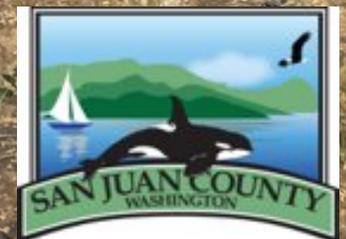
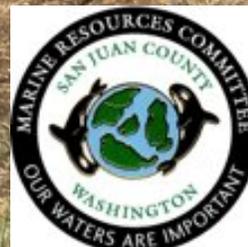


San Juan County Oil Spill Risk Consequences Assessment and Emergency Response Towing Vessel Cost Evaluation





SAN JUAN COUNTY OIL SPILL RISK CONSEQUENCES ASSESSMENT

A Business Model for Additional Investment in Oil Spill Prevention Measures

Protection against a major and catastrophic oil spill is the highest environmental priority for San Juan County. The San Juan Ecosystem Protection and Recovery Plan identifies investment in an emergency response towing vessel (ERTV) to reduce the risk of a spill at Boundary Pass/Haro Strait on the north and west sides of San Juan County as a priority risk mitigation measure. This measure also is recommended by the Governor's Southern Resident Orca Task Force, Department of Ecology's October 2016 Salish Sea Workshop, and Puget Sound Partnership Ecosystem Coordination Board and Leadership Council.

WHAT WE'RE DOING

To support the cost/benefit business case of investing in an ERTV for Boundary Pass/Haro Strait, San Juan County worked with specialty economics firms to complete two studies that:

- Evaluated the cost of positioning and operating a multi-mission ERTV for Haro Strait/Boundary Pass.
- Assessed the consequences and scale of impacts from two oil spill scenarios at the Haro Strait/Boundary Pass Turn Point to the natural resources health and economic vitality of San Juan County.

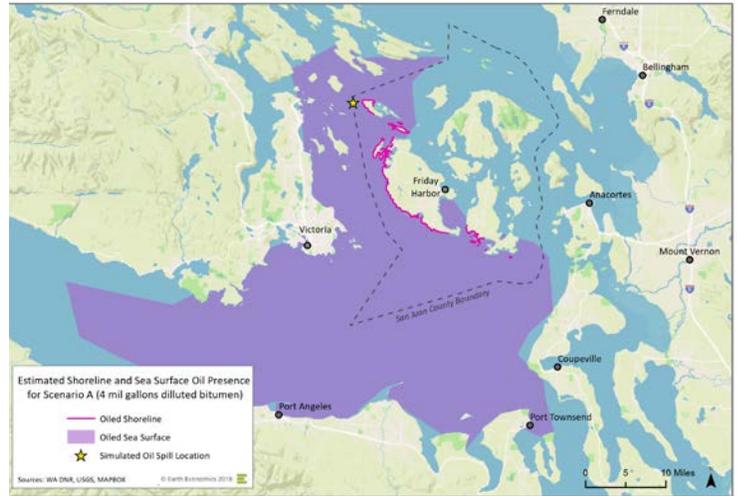
ASSESSMENT RESULTS

The studies conclude that the estimated annual cost of positioning an ERTV in San Juan County ranges from **\$4.3 to \$6.2 million**, largely dependent on crew size and wage rates.

In comparison, the damages incurred by the county associated with an unmitigated oil spill at Haro Strait/Boundary Pass are very conservatively estimated at **\$84 to \$243 million** for a 1-million-gallon spill of heavy fuel oil, and **\$142 to \$510 million** for a more severe 4-million-gallon spill of diluted bitumen, over a thirty-year time period.

FOR MORE INFORMATION

Marta Green, Puget Sound Recovery Coordinator
San Juan County Environmental Resources Division
martag@sanjuanco.com, (360) 370-7587



Estimated Shoreline and Sea Surface Oil Presence for a 4-Million-Gallon Diluted Bitumen Spill at Turn Point

These estimated damages are based on observed impacts from past major oil spills in North America, and include the following affected sectors:

- Tourism Spending, Wages and Tax Revenue
- Property Values and Taxes
- Commercial Fishing and Aquaculture
- Recreational Use Value
- Ecosystem Services

The damages do not include the exorbitant costs associated with spill response and natural resources damage assessment and restoration. They do not include known oil spill impacts such as marine transportation, human health, social services, and science and education, not to mention the loss of tribal treaty rights, the value of which is beyond economic measure.

WHAT YOU CAN DO

San Juan County encourages those with environmental, economic, social, and cultural interests in the region to engage in the legislative process and related initiatives including the Southern Resident Orca Task Force. Engagement may increase public and political will and inform decisions that protect the San Juan Islands and regional ecosystems, communities, and businesses from the consequences of a large oil spill.

PROJECT CONTRIBUTORS

Earth Economics, Northern Economics and The Glostén Associates authored this study for the San Juan County Environmental Resources Division with support from the Marine Resources Committee.



COST ALTERNATIVES FOR AN EMERGENCY RESPONSE TOWING VESSEL IN SAN JUAN COUNTY

Annual Cost	Permanently Moored	Permanently Underway	Seasonally Moored
Low Daily Rate	\$ 4,351,000	\$ 4,460,000	\$ 4,416,000
High Daily Rate	\$ 6,176,000	\$ 6,285,000	\$ 6,241,000



Source: Northern Economics, Inc. and The Glosten Associates (2018)

SAN JUAN COUNTY OIL SPILL DAMAGE ESTIMATES

Total damages: \$84 million to \$510 million

Impact Category	4-million-gallon spill of diluted bitumen		1-million-gallon spill of heavy fuel oil	
	Low	High	Low	High
Commercial Fishing	\$932,000	\$2,505,000	\$69,000	\$223,000
Aquaculture	\$99,000	\$149,000	\$57,000	\$86,000
Tourism Spending, Wages, and Local Tax Revenue	\$21,096,000	\$161,466,000	\$8,645,000	\$59,241,000
Property Values and Taxes	\$89,670,000	\$245,050,000	\$60,544,000	\$134,957,000
Recreational Use Value	\$8,032,000	\$37,156,000	\$2,688,000	\$18,422,000
Ecosystem Services	\$22,465,000	\$63,586,000	\$12,275,000	\$30,268,000
<i>Total Damages</i>	\$142,294,000	\$509,912,000	\$84,278,000	\$243,197,000



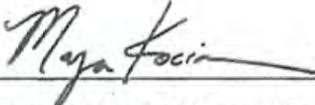
Source: Earth Economics (2019)

San Juan County Oil Spill Risk Consequences Assessment

EARTH
ECONOMICS 



APPROVALS



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Date 12/19/18



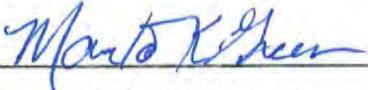
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Date 1/9/2019

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San Juan County Oil Spill Risk Consequences Assessment

Version 3.0

March 2019

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The authors are responsible for the content of this report.

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San Juan County
Environmental Resources Division



San Juan County
Marine Resources Committee

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Acronyms

IOSA	Islands Oil Spill Association
Dilbit	Diluted Bitumen
Bbl	Barrels (1 bbl = 42 gallons)
NOAA	National Oceanic and Atmospheric Administration
EVOSTC	Exxon Valdez Oil Spill Trustee Council
Gal	Gallon
SRKW	Southern Resident Killer Whale
PAH	polycyclic aromatic hydrocarbons

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1. Executive Summary

The natural assets of San Juan County's marine ecosystems provide a number of critical benefits to San Juan County communities, including attracting and sustaining a large tourist industry, world-class recreational opportunities, high property values, commercial fishing and aquaculture industries, and other critical ecosystem services. An oil spill in San Juan County waters would generate significant economic, social, and environmental damages to the Islands. San Juan County is situated among major commercial shipping routes that connect ports in Washington and British Columbia and is thus vulnerable to the threat of oil spills caused by incidents involving both cargo vessels (carrying oil as fuel) and oil tankers (carrying oil both as cargo and as fuel). In an attempt to better understand the impacts associated with a large oil spill in Haro Strait/Boundary Pass, San Juan County engaged Earth Economics to conduct an Oil Spill Risk Consequence Assessment that identifies the anticipated impacts of two hypothetical spill scenarios and estimates the economic impacts associated with each scenario.

