. Therefore, exposure can be avoided by hiding behind an object or escaping. Table 4-17 presents the impacts on the human body that could be expected at different thermal radiation exposure levels.

Table 4-17 Impacts of Exposure to Thermal Radiation on the Human Body

Thermal Radiation (kW/m^2)	Impact on the Human Body	Ability to Escape or Find Shelter
4 kW/m^2	Pain within 15 to 20 seconds and injury after 30 seconds	Escape or finding shelter is likely if available
6 kW/m^2	Pain within approximately 10 seconds	Escape or finding shelter is possible, but only during a very short period of time
12.5 kW/m^2	Extreme pain within 20 seconds of exposure; fatality if escape is not possible	Movement to shelter is instinctive
20 kW/m^2	Incapacitation, leading to fatality unless rescued	Escape or finding shelter is not possible
35 kW/m^2	Immediate fatality	Escape or finding shelter is not possible

Source: OGP 2010.

Overpressure from a Vapor Cloud Explosion or BLEVE

Overpressure is the pressure caused by a shockwave over and above normal atmospheric pressure. It is measured in pounds per square inch (psi). If a crude-by-rail accident resulted in a vapor cloud explosion or BLEVE, it could generate a potentially harmful shockwave. At each modeling location, the extent of overpressure resulting from specific vapor cloud explosions was modeled by varying the quantity of oil released, the size of the pool, and the ambient weather conditions (including wind speed, humidity, temperature, and air turbulence). Figure 4-17 presents the impacts on structures and the human body that could be expected at different overpressure levels.

The extent of overpressure from a BLEVE was modeled by varying the number of tank cars that would be involved. The results for the BLEVE modeling would be the same at all three locations.

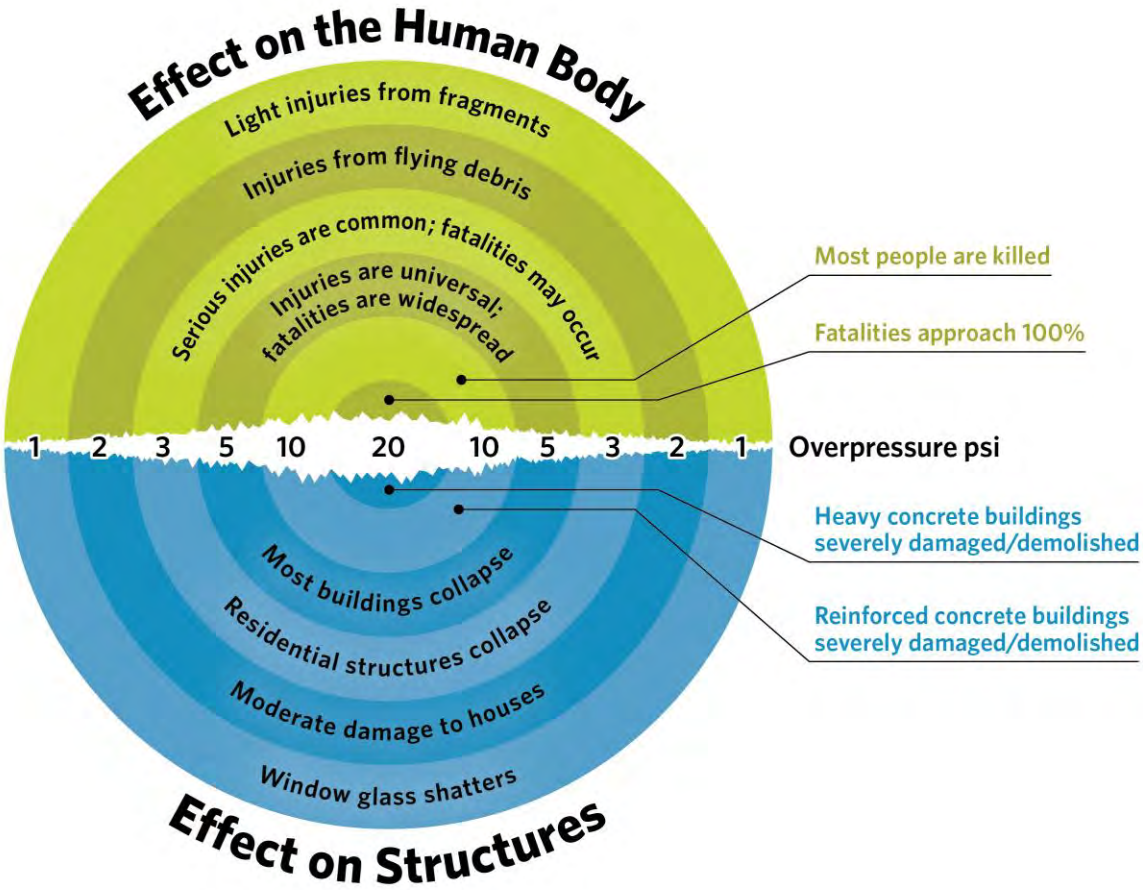
Probability of a Fire or Explosion

The probability of a fire or explosion in the event of an oil release is dependent on an accident and release first occurring. The expected frequency of a fire or explosion was calculated using the spill frequency rates and the probability of a fire or explosion occurring during a spill.

> The return period of a fire or explosion is the amount of time, on average, that passes between consecutive events of a similar magnitude.

Based on a review of historic fires in the petrochemical industry (Cox et al. 1990), there would be an 8-percent probability of an ignition leading to a fire in the event of a spill. Of these ignited events, there is a 30-percent probability of that fire resulting in a vapor cloud explosion. Table 4-18 outlines the expected frequencies and return periods of a fire or explosion based on combining these probabilities with the spill frequencies calculated above.

Figure 4-17 Impacts of Overpressure on Structures and the Human Body



Source: CDC 2016.

Although physically possible, there have been no BLEVEs involving crude-by-rail trains in the United States. There were roughly a dozen BLEVE events documented in the 40 years of reviewed freight train data from the FRA (FRA 2016). All of these BLEVEs involved cargoes of lighter hydrocarbon products with greater volatility (e.g., liquid petroleum gas, ethanol, mineral spirits), and, as such, are not comparable to crude oil. Because no crude-by-rail train accidents involving BLEVEs have taken place, it is not possible to perform a statistical estimate; therefore, the probability of a BLEVE occurring was not calculated.