Two scenarios were defined to drive this assessment: Scenario A (4 million gallons of diluted bitumen) and Scenario B (1 million gallon of heavy fuel oil). To estimate the magnitude and duration of impacts from these two hypothetical spills, literature on the impacts of historical oil spills in North America was reviewed. A range of potential short- and long-term impacts were identified and synthesized from this literature review. Ultimately, damages from each spill scenario were estimated using available county-level data, across five impact categories: 1. Commercial Fishing and Aquaculture; 2. Tourist Spending, Wages, and Tax Revenue; 3. Property Values; 4. Recreation Use Value; and 5. Ecosystem Services. Total damages for each spill scenario were estimated as follows:

Scenario A (4 million gallons of diluted bitumen): \$142.3 million to \$509.9 million

- Commercial Fishing: \$932,308 to \$2.5 million
- Aquaculture: \$99,204 to \$148,806
- Tourist Spending, Wages, and Local Tax Revenue: \$21.1 million to \$161.5 million
- Property Values and Taxes: \$89.7 million to \$245.0 million
- Recreational Use Value: \$8.0 million to \$37.2 million
- Ecosystem Services: \$22.4 million to \$63.6 million

Scenario B (1 million gallons of heavy fuel oil): \$84.3 million to \$243.2 million

- Commercial Fishing: \$69,438 to \$223,468
- Aquaculture: \$57,342 to \$86,012
- Tourist Spending, Wages, and Local Tax Revenue: \$8.6 million to \$59.2 million
- Property Values and Taxes: \$60.5 million to \$135.0 million
- Recreational Use Value: \$2.7 million to \$18.4 million
- Ecosystem Services: \$12.3 million to \$30.3 million

These damage estimates (including the upper bound of estimate ranges) should be considered underestimates, due to the conservative approach taken to estimate impact rates (in general, the average of the full range of observed impact rates/durations was taken as the upper bound of our estimates) and the exclusion of multiple impact categories that could not be integrated into this assessment due to data, methodology, and/or resource limitations, including: marine transportation, science and education, endangered species (such as the Southern Resident Killer Whales), human health, social services and cultural value.

2. Introduction

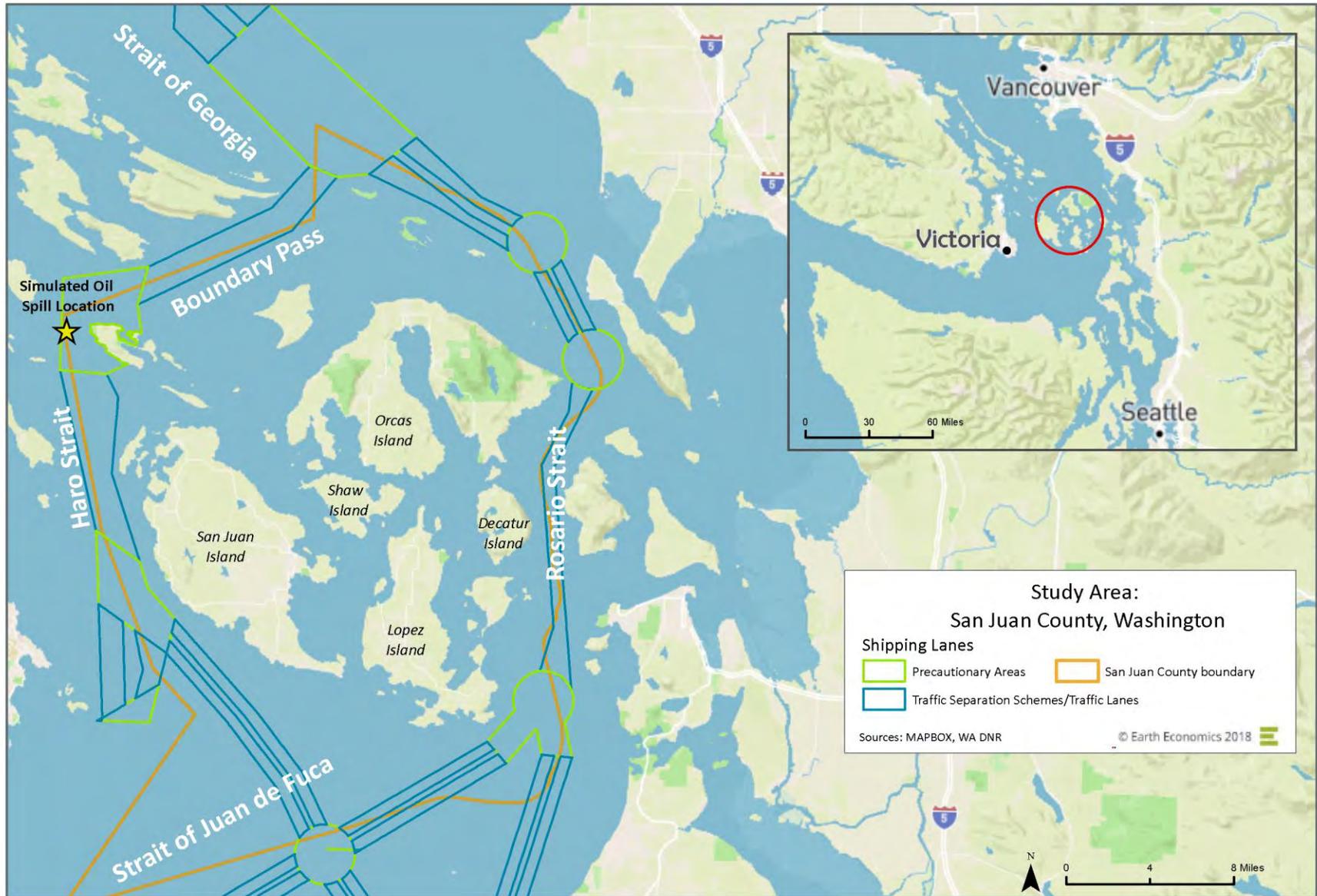
San Juan County is located in the Salish Sea, bounded by Haro Strait and Boundary Pass to the west, Rosario Strait to the east, Georgia Strait to the north, and Strait of Juan de Fuca to the south (Figure 1). While renowned for their remoteness and pristine natural beauty, the Islands are situated among major commercial shipping routes that connect ports in Washington and British Columbia and are vulnerable to the threat of oil spills caused by incidents involving both cargo vessels (carrying oil as fuel) and oil tankers (carrying oil as cargo). Oil tanker traffic specifically is projected to increase significantly with planned and ongoing expansions to port activities, which will in turn increase the risk of large oil spills in the region.¹

Past oil spills have demonstrated the widespread and lasting economic impacts oil spills have on coastal communities. Business disruption, loss of tourist visitation and spending, and impacts to commercial fishing are well-documented impacts of oil spills of all types and sizes. However, other economic impacts, such as impacts to property values and ecosystem services, are often excluded from ex-post analyses. Moreover, the social and environmental impacts of oil spills are often unaccounted for. In an attempt to better understand the impacts associated with a large oil spill in Haro Strait/Boundary Pass, San Juan County has engaged Earth Economics to conduct an Oil Spill Risk Consequence Assessment that identifies the anticipated impacts of two hypothetical spill scenarios and estimates the economic impacts associated with each scenario. This assessment utilizes economic and geospatial modeling techniques to provide a holistic account of the economic, social, and environmental impacts of hypothetical spills to San Juan County, based on the best available literature and data on historical oil spill impacts and behavior of oil in the environment.

At its October 2016 Salish Sea Workshop, the Department of Ecology solicited input on potential additional oil spill prevention risk mitigation measures from a diverse group of governmental, non-governmental, and tribal participants. The output of this workshop was a prioritized list of nine RMMs, presented in the Salish Sea Oil Spill Risk Workshop Summary Report (Dept of Ecology, December 2016). Among these priorities is a measure that would reduce spill risk at particularly vulnerable locations. The measure would pre-position a fit-for-purpose multi-mission emergency response towing vessel (ERTV) based on best achievable technology for Boundary Pass and Haro Strait on the northwest and west sides of San Juan County. The recommended implementation strategy is to develop a strong case statement and a cost/benefit business model, drawing upon the success of the Neah Bay ERTV. This consequence assessment directly supports such a cost/benefit business model.