Table 4-18 Frequency and Return Period of a Fire or Explosion in the Event of a Release

	High Estimate Evaluation			Low Estimate Evaluation		
	Frequency (Event/Year)	Average Return Period (Years)	Probability **("Odds")** in a Given Year	Frequency (Event/Year)	Average Return Period (Years)	Probability **("Odds")** in a Given Year
Oil Release	0.046	22	1 in 22	0.0055	180	1 in 180
Pool Fire	0.0037	270	1 in 270	0.00044	2,300	1 in 2,300
Vapor Cloud Explosion	0.0011	910	1 in 910	0.00013	7,600	1 in 7,600

Potential Pool Fire Hazard Range

In the event of a crude oil pool fire, the resulting *thermal radiation* from the ignited pool was analyzed. Table 4-19 presents the distances from the center of the source pool fire at which different modeled levels of thermal radiation would be experienced during early and late pool fires. The extent of heat generated by a pool fire would vary depending on the size of the pool, the quantity of oil released, and the amount of time that elapses between release and ignition (early vs. late pool fire).

When a person is 203 meters (666 feet) away from the center of the pool fire, the individual would experience pain within 15 to 20 seconds of exposure (equivalent to 4 kW/m^2). Within this area, there was a smaller area 74 meters (243 feet) from the source where the thermal radiation level reached 12.5 kW/m^2. At this radiation level, extreme pain would result within 20 seconds of exposure and mortality would reach 50 percent after 80 seconds of uninterrupted exposure.

None of the modeled scenarios resulted in thermal level rise to a point where immediate fatalities would occur (35 kW/m^2). This is why no values are presented in Table 4-19 for the extent of thermal radiation that would cause immediate fatalities.

Exposure to thermal radiation requires line of sight to the source. Therefore, exposure could be minimized by hiding behind an obstacle. To be conservative, the thermal radiation values presented throughout this analysis are worst case, where no cover is available.

As an example, Figure 4-18 presents the hypothetical thermal radiation levels at each modeled location for a 28- to 30-car release with medium winds. Appendix I presents the graphical representations for all of the modeled scenarios presented in Table 4-19.

Table 4-19 Thermal Radiation Hazards From a Pool Fire

			Level of Thermal Radiation					
			Pain within 15 to 20 seconds and injury after 30 seconds (4 kW/m²)		Extreme pain within 20 seconds; fatality if escape is not possible (12.5 kW/m²)		Immediate fatality (35 kW/m²)	
			Maximum Distance from Pool Fire (meters [feet])					
Location	Release Size	Wind Speed	Early Pool Fire	Late Pool Fire	Early Pool Fire	Late Pool Fire	Early Pool Fire	Late Pool Fire
Swinomish Channel Swing Bridge	5,700-Barrel Release (7-8 Cars)	Medium Wind	114 m (374 ft)	168 m (551 ft)	46 m (151 ft)	70 m (230 ft)	--	--
		High Wind	136 m (446 ft)	203 m (666 ft)	49 m (161 ft)	74 m (243 ft)	--	--
	20,000-Barrel Release (28-30 Cars)	Medium Wind	114 m (374 ft)	168 m (551 ft)	46 m (151 ft)	70 m (230 ft)	--	--
		High Wind	136 m (446 ft)	203 m (666 ft)	49 m (161 ft)	74 m (243 ft)	--	--
Skagit River Crossing	5,700-Barrel Release (7-8 Cars)	Medium Wind	114 m (374 ft)	165 m (541 ft)	46 m (151 ft)	69 m (226 ft)	--	--
		High Wind	136 m (446 ft)	199 m (653 ft)	48 m (157 ft)	72 m (236 ft)	--	--
	20,000-Barrel Release (28-30 Cars)	Medium Wind	114 m (374 ft)	165 m (541 ft)	46 m (151 ft)	69 m (226 ft)	--	--
		High Wind	136 m (446 ft)	199 m (653 ft)	48 m (157 ft)	72 m (236 ft)	--	--
Edmonds Ferry Terminal	5,700-Barrel Release (7-8 Cars)	Medium Wind	56 m (184 ft)	56 m (184 ft)	19 m (62 ft)	19 m (62 ft)	--	--
		High Wind	67 m (220 ft)	67 m (220 ft)	21 m (69 ft)	21 m (69 ft)	--	--
	20,000-Barrel Release (28-30 Cars)	Medium Wind	66 m (217 ft)	66 m (217 ft)	22 m (72 ft)	22 m (72 ft)	--	--
		High Wind	75 m (246 ft)	75 m (246 ft)	23 m (75 ft)	23 m (75 ft)	--	--

Note: The 35 kW/m² level of thermal radiation was not reached under any scenario. The modeling at the Edmonds Ferry Terminal includes analysis of land and water; however, the maximum modeled distance was the same over both land and water so only one value is reported.

Figure 4-18 Example of Pool Fire Thermal Radiation Levels from a 28- to 30-Car Release with Medium Winds

Potential Vapor Cloud Explosion Hazard Range

In the event of a vapor cloud ignition, the resulting overpressure from an explosion was analyzed. Table 4-20 presents the distance from the explosion at which different levels of overpressure would be experienced. The extent of overpressure resulting from vapor cloud explosions would vary depending on the quantity of oil released, the size of the pool, and the ambient weather conditions (including wind speed, humidity, temperature, and air turbulence).

The overpressure level at which window glass would shatter and light injuries from fragments would result (1 psi) extended on land up to 777 meters (2,549 feet). Over water, the 1 psi level extended up to 1,204 meters (3,950 feet). Within the 1 psi level, there was a smaller area where the psi level reached 3.5. At this level, which extended up to 509 meters (1,670 feet), residential structures would collapse and serious injuries would be common.