The scope of this project also is consistent with the recommendations made in the San Juan County Marine Resources Committee's (MRC) 2015 and 2017 Marine Managers Workshops. It implements recommendations made by the MRC, approved by the Local Integrating Organization and adopted to the 2016 Action Agenda for Puget Sound. It is a central strategy of the San Juan Islands Action Area Ecosystem Protection and Recovery Plan (San Juan Action Agenda Oversight Group, June 2017) to promote additional oil spill prevention measures and justify additional oil spill prevention financing for an ERTV positioned near Haro Strait/Boundary Pass to regulators and elected officials. The Puget Sound Partnership Ecosystem Coordination Board and Leadership Council have formally encouraged elected officials to support the ERTV and other high priority risk mitigation measures. Additionally, the Department of Ecology's 2015 Vessel Traffic Risk Assessment¹ and the Governor's Orca Task Force² recommend the ERTV.

Figure 1. San Juan County, Surrounding Waterways, and Surrounding Shipping Lanes



3. Study Site Overview

Geography and Ecosystems

San Juan County is comprised of over 400 islands with 172 named islands and reefs. The four most populated islands serviced by Washington Department of Transportation (WDOT) ferries include San Juan Island, Orcas Island, Lopez Island, and Shaw Island.³ San Juan County is located in the estuarine waters of the Salish Sea and is home to some of the most ecologically rich and sensitive areas in Washington State.⁴ San Juan County has 410 miles of marine shoreline, 447 square miles of water, and a land surface of about 175 square miles, making it the smallest county by land area in Washington State. Many of the smaller islands within the county are uninhabitable or publicly owned.⁵

A wide diversity of shoreline and marine habitats can be found throughout the islands, including marine mammal habitat, waterfowl nesting sites, feeding, rearing, and spawning habitat for fish, and a rich diversity of intertidal and subtidal invertebrate communities. The shorelines throughout San Juan County are equally diverse, ranging from exposed rocky shores on the west side of San Juan Island to sheltered beaches and marshes on the more protected interior shorelines.⁴

Tidal currents throughout San Juan County vary significantly due to the intricate system of passages and inlets that exist between the islands. Generally speaking, tidal currents are stronger in the straits and passages along the outer edges of the islands than on the inner passes, and tidal currents are stronger in the channels surrounding San Juan County than in Puget Sound.⁴ The waterways bounding the county to the west (Haro Strait and Boundary Pass) and east (Rosario Strait) are both narrow and contain many shallow-water rocks and reefs that require careful navigation by vessels transiting those waters.⁶

Socioeconomic Characteristics

The estimated year-round resident population of San Juan County in 2017 was 16,715.⁷ The proportion of County residents over the age of 65 is larger than the average proportion found in other Washington State counties, while the proportion of residents under the age of 18 is smaller than average.⁵ The number of island residents increases significantly during the summer months. The county estimates that the summer resident population swells to double the year-round population on any given summer date.⁸

Tourism is a major economic driver within San Juan County. According to NOAA Coastal Economy data from 2015, the leisure and hospitality sector was responsible for \$70.4 million of the county's \$463 million in GDP. Some estimates put the average annual number of non-resident visitors to the Islands at 750,000 to 1,000,000, approximately 47 to 63 times the local year-round population.⁸ In addition to tourism, the construction industry is also a major economic driver within the county and is highly dependent on daily ferry service.^a

Tribal Resources

Archaeological evidence shows that the San Juan Islands were first inhabited between 6,000 and 8,000 years ago.⁹ Traces of once-thriving villages are found in shell middens throughout the islands. The indigenous right of Coast Salish peoples to hunt, gather shellfish and fish within the San Juan Islands and

^a M. Green, personal communication, October 2018.

its surrounding waters was expressly reserved in the 1855 Treaty of Point Elliot, even without creation of a specific Indian Reservation on the islands. Today, the tribes who were signatories to that treaty continue to hold treaty rights within San Juan County, including rights to fishing, gathering shellfish and hunting. Loss of access to traditional tribal fishing and gathering areas within the County, due to an oil spill, results in deprivation of rights in violation of the treaty. Placing a dollar value on important cultural activities and resources can be controversial. The cultural value tribal communities place on ecosystems is far beyond economic measure; and there is no replacement for the loss of treaty rights. Therefore, this assessment does not take into account oil spill impacts to tribal resources. Due to this omission, the estimates presented in this report greatly underestimate the full impact of an oil spill in San Juan County waters. Tribes may provide their own resource assessments for future reference.

Vessel Traffic and History of Oil Spills in the Region

The Salish Sea sees a high volume of marine vessel traffic, including cargo vessels, tanker vessels, passenger vessels such as ferries and cruises, fishing boats, and recreational boats. The U.S. Coast Guard manages approximately 230,000 transits annually¹; among those, approximately 11,000 large vessels transit the Salish Sea every year.¹⁰ While smaller passenger, fishing, and cargo vessels can be found throughout the Salish Sea waters, tanker vessels transporting oil products utilize designated commercial vessel routes through Haro Strait/Boundary Pass, Georgia Strait, Rosario Strait, and the Strait of Juan de Fuca, to travel between ports and refineries in Washington state, British Columbia, and international waters. The Port of Vancouver, the largest port in Canada, is responsible for much of the vessel traffic entering and existing the Strait of Juan de Fuca. According to port's website, the port "supports trade with more than 170 economies around the world and is home to 27 major marine cargo terminals."¹¹ San Juan County is surrounded by these commercial vessel routes (see figure 1), which are projected to see increased rates of tanker vessel traffic with the completion of port expansion projects.¹

Regardless of the fate of future expansion projects, the Salish Sea is already at risk of oil spills. Oil spills can be caused by incidents involving oil carried as cargo, as well as incidents involving the spill of oil carried as fuel. While fuel-related incidents could occur throughout the Salish Sea, the risk of an incident involving oil tanker vessels is concentrated along the commercial transit routes surrounding San Juan County. Specifically, Haro Strait/Boundary Pass is primarily transited by tanker vessels traveling to/from the B.C. ports and the Strait of Juan de Fuca, while Rosario Strait is transited by vessels connecting between B.C. ports and Washington refineries. Both routes are navigationally complex and feature shallow-water hazards (rocks and reefs) and significant bends (Haro Strait/Boundary Pass requires vessels to make three sharp turns).⁶ If planned terminal expansion projects in Washington and BC are completed, the number of tankers passing through Haro Strait/Boundary Pass and Rosario Strait is projected to increase by 37% and 24%, respectively.¹ Completion of the Trans Mountain Pipeline Westridge Terminal expansion project alone would cause the number of tank ship visits to Westridge terminal to increase from 60 ships per year to 325-408 ships per year, the majority of which would travel through Haro Strait/Boundary Pass.⁶

For more than two decades, oil spill incidents in Washington State have involved small amounts of oil, due to existing risk mitigation measures, regulations and resources, including Washington State Department of Ecology Spills Program, the U.S. Coast Guard, international maritime regulations, emergency response towing resources, and shipping industry regulations.⁶ Twenty-six tank barge incidents involving oil spills occurred between 2008 and 2017 in Washington and Oregon waters. Among those 26 incidents, 12 spills involved 1 gallon or less of oil, and 18 spills involved 10 gallons or less. Only three of the spills occurred while vessels were in transit (as opposed to moored).⁶ Prior to the past two

decades, two major oil spills (defined as spills over 10,000 gallons) were recorded in the area, including a fishing vessel and cargo vessel collision near Cape Flattery in 1991 resulting in 361,000 gallons spilled, and an oil barge grounding incident in 1991 near Anacortes resulting in an estimated 26,936 gallons of diesel spilled.¹ While a large oil spill in the region is a low-probability event, the economic, social, and environmental impacts of past large-scale oil spills shed light on the potential devastation that one low-likelihood event could inflict on San Juan County and surrounding communities.

4. Oil Spill Scenarios for San Juan County

a. Purpose and Methodology

Purpose

Oil spills are inherently high-consequence, low-probability events that cannot be readily predicted. Scenario modeling is a useful decision-support tool for considering risks with high uncertainty. Using a scenario-based approach to assess the economic risks of oil spills for San Juan County allows for a holistic characterization of multiple potential futures and tangible descriptions of the full range of potential consequences that must be taken into consideration when making critical risk mitigation decisions and investments.