Over water, the 3.5 psi level extended to 938 meters (3,077 feet). Within the 3.5 psi level, there was a smaller area where the psi level reached 8. At this level, which extended up to 444 meters (1,457 feet), destruction of buildings would occur and most people would be killed. Over water, the 8 psi level extended to 729 meters (2,392 feet). As an example, Figure 4-19 presents the overpressure levels at each modeled location for a 28- to 30-car release with medium winds. Appendix I presents the graphical representations for all of the modeled scenarios presented in Table 4-20.

Potential BLEVE Hazard Range

In the event of a BLEVE, the resulting overpressure from the explosion was analyzed. Table 4-21 presents the distance from the explosion at which different levels of overpressure would be experienced. During a BLEVE involving one tank car at any of the three potential event sites, the 1 psi overpressure level (where glass shatters and light injuries result from fragments) extended approximately 157 meters (516 feet); the 3.5 psi overpressure level (where residential structures collapse and serious injuries are common) extended approximately 74 meters (243 feet).

Table 4-20 Overpressure from a Vapor Cloud Explosion

			Level of Overpressure		
			Window glass shatters and light injuries from fragments (1 psi)	Residential structures collapse and serious injuries are common (3.5 psi)	Destruction of buildings and most people are killed (8 psi)
Location	Release Size	Wind Speed	Maximum Distance from Vapor Cloud Explosion (meters [feet])		
Swinomish Channel Swing Bridge	5,700-Barrel Release (7-8 Cars)	Medium Wind	1,164 m (3,819 ft)	837 m (2,746 ft)	758 m (2,487 ft)
		High Wind	615 m (2,018 ft)	428 m (1,404 ft)	383 m (1,257 ft)
	20,000-Barrel Release (28-30 Cars)	Medium Wind	1,156 m (3,793 ft)	834 m (2,736 ft)	756 m (2,480 ft)
		High Wind	614 m (2,014 ft)	428 m (1,404 ft)	383 m (1,257 ft)
Skagit River Crossing	5,700-Barrel Release (7-8 Cars)	Medium Wind	777 m (2,549 ft)	509 m (1,670 ft)	444 m (1,457 ft)
		High Wind	443 m (1,453 ft)	288 m (945 ft)	251 m (823 ft)
	20,000-Barrel Release (28-30 Cars)	Medium Wind	773 m (2,536 ft)	508 m (1,667 ft)	444 m (1,457 ft)
		High Wind	442 m (1,450 ft)	288 m (945 ft)	250 m (820 ft)
Edmonds Ferry Terminal	5,700-Barrel Release (7-8 Cars)	Medium Wind	Water: 1,204 m (3,950 ft) Land: 317 m (1,040 ft)	Water: 938 m (3,077 ft) Land: 172 m (564 ft)	Water: 729 m (2,392 ft) Land: 119 m (390 ft)
		High Wind	Water: 599 m (1,965 ft) Land: 221 m (725 ft)	Water: 440 m (1,444 ft) Land: 129 m (423 ft)	Water: 402 m (1,319 ft) Land: 106 m (348 ft)
	20,000-Barrel Release (28-30 Cars)	Medium Wind	Water: 1,045 m (3,428 ft) Land: 273 m (896 ft)	Water: 790 m (2,592 ft) Land: 148 m (486 ft)	Water: 729 m (2,392 ft) Land: 119 m (390 ft)
		High Wind	Water: 599 m (1,965 ft) Land: 221 m (725 ft)	Water: 440 m (1,444 ft) Land: 129 m (423 ft)	Water: 402 m (1,319 ft) Land: 106 m (348 ft)

Note: The modeling at the Edmonds Ferry Terminal includes analysis of both land and water.

Figure 4-19 Example of Vapor Cloud Explosion Overpressure Levels from a 28- to 30-Car Release with Medium Winds

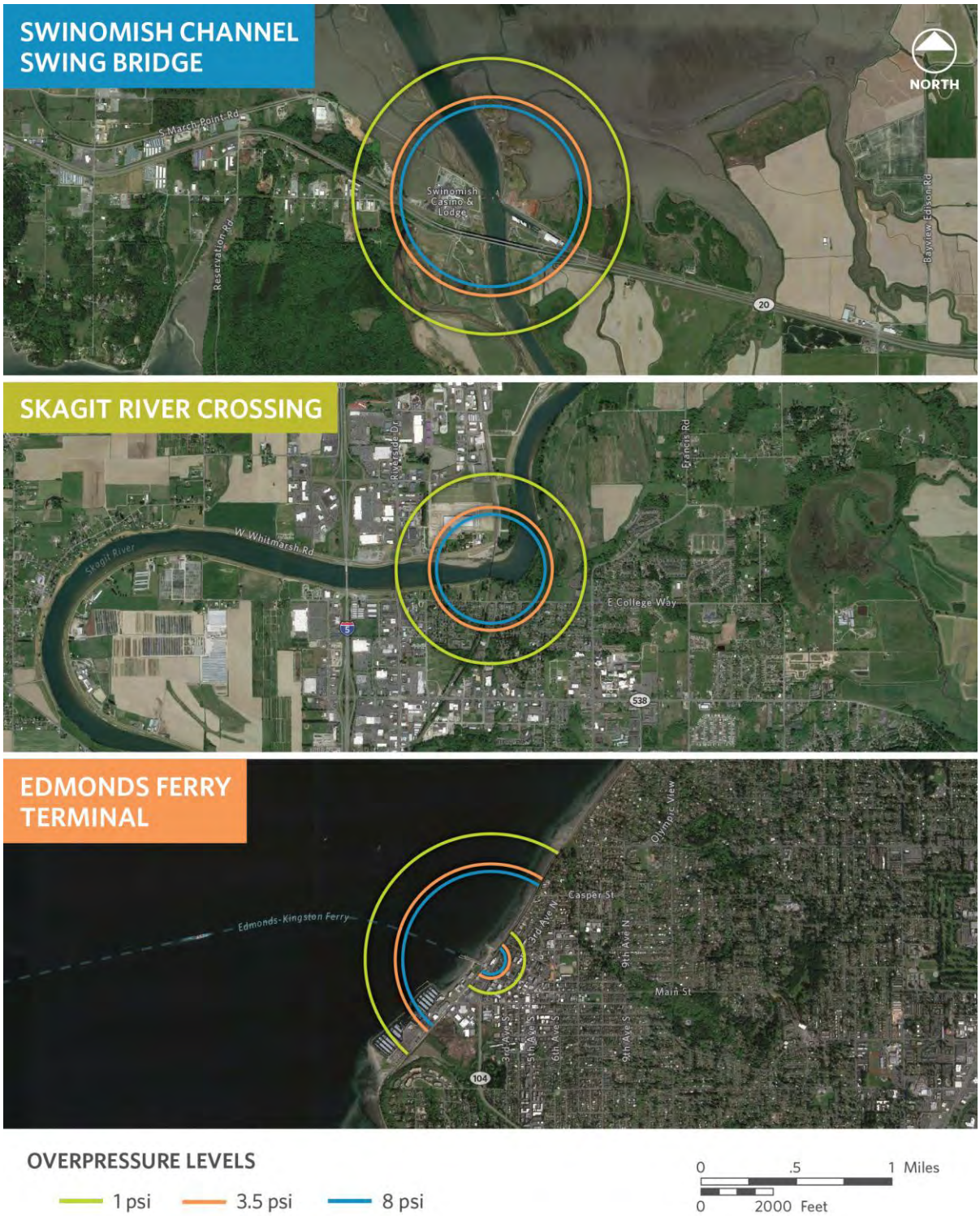


Table 4-21 Overpressure from a Potential BLEVE

	Level of Overpressure		
	Window glass shatters and light injuries from fragments (1 psi)	Residential structures collapse and serious injuries are common (3.5 psi)	Destruction of Buildings and most people are killed (8 psi)
	Maximum Distance from BLEVE (meters [feet])		
1 tank car (650 barrels)	157 m (515 ft)	74 m (243 ft)	46 m (151 ft)
7 tank cars (4,550 barrels)	300 m (984 ft)	142 m (466 ft)	88 m (289 ft)
28 tank cars (18,200 barrels)	476 m (1,562 ft)	225 m (738 ft)	139 m (456 ft)

Cumulative Probability and Consequences of a Fire or Explosion

As described in Chapter 1 – Introduction, four refineries in Washington currently receive crude by rail from the mid-continent area. If all facilities, including the proposed project, were approved and implemented, weekly trainloads of crude oil in the state would increase to approximately 70 trains from the current level of approximately 21 trains.

The cumulative probability of a fire or explosion in the event of a release depends on an accident and release first occurring. As such, the cumulative high and low estimate evaluations for the 70 possible weekly trains was calculated based on the probability of an accident occurring from the previously described probability analysis. The cumulative High Estimate is a purposefully conservative evaluation of the probability of an accident and release occurring based on the historic rates of accidents and releases. As outlined in Table 4-22, the cumulative High Estimate frequency of a pool fire would be 0.038 pool fires per year or, on average, one pool fire every 26 years (compared with a frequency of 0.00037 pool fires per year or, on average, one release every 270 years for proposed project trains). In other words, there is a 1 in 26 chance that a pool fire would occur in any given year. The cumulative High Estimate frequency of a vapor cloud explosion would be 0.012 events per year or, on average, one vapor cloud explosion every 87 years. In other words, there is a 1 in 87 chance that a vapor cloud explosion would occur in any given year. For comparison, the frequency of a vapor cloud explosion per year for the proposed project trains would be 0.0011 events per year, or one vapor cloud explosion every 911 years.

The cumulative Low Estimate incorporates the various safety measures specific to crude-by-rail unit trains that have been, or are anticipated to be, implemented to make trains safer. These include positive train control, enhanced braking, wayside detectors and track upgrades. Several of these measures would need to be sustained over time for the release rate probabilities to remain constant (e.g., improved track maintenance). The cumulative Low Estimate frequency of a pool fire would be 0.0055 pool fires per year or, on average, one pool fire every 180 years. In

other words, there is a 1 in 180 chance that a pool fire would occur in any given year. For comparison, the frequency of pool fires per year (average) for the proposed project trains would be 0.00044 pool fires per year or, on average, one release every 2,290 years. The cumulative Low Estimate frequency of a vapor cloud explosion would be 0.00166 events per year, or one vapor cloud explosion every 600 years. In other words, there is a 1 in 600 chance that a vapor cloud explosion would occur in any given year. For comparison, the frequency of vapor cloud explosions (average per year) for the proposed project trains would be 0.00013 events per year or, on average, one vapor cloud explosion every 7,617 years.

Table 4-22 shows the probability of an explosion or fire if all crude-by-rail projects proposed in Washington State were constructed and the number of unit trains operating in the state increased to about 70 per week. The probability of an explosion or fire involving a proposed project unit train is independent of the total number of unit trains operating in the state and would not change if more crude-by-rail projects were constructed. However, in general, if the number of unit trains increased, the overall probability of an explosion or fire would be higher. Regardless of the probability, the potential consequences from an individual accident resulting in a release, fire, or explosion would be similar to that described above.

Table 4-22 Cumulative Frequency and Return Period of a Fire or Explosion in the Event of a Release

	High Estimate Evaluation			Low Estimate Evaluation		
	Frequency (Event/Year)	Average Return Period (Years)	Probability in a Given Year	Frequency (Event/Year)	Average Return Period (Years)	Probability in a Given Year
	Shell Unit Trains Estimate					
Oil Release	0.046	22	1 in 22	0.0055	180	1 in 180
Pool Fire	0.0037	270	1 in 270	0.00044	2,300	1 in 2,300
Vapor Cloud Explosion	0.0011	910	1 in 910	0.00013	7,600	1 in 7,600
	Cumulative Estimate					
Oil Release	0.48	2.1	1 in 2.1	0.069	14	1 in 14
Pool Fire	0.038	26	1 in 26	0.0055	180	1 in 180
Vapor Cloud Explosion	0.012	87	1 in 87	0.0017	600	1 in 600

REGIONAL ECONOMIC RISK

Releases of oil from unit trains can have wide-ranging economic consequences. The public expressed concerns about potential economic impacts of a crude-by-rail accident during the scoping process (Skagit County and Ecology 2015). The potential consequences described below are hypothetical and are meant to encompass the types and range of impacts that could occur rather than offer a complete accounting of all the potential impacts. The impacts begin with the occurrence of a release at a specific location, time, and rate with a certain size, toxicity, and duration.