Methodology Overview

To select plausible and meaningful oil spill scenarios, Earth Economics reviewed existing relevant oil spill models, vessel traffic data, and response plans for Washington State and British Columbia (see Appendix A). Through this review, we identified relevant parameters of a hypothetical oil spill that must be defined to reasonably estimate the economic social, and environmental impacts to San Juan County – such as material spilled, volume of oil spilled, location, season, etc. We ultimately defined two hypothetical scenarios (“Scenario A” and “Scenario B”) based on available data on likely spill sizes and types in the location of interest (i.e. Haro Strait/Boundary Pass) and discussions with San Juan County Environmental Resources Division and local experts.

Earth Economics’ approach to ecosystem services valuation and place-based economic analysis is both spatial and temporal in nature, requiring the ability to map the geographic extent of sea surface and shoreline oiling during and after a spill as well as estimate the persistence of surface and shoreline oiling over time. Modeling the spatial and temporal trajectories of hypothetical oil spills was beyond the scope of this assessment. We therefore drew from existing regional oil spill modeling results and data on recovery rates of past oil spills to estimate the likely geospatial extent of sea surface and shoreline oiling and the likely impact recovery rates for our hypothetical spill scenarios.

Specifically, we utilized stochastic oil spill model results conducted as part of the Trans Mountain Pipeline Expansion Application, which include probabilistic surface oiling and shoreline oiling maps for hypothetical diluted bitumen spills in Haro Strait/Boundary Pass by season (spring, summer, fall, winter) and spill volume (8,250 m³ and 16,500 m³). Sea surface and shoreline oiling maps for the 16,500 m³ stochastic model runs were manually reconstructed in GIS to estimate the likely trajectory of the two hypothetical spills (see reconstructed maps in Appendix C). The models do not take into consideration mitigation activities, such as oil spill response efforts. In reality, U.S. and potentially Canadian response

resources would be mobilized to recover some portion of floating oil within the first few days of the spill.¹²

b. Overview of Spill Scenario Parameters

Several existing studies and guidelines offer insight into the different characteristics of oil spills that influence the severity of spill damages and the combination of oil spill parameters that would most realistically occur in the Haro Strait/Boundary Pass waters next to San Juan County. These parameters are summarized below:

- *Location of spill.* The location of an oil spill plays a significant role in determining the relative economic, social, and environmental impacts of a spill. In general, spills in open marine environments tend to produce relatively lower environmental and economic impacts than spills in sensitive coastal and island areas.¹³ The nearshore waters surrounding San Juan County are considered to be of high ecological value, with wide diversity of habitats, abundant food resources, and exceptional water quality.⁴ As described above, the waterways surrounding San Juan County (Strait of Juan de Fuca, Haro Strait, Boundary Pass, Georgia Strait and Rosario Strait) serve as a major “highway” for commercial vessel traffic, including cargo ships and oil tankers. The waters surrounding San Juan County, specifically Haro Strait/Boundary Pass, are projected to see higher increases in potential oil loss and potential oil spill frequency than any other area of the Salish Sea.¹ The navigational complexity of the Haro Strait/Boundary Pass junction, also referred to as *Turn Point*, increases the risk of an oil spill in this specific location.¹⁴
- *Material spilled.* The type of oil spilled also influences the relative impact of an oil spill. San Juan County is vulnerable to medium crude oil spills and diluted bitumen (tar sands) spills from oil tanker accidents as well as heavy fuel oil spills from cargo vessel accidents.⁸ Tank vessels transporting crude oil to Washington State refineries generally transit Rosario Strait, while Haro Strait/Boundary Pass is transited by tankers carrying diluted bitumen (otherwise known as dilbit) traveling to/from Canadian ports and the Strait of Juan de Fuca.⁶ Heavy fuel oil could in theory be spilled in any of the waterways surrounding the Islands.¹² While dilbit and heavy fuel oil are the most feasible material to be spilled in a hypothetical spill in Haro Strait/Boundary Pass, detailed data on past dilbit/heavy fuel oil spills is sparse, due to the lack of marine dilbit spill events and the smaller nature of heavy fuel oil spills that has not attracted extensive ex-post research. Crude oil is often the focus of oil spill studies, as the largest oil spills (*Exxon Valdez*, *Deep Water Horizon*) have involved crude oil and its behavior in the environment is better understood than heavier, more viscous materials such as diluted bitumen and heavy fuel oil.¹² While crude oil is different in nature to dilbit and heavy fuel oil in terms of its weathering behavior (see ‘Weathering Behavior’ sub-section below), data from well-studied crude spills such as *Exxon Valdez* and *Deep Water Horizon* still offer important insights into the long-term economic, social, and environmental impacts of hypothetical dilbit and heavy fuel oil spills and can be used to estimate impact magnitudes and durations for hypothetical spills in this assessment.
- *Volume of oil spilled.* The volume of oil spilled has the greatest relative influence on the overall impact of an oil spill, as compared to other characteristics such as material, timing, weather, etc.¹² There are two types of oil that could be discharged in an oil spill incident – oil that is carried

as cargo (e.g. refined petroleum products, crude oil, diluted bitumen) and oil that is carried as fuel (persistent heavy fuel oils or non-persistent fuels such as diesel and gasoline). The plausible volume of oil spilled in a given spill scenario depends on the total oil/fuel carrying capacity and likely volume of oil/fuel found on a vessel transiting Haro Strait/Boundary Pass waters. The fuel capacity of a large cargo vessel moving through Haro Strait is approximately 2 million gallons.¹⁵ Most cargo ships run on diesel or heavy fuel oil (a.k.a. bunker fuel)¹⁶ and do not typically transit Salish Sea waters carrying a full load of fuel.¹⁵ The average carrying capacity of oil tankers carrying crude oil or dilbit is 24 million gallons.⁶ Similar to cargo vessels, oil tanker vessels are often not at full capacity while transiting Salish Sea waters.⁸ The Trans Mountain Expansion application includes a “credible worst-case” spill volume for a dilbit-carrying oil tanker, as approximately 4 million gallons (16,500 m³), which is roughly the equivalent of two cargo tanks in a typical Aframax oil tanker transiting Haro Strait/Boundary Pass waters. It is important to note that Washington State defines “worst case spill” in the Washington Administrative Code (WAC) as “a spill of the vessel's entire cargo and fuel complicated by adverse weather conditions”.¹⁷ The Washington State Department of Ecology’s 2012 Cost-Benefit and Least Burdensome Alternative Analysis (based on reports prepared in 2005) modeled a 250,000 bbl (roughly 10.5 million gallons) spill of crude oil spill in Rosario Strait, a 65,000 bbl (roughly 2.7 million gallons) diesel spill, and 25,000 bbl (roughly 1 million gallons) heavy fuel oil spill. This assessment, which includes spill scenarios of 4-million gallons of dilbit and 1-million gallon of heavy fuel oil, builds on existing hypothetical spill volumes defined in industry- and government-sponsored studies.

- *Weathering behavior.* The key differences among different oil types are a) weathering behavior, b) difficulty of shoreline cleanup, and c) toxicity. An estimated one third of crude oil will evaporate within 24 hours, with the remainder dissolving into the water column and washing up onto shorelines.⁴ This results in an overall smaller percentage of oil spilled persisting in the environment and ending up on shorelines. Heavy fuel oil exhibits little or no evaporation/dissolution (5-10% is expected to evaporate within the first few hours¹⁸) and weathers more slowly⁴, therefore likely resulting in a larger volume of oil persisting in the environment and ultimately washing up on shorelines. The weathering behavior of dilbit is less understood. Dilbit is made up of approximately 30% diluent, made up of light-weight molecules, and 70% bitumen, made up of heavy-weight molecules and similar in density to other heavy oils.¹⁹ As a result, the light components of dilbit evaporate rapidly after a spill, leaving a dense residue that, as the material weathers, becomes increasingly dense and is likely to sink below the sea surface.¹⁹ In theory, the non-floating properties of dilbit residue would result in a larger portion of dilbit sinking and less oil washing up onto shores as compared to medium crude or heavy fuel oils. However, a dilbit spill occurring in close proximity to island areas (such as Haro Strait/Boundary Pass) would likely wash up onto shores as quickly as other oil materials, before significant weathering occurs.^b In addition to the relative influence of weathering behavior, crude, dilbit, and heavy fuel oils behave differently in intertidal areas: while crude oil contamination of intertidal areas can be severe and long-term, heavy fuel oil and dilbit residue are likely to cause longer-term contamination to sediments, and shoreline cleanup is considered to be difficult under all conditions.^{4,20} While the toxic properties of oil types varies, crude, dilbit, and heavy fuel

^b S. McCreery, personal communication, November 2018.

oil all have severe ecological impacts to marine and nearshore habitat and for the purposes of this assessment are assumed to inflict equal damage on natural resources on a gallon-per-gallon basis.