Approach to Economic Risk Analysis

This analysis focuses on the potential indirect consequences of a release of oil. The direct economic impacts of a release (i.e., the loss of crude oil revenue) were not evaluated. The indirect consequences are the damages that are imposed upon third parties, such as the public or natural resources. By definition, third parties would not be involved in the transport of crude oil that resulted in a release into the environment. Some indirect consequences may eventually be offset by direct compensation, either from government programs or through litigation. In Washington State, under state law (RCW 90.56.370), anyone responsible for spilling oil into state waters is liable for damages resulting from injuries to public resources. The process for determining damages is defined in the Oil Spill Natural Resource Damage Assessment rule (WAC 173-183).

The potential economic consequences may be both market- and nonmarket-based. Market-based damages are those that are felt directly in market transactions. Examples include losses in aquaculture, agriculture, commercial fishing, transportation services, damages to private property, reductions in the hospitality industry, or increased employee absenteeism from impaired health. Nonmarket damages include losses of ecosystem function, risks to public health, impairments to public recreation, or decreases in *nonuse values*.

> Nonuse values represent the willingness of households to pay to avoid environmental damage to an environmental resource even if they never have and never will use the resource.

Potential consequences may be short term or long term. Short-term impacts are more immediate. They include decreases in tourism that would affect the hospitality industry during the initial release phase and last through the containment, cleanup, and restoration phases of the release. Longer-term impacts may take years to play out and include reductions in the salmonid stock, which could reduce commercial fishery harvests in future years due to losses of juvenile populations.

Some consequences may have both short-term and long-term impacts, e.g., health-related impacts. Cleanup workers may suffer immediate impacts from prolonged exposure to toxic chemicals released from the crude oil, such as developing rashes and other ailments. Long-term health impacts could result years later from cancers and other conditions as a result of exposure.

This evaluation of the potential economic consequences is organized using three major consequence categories: environmental, economic, and social (Table 4-23). The damages would range considerably, depending on environmental factors and where the release occurred (e.g., in aquatic or terrestrial habitat; in a rural or urban area; or during calm or windy conditions).

Table 4-23 Potential Economic Consequences Categories

Environmental	Economic	Social
Ecosystem Services	Commercial Fishing	Public Health Impacts
Nonuse Values	Transportation	Psychological Stress
Water Recreation	Private Property Loss or Damage	Public Recreation
	Tourism	
	Related Industries	
	Employee Health (Absenteeism)	
	Aquaculture	

Potential Economic Consequences of a Release of Oil

The potential economic consequences of an oil release resulting from the proposed project are discussed below for each category outlined in Table 4-23. While most of the damages of a release tend to be negative in value, some impacts can be offsetting. For example, a release may decrease tourist activities. The decrease in tourism could reduce sales of goods and services in hospitality and related industries (e.g., food, lodging, miscellaneous retail, and gas). During cleanup of the release, workers supported by government aid would likely spend dollars received, thereby offsetting some of the impacts to the local economy. Similarly, government relief programs or litigation could also help recoup some of the economic damages.

Environmental Consequences

Ecosystem Services

Ecosystem services are the beneficial outcomes that result from *ecosystem functions* such as support of the food chain, harvesting of animals or plants, and the provision of clean water or scenic views. A release of crude oil in an ecosystem could impair one or more of the functions and services. For example, a release occurring near estuarine wetlands could damage wetland vegetation. The die-off of plants could destabilize local soils, increasing the risk of erosion. It could also reduce the natural flood protection provided by estuarine wetlands.

> Ecosystem functions are the physical, chemical, and biological processes that contribute to the self-maintenance of an ecosystem. Some examples of ecosystem functions are carbon cycling, removal of nutrients and pollutants from water bodies, and flood risk reduction.

Nonuse Values

Nonuse values represent the willingness of individuals to pay for avoiding damages to an ecosystem, apart from the direct use (such as fishing) or indirect use (such as ecosystem services) of that system. People tend to care about events that reduce fish populations, kill birds, or

damage habitat even if they never directly interact with those species or habitat. Nonuse values are not localized and tend to have wide-reaching effects.

A release of crude oil into local waters could kill salmon. The loss of salmon would have a damage value beyond the impacts on sport and commercial fishing industries. There are many studies on salmon that demonstrate their value to Washington State residents and tribes. This value comes from knowing that the fish exist. Even though people may not receive a direct benefit through interaction (e.g., commercial or sport fishing), they are willing to pay to preserve them. As such, any ecological impact on local salmon stocks would have an impact on nonuse values, which would be in addition to those measured by the direct impacts on the fisheries production. Further, as described in Chapter 3.8 – Treaty and Traditionally Used Resources, Swinomish Tribe members have been harvesting salmon within the study area since ancient times (Goren 2012). These resources are considered by the Swinomish to be culturally significant and represent their connection with the environment.

Water Recreation

Water-based recreation is a broad category including all paid water recreation, such as boating, scuba diving, and sport fishing. Water recreation is often valued based on the expenditures of individuals to take part in the activities. For example, an angler will spend money on bait and tackle to catch fish; purchase a permit; or charter a boat. Damages would be measured as the lost revenue that individuals would have spent on trips that were cancelled because the recreation resource had been impaired.

If a release of crude oil were to occur in the vicinity of either the Swinomish Channel marinas or the Swinomish Channel boat launches, for example, recreational boating could be affected in two ways. First, the amount of money that boaters would spend on recreational trips to the channel would decrease. Second, for boats that were docked in the water and damaged by the release, boat owners would be economically impaired by additional maintenance costs. These damages are realized as increases in operation, maintenance, and repair costs for boats and equipment, as well as in insurance claims for losses.

Economic Consequences

Commercial Fishing

Damages to commercial fisheries accrue from decreases in fish populations and revenues to fishermen. As described above, population reductions may occur to species such as coho salmon, Chinook salmon, chum salmon, sockeye salmon, steelhead, Dolly Varden, herring, halibut, and shellfish. Damages could result in the short term from mortality of adult fish in an area of a release. Damages could also occur over a longer period as a result of impacts to spawning grounds and juvenile fish populations. Damages to habitat may result in the movement of fishery populations away from traditional grounds.

Following a high-volume release, substantial reductions in populations can result in closures of fisheries until the population recovers. Decreases in market confidence about the safety of eating the fish may occur, leading to a drop in the price of fish or the outright rejection of seafood products by commercial buyers and consumers. In addition to production impacts for commercial fisheries, oil in the water can damage marine vessels, equipment, and engines if

fishing activities occur in the vicinity of an uncontained release. These damages could increase operational costs for commercial fisheries through added repair costs.

As described above, a crude oil release in Puget Sound could impact commercial fisheries in a number of ways. Direct contact between salmonid populations and oil could lead to immediate mortality of salmon stocks in local waters because crude oil could contaminate fish and make them unsafe for human consumption. These impacts would reduce the available harvest for both tribal and nontribal commercial fisheries and decrease revenues for locally caught salmon species.

If a ban on fishing in local waters were to occur, fishermen could go out of business. Others might seek temporary fishing grounds farther away, which would increase their operational costs and lower net revenues. There could also be future damages to the local salmonid commercial fishery if juvenile fish stocks are affected through direct mortality, loss of habitat, or loss of spawning grounds. This could lead to additional impacts on the commercial fisheries in the form of lost production and revenue.

Aquaculture

The potential consequences to aquaculture would be similar to those described for commercial fisheries. The most serious threat that releases of oil pose to aquaculture activity is the economic losses from business interruption. Population reductions can result in closures of fisheries until the populations recover. Decreases in market confidence could occur, leading to a drop in the price of fish or outright rejection of seafood products by commercial buyers and consumers.

A marine release could impact salmon net-pen operations and commercial shellfish beds. Direct contact between the fish and shellfish populations and crude oil could lead to immediate mortality. In addition, fish exposure to crude oil could leave them contaminated and unsafe for human consumption. Both impacts would reduce the available harvest, thereby leading to a decrease in revenues.

Transportation

Damages from closures to the transportation network can impact individuals and businesses. The value of a person's time because of delays is considered when assessing such damages. For example, a release could affect access across State Route (SR) 20 over the Swinomish Channel. If SR 20 were to suffer traffic restrictions or closures, regional commuters and shipping networks would experience delays as they travel between Fidalgo Island, Whidbey Island, the San Juan Islands, and surrounding areas.

To demonstrate how this example could play out, if a commuter travels to work between Anacortes and Burlington, the most direct route would be the SR 20 Bridge over the Swinomish Channel. If the bridge were closed, the commuter would seek an alternate route such as Pioneer Parkway in LaConner. This alternate route would add 40 minutes to the trip, assuming there were no additional congestion delays. Economic damages would result in lost income to the commuter—income that could have been earned from doing other activities such as working. Damages would also extend to the value of freight inventory that is shipped along the same corridor but is delayed between its origin and destination.

Private Property Loss or Damage

Private property loss or damage includes either partial of full loss of property value from an oil release. For example, a release could affect waterfront real estate in the region. First, the proximity to a release could decrease overall property values. Beaches provide an amenity value to properties and people are often willing to pay more for them than others. If a release of oil were to occur and damage beaches, waterfront properties could become less desirable and their values could decrease. At that point, a second impact could occur; the regional market for waterfront real estate could slow and result in fewer home sales. This impact could last until all cleanup activities had been completed, and possibly longer.

Tourism

Damages to the hospitality industry include changes in the economic activity of restaurants, hotels, and other businesses that cater specifically, although not exclusively, to visitors or tourists. A release in the Swinomish Channel, for example, could affect the town of La Conner and the Swinomish Casino, both of which rely on summer day trips to the area. A decrease in summer tourism would reduce the revenues for the local hospitality industry.

Related Industries

Related industries, like canneries and fish processors, could also be impacted. Following an oil release, these industries could slow or shut down operations because of lower inputs due to fishing losses. Related industries are also linked to agriculture and aquaculture.

If a release were to reduce salmonid stocks, the decrease in catch would affect multiple industries linked to commercial and recreational fishing. The reduction in commercial harvests of salmon would damage both tribal and nontribal commercial fish canneries and other food processors. Because the release could impact other commercial species, the canneries would not likely be able to substitute lost revenues from salmon processing with increased production of products from other species. In addition, a reduction in recreational fishing could impact fishing charters and gear shops, as fewer trips would be taken for sport fishing.

Employee Health (Absenteeism)

Exposure to toxic chemicals can increase the rates of labor force absenteeism due to chronic medical problems. This exposure would affect residents living near the release site who could experience a range of health problems, including headaches, eye irritation, or respiratory issues. Absenteeism increases direct costs for businesses through wages paid to absent employees; high-cost replacement workers (overtime pay for other employees or temporary workers); and administrative costs to manage absenteeism. Absenteeism can also lead to indirect damages such as overtime fatigue, which could reduce the quality of goods/services; decreases in productivity; increases in managerial time and costs; increases in safety issues; and diminished worker morale.

Social

Public Health Impacts

Damages to public health could occur when persons either inhale vapors or touch crude oil, or consume contaminated food. Health impacts from exposure could affect residents located in the

vicinity of a release or cleanup workers. Health impacts can be immediate, such as headaches, eye irritation, and respiratory issues; or they can be long term, such as cancers from breathing volatile organic compounds or coming into contact with oil.

Damages to public health resulting from a release of oil are measured either through the increase in the incidence of health cases, or the change in costs for the medical assistance required to treat them. In addition to physical health problems, individuals who are economically harmed through job or business losses, or individuals who have a strong connection to the environment, might also suffer emotionally. Technological disasters such as oil releases are shown to be more stressful than natural disasters. Threatened livelihoods could lead to stress and social breakdown. These events could result in an increased demand for clinical, mental health, and rehabilitation programs. The net impact could include increased direct costs through hospital bills and related expenses, or broader social costs through work stoppages and shorter life expectancy.