- *Season, weather/current conditions, and time of day.* Season and time of day both affect the relative severity of an oil spill in terms of the physical behavior of oil in the environment as well as the socioeconomic and ecological context of the spill timing. In the Puget Sound region, wind speeds are, on average, higher in the winter than in other months. Rougher conditions in winter months increase the likelihood of an oil tanker or cargo vessel incident.^b In addition, daylight is shorter, which in theory strains response efforts that typically only occur during the daylight for safety reasons.^{12 c} However, late spring through early fall months (May-September) are critical months for economic and social activities such as tourism, fishing, and recreational activities. A study of oil spill economic consequences for the City of Vancouver modeled the significance of season in determining economic costs of a hypothetical oil spill and found that a spill occurring at the beginning of the primary season for tourism and commercial fishing (May) results in substantially larger losses than a spill occurring in the fall.²¹ The ecological timing of fish spawning also influences long-term impacts to commercial fishing: *Exxon Valdez* occurred in March 1989 during critical spawning season, causing significant impacts to certain fish populations.²² While oil spills in May through September are less probable due to generally calmer conditions,^b a spill at the beginning of this economically important season would generate more severe damages for a tourism- and recreation-dependent county such as San Juan County. Both spill scenarios are therefore defined as occurring in the spring.
- *Extent of shoreline and sea surface oiling.* The extent of shoreline oiling (total length of shoreline covered by oil) – in terms of the length of shoreline impacted, the concentration of oil found on shorelines, and the width of the oil band on affected shores – all have an influence on the relative ecological impact of an oil spill on intertidal and terrestrial ecosystems. The total amount of shorelines impacted depends on the trajectory of the spilled oil as it travels through the marine environment, and is highly influenced by currents, wind conditions, water temperatures, and geomorphic shoreline characteristics. Stochastic oil spill models for hypothetical spills at Turn Point conducted as part of the Trans Mountain Expansion Application reflect the full range of observed conditions, in addition to stochastic variability, that occurs in March through May of 2011. The resulting trajectory maps therefore present a range of probability contours for sea surface and shoreline oiling. For a spring-time spill at Haro Strait/Boundary Pass releasing ~4.2 million gallons (16,500 cubic meters), a range of 47 miles (>90% probability) to 473 miles (>10% probability) of shoreline could be impacted. Surface oiling (total area of sea surface swept by oil) was also modeled for the same scenario; 1126 mi² (>90% probability) to 2573 mi² (>10% probability) could be covered in oil at some point by the trajectory of the spill. To reflect the likely discrepancies of oiling extent between the two hypothetical scenarios, the extent of oiling for Scenario A of 4-million gallons of dilbit is assumed to be roughly equivalent to sea surface and shoreline areas with a >60% chance of being oiled, and for Scenario B the extent of 1-million

^c Because the hypothetical spill scenarios for this analysis assume no response efforts, the time of day of the spill scenario is not relevant for our analysis.

gallons of dilbit is assumed to be roughly equivalent to sea surface and shoreline areas with a >90% chance of being oiled, based on Trans Mountain modeling results for a roughly 4.2 million gallon spill.^d In addition to considering what shorelines and marine areas come into contact with oil, the relative impact of oiling also depends on relative sensitivity to oiling, based on shoreline characteristics (sediment types, degree of exposure) and water column depth, respectively.¹⁴ Shoreline sensitivity was not taken into consideration for impact categories specifically tied to shoreline impacts (e.g. property values); however, water column areas beneath oiled sea surface areas were assumed to experience varying degrees of impact based on water column depth (see section 7e 'Ecosystem Services' for more details).

- *Free-oil recovery and shoreline clean-up capacity.* The amount of available resources for oil spill response and clean-up plays a significant role in the magnitude and duration of oil spill impacts. Existing US-based resources for oil spill response in Puget Sound waters would allow for a maximum of 1.6 million gallons of floating crude oil to be recovered under otherwise ideal response conditions.¹² As for shoreline cleanup, regional resources would be mobilized to support shoreline cleanup in the event of a spill impacting San Juan County,^b though shoreline oiling recovery rates depends on a number of factors, including thickness/concentration of oil, weather conditions, degree of submergence, etc. The *Exxon Valdez* spill caused approximately 497 mi of shoreline in the Prince William Sound to be oiled in 1989, which dropped to 6 mi by 1991²³, though persistence of small amounts of subsurface oil have been reported as recently as 2018.²⁴ Shorelines oiled from the *Deep Water Horizon* spill recovered at a similar rate, with the amount of heavily oiled shorelines declining to 96% by Year 3 after the spill and oil still lingering on shorelines today.²⁵ For this assessment, we assumed no free-oil recovery efforts were made; duration of ecological and market impacts were based on published impact recovery rates from past oil spills and were not specifically tied to assumptions about shoreline clean-up / recovery rates.

c. Detailed Scenario Descriptions

Based on available oil spill models and literature reviewed, we identified two scenarios to drive this economic assessment: a cargo oil spill and fuel oil spill. We selected spill sizes for each scenario that represent conservatively *plausible* scenarios, based on the volumes of each oil type found on vessels that travel the Haro Strait/Boundary Pass waters. Though the technical definition of a worst-case spill, according to the Washington Administrative Code (WAC), is “a spill of the vessel’s entire cargo and fuel

^d We chose to utilize the >60% probability sea surface oiling contour from Trans Mountain 4.2 mil gal spill model as the basis for the oiling extent of Scenario A, to align with key assumptions utilized in the Trans Mountain Expansion Ecological Risk Assessment 2013. In the Ecological Risk Assessment, >50% probability of oiling is defined as “high probability” and is used as the basis for ecological impact estimates for a hypothetical 4.2 mil gal dilbit spill. A >50% probability contour was not included in the Trans Mountain model map, so we therefore selected the >60% probability contour to be conservative. For Scenario B, we calculated the estimated reduction in geographic coverage of sea surface oiling when the spill size is reduced from 4 mil gal to 1 mil gal, based on the >50% probability sea surface oiling areas reported in the 2013 Ecological Risk Assessment for a 4.2 mil gal dilbit spill and a 2.1 mil gal dilbit spill. Assuming a linear relationship between spill volume and geographic extent of oiling, the oiling extent of a spill decreases by approximately 11% with every 1-mil gal reduction in spill volume. Based on our manual reconstruction of probability contour lines from the Trans Mountain 4-mil gal dilbit spill model, an 11% decrease with every 1-mil gal reduction in spill size results in approximately 878 square miles of oiling for Scenario B (1-mil gal). We selected the >90% probability contour line from the Trans Mountain model (781 square miles) as a rough estimate of the geographic extent of sea surface oiling for Scenario B, based on the assumption that the geographic impact of dilbit in the water column is greater than heavy fuel oil due to greater potential for sinking. Using this crude approach was the best available option given our inability to conduct scenario-specific trajectory modeling and given the lack of other available model results for the Haro Strait/Boundary Pass region.

complicated by adverse weather conditions,” we defer to spill volumes modeled in other government- or industry-supported studies in order to build on the existing work of key stakeholders. Though in reality national – and likely international – response efforts would be deployed to recover floating oil, in these scenarios we assume no floating oil recovery or containment efforts are taken, to illustrate the full potential damages that could occur in each scenario. Table 1 presents a side-by-side comparison of the key parameters of each scenario. Appendix A presents qualitative confidence levels and justification for each parameter selection.

Table 1. Comparison of Scenario A and Scenario B Parameters

Parameter	Scenario A	Scenario B
Size	4 million gal	1 million gal
Material	Diluted Bitumen	Heavy Fuel Oil
Season	Spring (May)	Spring (May)
Weathering	70% (2.8 mil gal) washes up on shorelines	90% (900,000 mil gal) washes up on shorelines
Shoreline Oiling	72 mi in San Juan County	30 mi in San Juan County
Sea Surface and Water Column Oiling	1246 mi ² , 232 mi ² within county borders	763 mi ² , 181 mi ² within county borders

i. Scenario A: 4 million gallons of diluted bitumen

Scenario A is defined as a **4-million-gallon spill of diluted bitumen** at Turn Point at the junction of Haro Strait and Boundary Pass. It is assumed that the spill occurs in late spring (May 1), which is a critical time of year for both economic activity (e.g., tourism) and ecological processes (e.g., fish spawning). It is assumed that no response resources are deployed and that 70% of oil is stranded on shorelines, while the remaining 30% disintegrates through weathering (evaporation/dissolution/ biodegradation/sinking), based on results from Trans Mountain oil spill models. The estimated length of oiled shorelines within San Juan County is 72 miles. The estimated total square miles of sea surface and associated water column assumed to come into contact with oil at some point during the spill trajectory is 1246 mi², with roughly 232 of those square miles located within San Juan County administrative borders. Figure 2 shows the spatial extent of estimated shoreline and sea surface oiling in Scenario A. See Appendix A for a full list of references and confidence levels for each assumption within this scenario.

ii. Scenario B: 1 million gallons of heavy fuel oil

Scenario B is defined as a **1-million-gallon spill of heavy fuel oil** at Turn Point at the junction of Haro Strait and Boundary Pass. The spill occurs in late spring (May 1), which is a critical time of year for both economic activity (tourism) and ecological processes (fish spawning). It is assumed that no response resources are deployed. Ninety percent of oil is assumed to be stranded on shorelines, while the remaining 10% disintegrates through weathering (evaporation/ dissolution/ biodegradation/sinking). 30 miles of shoreline in San Juan County are assumed to be contaminated with oil, and 763 square miles of sea surface and associated water column are assumed to come into contact at some point during the spill, with roughly 181 of those square miles located within San Juan County administrative borders. Figure 3 shows the spatial extent of estimated shoreline and sea surface oiling in Scenario A. See Appendix A for a full list of references and confidence levels for each assumption within this scenario.

Figure 2. Estimated Shoreline and Sea Surface Oiling for Scenario A



Figure 3. Estimated Shoreline and Sea Surface Oiling for Scenario B.



5. Overview of Potential Oil Spill Impacts

An extensive literature review was conducted to understand the various ways in which oil spills impact the economic, social, and environmental resources that communities care about. The response and restoration costs of an oil spill were excluded from our literature review in order to isolate economic, social, and environmental consequences resulting from a spill. Where applicable, we distinguished between the anticipated short- and long-term effects of each of the impact categories. Table 2 summarizes the range of short- and long-term impacts identified in our literature review, including: infrastructure, marine transportation, tourism and recreation, property values, commercial fishing, aquaculture, recreation use value, science and education, cultural value, public health, subsistence activities, and ecosystem services. Table 2 also serves as a gap analysis for this valuation: filled-in circles (●) indicate impacts that were included in our valuation of oil spill damages, based on data availability. Summaries of key literature findings associated with each impact category is discussed in section 6.

6. Impact Estimation and Valuation Approach

Overview of Impact Rate Estimation Approach

While the impacts of oil spills are highly contextual and dependent on biophysical conditions, socioeconomic context, and characteristics of the spill events themselves,²⁶ analysis of past oil spills can provide insights into how a set of hypothetical oil spills might impact San Juan County.²¹ We derived assumptions about the magnitude and duration of impacts for the San Juan County hypothetical spill scenarios from analyzing literature and available data on the impacts of past oil spills in North America. Oil spills were selected for analysis based on similarities in a) biophysical and socioeconomic characteristics of the spill area and b) spill material, volume, and conditions. Availability of data was also a key determinant and limiting factor for the inclusion of past oil spills in the analysis. We ultimately utilized durations and magnitudes of impacts of six North American oil spills to inform our analyses: *Deep Water Horizon* (2010), *Exxon Valdez* (1989), *Refugio* (2015), *Ixtoc I* (1979), *Bouchard 120* (2003), and *Cosco Busan* (2007).

In cases where data was available on a past spill that shares key similarities to our hypothetical spills for the impact under consideration, we directly utilized the impact magnitudes and durations from a singular past spill in our analysis. In cases where data is only available on past spills that exhibit considerable differences to our hypothetical spill scenarios, a range of magnitude and duration values was utilized and, in some cases, scaled up or down based on the spill volume and material. Because of the considerable uncertainties embedded in this approach, we utilized a range of magnitude and duration values for each impact category and present aggregated low and high values. This approach to estimating magnitude and duration of impacts from a hypothetical oil spill scenario is the best available option in light of the highly contextual nature of oil spills²⁶ and lack of usable data on relevant past spills. Moreover, this approach has been utilized in a number of government-sponsored studies.^e A summary of key oil spill characteristics and available data on impact magnitudes and durations for past spills analyzed is provided in Appendix B. A full list of references informing the historical spill analysis is listed in Appendix E.

^e Bjarnason et al 2015, Holmes et al 2016, Gustanski et al 2015, and Hotte et al 2015 all utilize a similar approach for estimating impacts of hypothetical spill scenarios based on reported impacts of a range of historical oil spills.

Table 2. Potential Economic, Social, and Environmental Impacts of Oil Spills and Gap Analysis (● = Impacts included in Impact Valuation)

Impact Type	Immediate Effect	Long-Term Effect	Ref.
Economic			
Infrastructure	○ Damage to shoreline/marine infrastructure (docks, boats, boardwalks, fishing equipment)		97, 35
Marine Transport	○ Immediate blockage of all marine transportation within oiled waters, including: ferries, cargo vessels, recreational boats, commercial fishing boats, and cruise ships ○ Loss of moorage income to ports and marinas ○ Loss of fare revenue for ferries and passenger vessels	○ Disruption (delayed income) to island-based industries dependent on regular ferry services (e.g. construction, agriculture, groceries)	16, 21, 97-98, f, b
Tourism and Recreation	○ Immediate disruption of tourism and recreation activities due to suspended ferry services and marine and shoreline amenity closures	● Reduced tourist visitation and recreational activities due to negative perception of safety and aesthetic quality of the Islands, resulting in loss of tourist spending, tourism-generated wages, and tourism-generated tax revenue	21, 41, 45-49, 51-52, 55, 58
Property Values	● Deflated property values for water-front and water-view properties in areas directly oiled, due to negative perception of aesthetic quality of environmental amenities ● Deflated property values for waterfront and water-view properties in areas not impacted by oil, due to stigma		57-60
Commercial Fishing	● Immediate mandatory commercial fishing closures due to seafood safety risks, resulting in loss of landings income	○ Lower wild fish catch yields due to acute fish and embryo mortality and sub-lethal effects on fish populations ○ Decreased market prices due to reputational impacts on regional seafood and reduced consumer demand	30-39
Aquaculture	● Immediate loss of aquaculture income due to forced closures, acute mortality of seafood products	○ Decreased market prices due to reputational impact on regional seafood and reduced consumer demand	31-33, 37-39
Social			
Recreation Use Value	○ Loss of use value associated with immediate disruption (closures, suspended transportation) of marine and shoreline recreational activities	● Loss of use value associated with decreased participation in marine and shoreline recreational activities due to negative perceptions of safety and aesthetic quality of environment	55, 58
Science and Education		○ Loss or delay of educational value associated with disrupted marine-based youth programs ○ Loss or delay of long-term ecological research efforts	27
Cultural Value		○ Lost cultural value associated with damages to marine and shoreline habitat (e.g. the iconic Southern Resident Killer Whales that is the County's local branding)	28-29
Public Health	○ Evacuation of beachfront residents in case of impaired local air quality from oiling (due to volatile organic compounds (VOCs)) ○ Direct physical contact with oiled waters or beaches	○ Consumption of contaminated water supply and/or contaminated seafood	30, 35
Subsistence Activities	○ Disruption to subsistence fishing and temporary loss of food sources due to harvest bans	○ Lower wild fish catch yields due to acute fish and embryo mortality and sub-lethal effects on fish populations ○ Long-term health impacts of lack of access to traditional foods	29-30, 31
Social Services	○ Deteriorated social services due to diversion of government resources toward spill response		94
Environmental			
Ecosystem Services	● Acute decline in marine and shoreline ecosystem health and associated ecosystem services (regulating, provisioning, supporting, information)	● Persistent reduction in marine and shoreline ecosystem health and associated ecosystem services (regulating, provisioning, supporting, information)	69-84

^f D. Byers, personal communication, October 2018.