Public Recreation

Public recreation is a broad category that captures all unpaid recreation activities, such as public beach use, trail use, swimming, and surfing. Damage to public recreation is usually measured in one of two ways: 1) by any loss of utility associated with the forgone recreation activity; or 2) by having to travel to recreation areas that are less desirable to an individual.

A release into local waters, for example, could impact beaches and recreation opportunities such as walking, bird watching, swimming, and kayaking. The release of oil could prevent aquatic recreation, access to public beaches and other day use facilities, and could damage the aesthetic quality of the beaches and surrounding environments. Furthermore, toxic fumes could impose serious health risks for recreational visitors. Studies have shown that a reduction in either the aesthetic quality, and/or quantity of recreation available at a beach changes the overall economic value that the public receives from use of the beach.

Hypothetically, a person could be willing to pay $10 per daily trip to walk along Padilla Bay in its current condition. If a release were to occur, access to the beach could be limited. There would be an inability to approach water, access to walking paths would be restricted, and the aesthetic quality could be impaired. These factors could reduce the value of the recreational experience from $10 to $5 per daily trip. Furthermore, the reduced quality of the experience could lead to fewer trips taken.

Potential Economic Damages to Tribes

A release of oil could impact fishing, hunting, and culturally important tribal lands. Impacts could include oil contamination of fish and shellfish, and damages to fisheries. These impacts could affect the cultural, traditional, and economic uses of the tribes (See Chapter 3.8 – Treaty and Traditionally Used Resources). Oil releases could affect tribal communities that rely on the natural environment for subsistence and social-cultural uses. Many tribes, such as the Swinomish, have traditional cultures rooted in harvesting fish and other wildlife. For tribal fisherman, a reduction in commercial fishing as a result of an oil release would affect their livelihoods and incomes. For tribal families who rely on subsistence fishing, the loss of dietary protein would have to be replaced. Those families would see a substantial increase in costs as

they replaced the protein with other food sources to meet dietary needs. These economic impacts would place a strain on the overall wellbeing of the community.

Potential Total Value of Economic Damages

The economic damage categories discussed above focused on the third-party impacts of an oil release. The consequences presented were broad and hypothetical; therefore, the monetary values of the consequences were not quantified. However, a potential value of economic damages was identified based on historical evidence from other releases in Table 4-24 below. These values helped to provide some evidence for the value of the damages associated with releases of oil.

The damage estimates tended to be reported as a combination of direct economic losses (petroleum), cleanup costs, and environmental damages. The other environmental damage categories and cleanup costs combined both market- and nonmarket-based categories. In some instances, environmental damages were measured as fines, punitive damages, and/or litigation. As such, these measures did not report the true value of the economic damages that the releases imposed on society. Some reports of commercial fishery losses, tourism losses, and property damages were found. No direct losses were included in the estimates (i.e., the loss of crude oil revenue).

Several historic releases were identified in the economic literature for which a range of damages were available. Three of the identified releases occurred in a marine environment. These releases included:

- Pemex Ixtoc I (1979), located in the Gulf of Mexico, about 138 million gallons of oil spilled.
- Exxon Valdez (1981), located near Alaska, about 11 million gallons of oil spilled.
- Deepwater Horizon (2010), located off the Gulf Coast, about 210 million gallons of oil spilled.

With crude-by-rail transport being relatively new, damage estimates for releases are limited for the Lac-Mégantic spill (2013) in Quebec, Canada. Meanwhile, data on smaller spills are unavailable.

Identified damage estimates are reported in Table 4-24. For purposes of comparison, the total damages were converted to dollars per gallon by dividing them by the total gallons released. For each type of damage, the lowest and highest value was reported. All of the identified damage estimates varied substantially. Lac-Mégantic was determined to have the highest value in real estate damages and cleanup costs. The Deepwater Horizon spill provided the source for reporting losses in commercial fishery revenues. The Exxon Valdez spill was reported in total cleanup costs and environmental damages.

Table 4-24 Observed Economic Damages from Historical Spills

Description	Average Damage per Gallon (2015 Dollars)	Average Damage per Barrel (2015 Dollars)
Clean up costs[1]	$8 - $117	$336 - $4,914
Environmental damages[2]	$8 - $255	$336 - $10,710
Total cleanup and environmental damages[3]	$17 - $685	$714 - $28,770
Tourism losses (reported)[4]	$0.10 - $20	$4.20 - $840
Commercial fishery losses[5]	$22	$924
Loss of real estate values[6]	$22 - $1,588	$924 – $66,696

Notes:

1. Low value from Pemex Ixtoc I, [Restrepo 1982]; high value from Lac-Mégantic [Portland Press Herald 2013].
2. Low value from Pemex Ixtoc I, [Restrepo 1982]; high value from Exxon Valdez [Cohen 2010] public willingness-to-pay to avoid environmental losses.
3. Low value estimated; high value from Exxon Valdez [Cohen 2010].
4. Low value from Pemex Ixtoc I, [Restrepo 1982]; high value from Deepwater Horizon [Ashcroft and Smith 2010].
5. Only one value reported, Deepwater Horizon [Ashcroft and Smith 2010].
6. Low value from Deepwater Horizon [Ashcroft and Smith 2010]; high value from Lac-Mégantic [Portland Press Herald 2013]. High value included full reconstruction of the town over 10 years.

For the proposed Shell PSR project, the true scale and extent of spills is difficult to forecast. The historical values presented above were not attributable to crude-by-rail operations and demonstrate that the range of potential economic damages is large and influenced by many factors. One study estimated that the average damage from oil spills in the U.S. was $17.39 per gallon adjusted to 2016 dollars (cleanup and environmental damages) based on accounts from actual spill data (Cohen 1986). Table 4-25 shows the approximate damages that would result with the average, 30PD and 90PD spill sizes.