Overview of Valuation Approach

For each impact category, we calculated baseline values from a no-spill scenario and estimated damages associated with each spill scenario, over a 30-year period. Though impacts of oil spills may very well persist for more than 30 years, this valuation timeframe accommodates the impact duration assumptions selected for these scenarios. For the baseline, no-spill scenario, we estimated and applied annual industry growth rates (e.g. tourism growth rate, property value growth rate) for each category based on historical trends, where appropriate. For both spill scenarios, we accounted for the effects of industry growth rates in addition to discounting values based on impact magnitude and duration assumptions. The annual values for each impact category were then summed across the 30-year time period, and these total values were then summed across categories to arrive at a total dollar value (in 2018 dollars) of economic, social, and environmental resources for the No-Spill Scenario, Scenario A, and Scenario B. Subtracting the Scenario A and Scenario B total values from the no-spill values produces estimated *total damages* or *marginal loss of economic value* associated with each spill scenario, as compared to a no-spill scenario.

Discount Rate

Costs associated with each oil spill scenario are valued over a 30-year timeline to capture the full damages that San Juan County would incur into the future. By thinking about how much future damages are worth today, decision makers can compare damages that are produced at various points in time. This process of converting the value of all future costs into present terms is called discounting. Discounting requires the careful selection of a discount rate which determines to what extent the value of future costs and benefits will be reduced when translating them into present terms. Public and private agencies vary in their standards for discount rates. However, many federal agencies, including the Congressional Budget Office, recommend a discount rate between 1.5 and 3 percent.³² The choice of discount rate is critical as it heavily influences the outcome of the present values of benefits and costs which occur over a long period of time. This report uses a 0 percent discount rate to demonstrate the long-term damages of each oil spill scenario. Using a 0 percent discount rate assumes that decision-makers today care just as much about future costs and benefits (in this case, costs associated with oil spills or benefits associated with preventing an oil spill) as those that will be incurred in the immediately.

Table 3. Impact Valuation Summary – Scenario A

Impact Category	Baseline Growth Rate	Total Baseline Value in No-Spill Scenario Over 30 Years	Scenario A Impact Estimate	Total Damages for Scenario A (low)	Total Damages for Scenario A (high)	Directional Bias <i>In addition to biases explained below, all impact estimates introduce negative directional bias due to use of average values of past spill impact estimates as the upper bound of scenario estimates.</i>
Economic						
Commercial Fishing	0%	\$88,269,594	100% loss of landings for 4-12 months	\$932,308	\$2,505,261	Negative: Underestimates total damage, does not account for negative impacts of decreased catch or loss of market demand
Aquaculture	0%	\$9,327,088	50% loss of sales for 18 to 36 months	\$99,204	\$148,806	Negative: Underestimates total damages, does not account for decreased productivity or loss of market demand post-spill
Tourism Economic Impacts		\$44,777,269,674	7-21% for 9 to 24 months	\$21,096,238	\$161,466,255	Negative: Underestimates total damages, due following exclusions: a) does not account for tourist activity impacts due to immediate disruption of transportation; and b) does not account for indirect and induced economic effects within the county (excluded due to data and resource limitations)
Tourism Spending	8.4%	\$33,972,999,667		\$15,928,288	\$121,929,033	
Tourism-Supported Wages	8.2%	\$10,016,417,831		\$4,872,646	\$37,263,695	
Tourism-Supported Tax Revenue	9.6%	\$787,852,176		\$295,303	\$2,273,527	
Property Values		\$22,246,513,757	4-10% decline for 3 to 30 months (oiled properties); 1.75-3.5% decline for 3 to 30 months (non-oiled properties)	\$89,669,667	\$245,049,679	Neutral/Negative: Underestimates total damages due to exclusion of properties on non-impacted islands, which could experience value loss due to overall damages to the county's reputation. However, property tax revenue may not be impacted depending on frequency and timing of property appraisal in the county in relation to the spill events.
Property Values	6.0%	\$22,153,763,183		\$89,295,815	\$244,028,014	
Local Property Tax		\$92,750,574		\$373,852	\$1,021,666	
Social						
Recreation Use Value - Tourists	8.4%	\$13,991,791,844	7-21% for 9 to 24 months	\$8,032,072	\$37,156,366	Negative: Underestimates total damages due to use of statewide average use values by land management type that assume smaller ratio between tourist and local users; tourist use values are much higher than local use values; also excludes use value loss to local residents
Environmental Ecosystem Services	0%	\$1,444,234,885 to \$3,363,745,444	20-40% decline over 1-10 years; 1% decline over remaining 20 years	\$22,465,043	\$63,585,734	Neutral/Negative: Positive directional bias due to assumption that baseline conditions of ecosystems are constant (rather than declining) over 30 years; however, exclusion of ecosystem service losses associated with oil impacts to shoreline trees, shrubs, grasses, pasture, non-vegetated beach results in likely overall underestimate of ecosystem services.
Total				\$142,294,533	\$509,912,101	

Table 4. Impact Valuation Summary –Scenario B

Impact Category	Baseline Growth Rate	Total Baseline Value in No-Spill Scenario Over 30 Years	Scenario B Impact Estimate	Total Damages for Scenario B (low)	Total Damages for Scenario B (high)	Directional Bias <i>In addition to biases explained below, all impact estimates introduce negative directional bias due to use of average values of past spill impact estimates as the upper bound of scenario estimates.</i>
Economic						
Commercial Fishing	0%	\$88,269,594	100% loss of landings for 1-3 months	\$69,438	\$223,468	Negative: Underestimates total damage, does not account for negative impacts of decreased catch or loss of market demand
Aquaculture	0%	\$9,327,088	50% loss of sales for 18 to 36 months	\$57,342	\$86,012	Negative: Underestimates total damages, does not account for decreased productivity or loss of market demand post-spill
Tourist Visitation Impacts			7-21% decline over 3-8 months	\$8,644,889	\$59,241,307	Negative: does not account for indirect and induced economic effects within the County
Tourism Spending	8.4%	\$33,972,999,667		\$6,527,149	\$44,728,952	
Tourism Wages	8.2%	\$10,016,417,831		\$1,996,730	\$13,683,100	
Tourism Tax Revenue	9.6%	\$787,852,176		\$121,010	\$829,255	
Property Value		\$22,153,763,183	4-10% decline for 1 to 10 months (oiled properties); 1.75-3.5% decline for 1 to 10 months (non-oiled properties)	\$60,291,961	\$134,394,520	Neutral/Negative: Underestimates total damages due to exclusion of properties on non-impacted islands, which could experience value loss due to overall damages to the county's reputation. However, property tax revenue may not be impacted depending on frequency and timing of property appraisal in the county in relation to the spill events.
Property Values	6.0%	\$22,153,763,183		\$60,291,961	\$134,394,520	
Local Property Tax		\$92,750,574		\$252,423	\$562,666	
Social						
Recreation Use Value	8.4%	\$13,991,791,844	7-21% decline over 3-8 months	\$2,688,209	\$18,421,635	Negative: Underestimates total damages due to use of statewide average use values by land management type that assume smaller ratio between tourist and local users; tourist use values are much higher than local use values; also excludes use value loss to local residents
Environmental						
Ecosystem Services	0.0%	\$1,454,424,641 to \$3,397,063,553	20-40% decline over 1-10 years; 1% decline over remaining 20 years	\$12,275,287	\$30,267,625	Neutral/Negative: Positive directional bias due to assumption that baseline conditions of ecosystems are constant (rather than declining) over 30 years; however, exclusion of ecosystem service losses associated with oil impacts to shoreline trees, shrubs, grasses, pasture, non-vegetated beach results in likely overall underestimate of ecosystem services.
Total				\$84,279,549	\$243,197,234	

7. Damage Estimate by Impact Category

a. Commercial Fishing and Aquaculture

Impact Description

Oil spills impact commercial fishing and aquaculture in a multitude of ways. Direct oiling of commercial fishing areas can prompt temporary harvest bans and closure of commercial fishing and aquaculture areas, resulting in immediate loss of fishery income. Mandatory bans are implemented by government agencies as a measure to protect consumers from potentially contaminated seafood.³³ Oil spills of all sizes can prompt harvest bans, and can range anywhere from a couple of days to multiple years.³⁴ Beyond the immediate impacts of fishing bans, longer-term economic impacts may also occur as a result of a) lower catch volumes due to overall lower fish stock, and b) decreased market demand (resulting in lower prices) for seafood due to negative perceptions of seafood safety.³⁵

Wild adult fish have a relatively low risk of oil exposure due to the fact that they are highly mobile and can avoid oiled areas.^{34 36} The primary impact of oil spills to fish populations occurs primarily in the form of sub-lethal effects and mortality of fish embryos resulting from oil exposure, and resulting implications for cohort survival.^{35 37 38} As a result, impacts to catch volumes may not be felt until several years after a spill (the average lifespan of most salmon species is 2 to 7 years.³⁹ Species cultivated via aquaculture operations have a much higher risk of exposure to oil due to their physical containment and inability to avoid oil in the water column.^{34 35 36} In general, species located in nearshore environments are at a higher risk of oil exposure than species located in open sea.^{34 35}

As for market impacts, negative public perception of seafood safety of a particular region can last far beyond actual measurable tainting of seafood.³⁵ Negative public perception of seafood safety was found to have impacted seafood prices to some degree after a number of oil spills, including *Hebei-Spirit* oil spill⁴⁰, *Exxon Valdez*⁴¹, and *Deep Water Horizon*⁴².