Table 4-25 Estimated Damages for the Release Volumes per Event

Statistical Parameter	Release Volume (Barrels)	Approximate Damages with Cohen 1986
Average Low Estimate Evaluation	10,498 (440,916 gallons)	$ 7,667,376
Average High Estimate Evaluation	11,144 (468,048 gallons)	$ 8,139,354
30th Percentile	5,700 (239,400 gallons)	$ 4,163,083
90th Percentile	20,000 (840,000 gallons)	$14,607,308

Source: Cohen 1986.

Potential Economic Consequences of a Fire or Explosion

The immediate economic consequences of a fire or explosion after the release of oil from a train derailment include impacts to human health and loss of life, property damages, impacts to transportation, and emergency response. Additional impacts such as damages to ecosystem services and nonuse values (see preceding section regarding the economic impacts of spills) could also occur when a fire or explosion results in damages to the natural environment. Variables affecting the extent of the damages are the physical environment, local economic conditions, land use, emergency response and preparedness, and government policy.

The following economic damages were assumed to likely occur as the result of a fire or explosion: losses or damages to private property; impacts to the transportation network; impacts to employee health; impacts to public health; and damages to ecosystem services.

Private Property Loss or Damage

A fire or explosion could result in private property losses or damages. This could be a partial or full loss of the economic value of the property. Impacts would be limited to the immediate area of the fire or explosion.

Transportation

Closures to the transportation network could cause damages to accrue to individuals and businesses. The value of a person's time because of delays is considered when assessing such damages. For example, a fire or explosion could result in the closure of the Edmonds Ferry Terminal. The potential economic consequences from a release would be similar to those described under the discussion of the potential economic consequences to transportation resources from a release of oil.

Employee Health (Absenteeism)

Personal injuries from a fire or explosion, such as burns, could increase the rates of labor force absenteeism. The potential for injuries near a fire or explosion is high, but the area potentially impacted is small. Absenteeism could increase direct costs for businesses through wages paid to absent employees, high-cost replacement workers (overtime pay for other employees and/or temporary workers), and administrative costs to manage absenteeism. Absenteeism could also lead to indirect damages such as overtime fatigue, which reduces the quality of goods/services, decreases in productivity, increases in managerial time and costs, increases in safety issues, and poor worker morale.

Public Health Impacts

While the likelihood is very low, a fire or explosion could have significant impacts on human health, ranging from light to fatal injuries in proximity to the event. Damages to public health from an oil release are valued either through the increase in the resulting events of health cases, or the change in costs for the medical assistance required to treat those health cases.

Ecosystem Services

A fire or explosion could impair one or more of the functions and services that are afforded by the environment. For example, a fire could damage a stand of trees along a riparian ecosystem, which could destabilize the bank and result in increased erosion. The erosion could cause a reduction in the quality of spawning habitat for fish species, thereby reducing future fish stocks. These damages are valued directly through either the cost to repair/replace the ecosystem, or indirectly through proxy benefits such as flood risk reduction.

ACCIDENT AND RELEASE RESPONSE AND MITIGATION MEASURES

The findings described in this chapter indicate that the probability of an accident involving a Shell PSR unit train in Washington State resulting in a release of oil is low; however, should such an accident occur, the consequences could be substantial. The co-lead agencies considered these findings in the development of the mitigation measures presented below. These measures are intended to achieve two goals: 1) to minimize the probability of a release from a Shell PSR unit train occurring, and 2) to augment response capabilities if an accident were to occur.

The consequences and impacts described above were derived from an unmitigated release (i.e., no emergency response) of oil into the environment. If an actual release of oil were to occur, response measures governed by regulatory agencies and provided by first responders, regulatory agencies, Shell, and BNSF Railway would provide a targeted intervention to minimize the potential impacts. The full list of existing and required response plans is outlined in Chapter 3.17 – Public Services and Incident Response.

BNSF Railway is the responsible party for fires, releases, or other events involving the railroad. The company maintains equipment and a network of contracted first responder teams. As described further in Chapter 3.17 – Public Services and Incident Response, the local fire departments act as the first responder to any accidents along the railroad. BNSF Railway coordinates with fire departments and districts when responding to accidents and provides accident response training along its entire rail network. In addition, there are multiple guidelines and requirements with which BNSF Railway, Shell, and other entities must comply in conducting activities related to the transport and handling of crude oil.

First responders and their broad response networks have benefited from the advancement of oil spill response technologies. Also, enhanced planning measures have followed the Oil Pollution Act of 1990. Existing regulations govern the movement of crude oil by train including federally mandated oil spill response plans (49 CFR 130.31[a] for transport of volumes of oil greater than 1,000 barrels [42,000 gallons]). These regulations require that preparation and response measures be in place to address potential releases of oil. In addition, Washington State has recently enacted rules for crude-by-rail projects that, when implemented, will require specific notification procedures for crude-by-rail train activity in the state and will require railroads shipping crude oil by rail to have contingency plans in place (see Chapter 3.17 – Public Services and Incident Response). These rules will help emergency responders and planners prepare for and respond to an accident.

The National Contingency Plan, the Northwest Area Contingency Plan, local response plans, facility plans, and transportation regulations provide additional coordinated preparation for an oil or hazardous substance release. These contingency plans establish roles and responsibilities, and identify resources and response procedures to protect life. They reduce and mitigate the impacts of a pollutant discharge on the environment and property. The applicable plans are described in Chapter 3.17 – Public Services and Incident Response.

Avoidance and Minimization

Minimizing potential impacts that could result from a release of crude oil associated with the proposed rail unloading facility begins with prevention measures. As described in Chapter 3.17 – Public Services and Incident Response, there are numerous regulations and policies that are currently or will soon be implemented to minimize the potential occurrence of crude-by-rail accidents.

Mitigation

The risk of a spill occurring during an incident would be minimized by using DOT-117 Specification tank cars that meet enhanced safety standards issued by the Pipeline and Hazardous Materials Safety Administration and the FRA. The Shell PSR would accept delivery of crude oil and petroleum products only in tank cars meeting or exceeding DOT-117 specifications.

Shell would fund the purchase of hand-held volatile organic compound (VOC) monitors for local responders. The co-lead agencies would determine the number and location of monitors to be provided. Shell would provide training to ensure that local responders know how to use and maintain air monitors.