Impact Estimation

Data on mandatory fishing bans from past spills are readily available. Commercial fishing closures persisted for 1-12 months after *Deep Water Horizon*,^{43 44} 9-24 months after *Exxon Valdez*,^{45 46} and between 2.5 weeks and 6 months for the smaller spills (*Refugio*, *Bouchard 120*, *Chalk Point*, and *Cosco Busan*).⁴⁷ While data on total commercial fishery landings losses is available for a number of spills, data on annual percent decreases relative to pre-spill conditions is sparse. After *Deep Water Horizon*, shrimp landings and forage fish landings decreased by 32-56% and 17% during the first year after the spill, respectively.⁴⁸ Shellfish and other sessile organisms (e.g., crabs, clams, mussels, shrimp) generally suffer higher mortality and contamination rates,^{34 49} which is reflected in longer closure durations and impacts to shellfish-related landings after *Deep Water Horizon*.

As discussed above, commercial fishing closures are not the only mechanism by which commercial fishing is impacted. Impacts to fish and shellfish populations could negatively affect catch volumes in the longer term, and negative public perception of seafood safety could result in decreased demand and lower seafood prices. However, for our analysis, we take a conservative approach and only considered the short-term impacts associated with fishing closures, though this likely significantly underestimates the full impacts to commercial fishing. For both scenarios, we drew from data on *Exxon Valdez*, given the

similarities between Prince William Sound and San Juan County in terms of wild fish/shellfish habitat and species harvested. For Scenario A, we scaled the commercial fishing closure durations for *Exxon Valdez* downward by 50% to reflect the 50% smaller volume of Scenario A spill size as compared to the *Exxon Valdez* spill volume. For Scenario B, we further scaled down the Scenario A impact duration by 75% to reflect the 75% smaller volume of Scenario B (1 mil gal) as compared to Scenario A (4 mil gal). **For Scenario A, we assumed 100% loss of commercial landings income associated with closures lasting 4-12 months; for Scenario B, we assumed 100% loss of commercial landings income associated with closures lasting 1-3 months.**

Aquaculture organisms are highly susceptible to acute mortality from oiling, as they are contained and unable to escape oiling in the water column (see discussion in section 5). Concrete data on impacts to aquaculture from past oil spills is sparse. We therefore followed estimation methods utilized by Sumaila et al 2012, which assumes that aquaculture sales for operations directly impacted by oiling would experience a 100% loss due to total mortality of all shellfish, lasting the duration of the shellfish growing cycle. **We took a conservative approach and only assume for both scenarios that 50% of aquaculture sales is lost due to acute mortality of 50% of harvest, lasting for 18 to 36 months.**^g

Valuation Data and Methods

To estimate the overall economic value of commercial fishing and aquaculture in San Juan County, we utilized county-level commercial fishery sales from 2003-2013^h and 2012 aquaculture sales and distribution within the county.ⁱ We assumed no annual industry growth rate due to lack of historical industry data.^j

To map the geographic location of commercial fishing and aquaculture activities, designated commercial fishing and aquaculture areas were extracted from management activities data layers within the 2006 NOAA Environmental Sensitivity Index (ESI) geodatabase for Puget Sound. Polygons representing commercial fishing and aquaculture activities were clipped to the San Juan County border (see Designated Commercial Fishing and Aquaculture Areas Map in Appendix C).^k Sea surface oiling maps from the two spill scenarios were overlaid with the clipped fishing and aquaculture polygons to determine the percentage of fishing and aquaculture areas that come into contact with oil in each scenario. The percentage oiled was then used to discount the county sales data, as a rough estimate of the percentage of fishing and aquaculture activities that would be impacted by harvest bans and direct damage, respectively.^l Average monthly breakdowns of percentage of annual sales for Washington State^m from 2014 and 2015 were applied to the average annual commercial fishing sales value (averaged over 2003 to 2013) to account for the effects of seasonal sales variation on each scenario. Table 5 summarized monthly percentages derived from Washington State landings data for 2014 and 2015.

^g Growing cycles for mussels, clams, and oysters grown at Friday-Harbor based aquaculture farm Westcott Bay Shellfish are 18-26 months, according to their website: <https://www.westcottbayshellfish.com/>

^h Source: Washington Department of Fish and Wildlife San Juan County Commercial Fishing Data 2003-2013, provided by San Juan County.

ⁱ Source: U.S. Census on Agriculture County Profiles

^j Landings data is highly variable from year to year and an annual growth rate is difficult to predict accurately; aquaculture sales data is only available from two census years, providing insufficient data points to estimate an annual growth rate.

^k In order to bound our analysis of fishing and aquaculture impacts incurred by the county, we assumed that landings in San Juan County result from wild fish catch occurring in waters within San Juan County border.

^l This approach does not account for the ripple effects that lost landings and sales would create in the county's local economy; modeling the full direct, indirect, and induced effects of reduced landings and sales was beyond the scope of this assessment.

^m Source: NOAA National Marine Fisheries Service

Table 5. Monthly Breakdown of Commercial Fishing Landings for WA State and San Juan County

Month	2014		2015		Average % of Annual Landings from 2014/15 data	Estimated Monthly Landings for San Juan County
	WA State Landings	% of Annual Landings	WA State Landings	% of Annual Landings		
Jan	30,248,363	9%	31,116,369	10%	10%	\$287,829
Feb	18,334,621	6%	20,688,149	7%	6%	\$183,426
Mar	17,550,887	5%	18,156,858	6%	6%	\$167,508
Apr	16,343,440	5%	18,305,333	6%	6%	\$162,839
May	24,264,173	7%	24,146,099	8%	8%	\$226,892
Jun	23,604,188	7%	25,688,643	9%	8%	\$231,508
Jul	31,136,480	9%	27,037,281	9%	9%	\$271,793
Aug	40,729,466	12%	37,249,578	12%	12%	\$364,762
Sep	39,812,060	12%	33,221,630	11%	12%	\$340,906
Oct	35,550,733	11%	27,851,104	9%	10%	\$295,517
Nov	18,741,329	6%	19,400,600	6%	6%	\$178,929
Dec	32,793,225	10%	17,089,934	6%	8%	\$230,410
Total	329,108,965	100%	299,951,578	100%	100%	\$2,942,320

Results

	No-Spill Scenario	Scenario A		Scenario B	
	Total Value Over 30-Years	Total Damages over 4 months (low)	Total Damages over 12 months (high)	Total Damages over 4 months (low)	Total Damages over 12 months (high)
Commercial Fishing Landings	\$88,269,594	\$932,308	\$2,505,261	\$69,438	\$223,468
	Total Value Over 30-Years	Total Damages over 18 months (low)	Total Damages over 36 months (high)	Total Damages over 18 months (low)	Total Damages over 36 months (high)
Aquaculture Sales and Distribution	\$9,327,088	\$99,204	\$ 148,806	\$57,342	\$86,012

For the no-spill baseline scenario, total commercial landings across the 30-year timeframe totaled \$88,269,594. Impacts to commercial fisheries in the Scenario A resulted a loss of landings income of **\$932,308 to \$2,505,261** as compared to the 30-year no-spill baseline. For Scenario B, decreased commercial fishing landings resulted in a marginal value loss of **\$69,438 to \$223,468**. The value of aquaculture sales and distribution in the no-spill baseline scenario was \$9,327,088, which dropped to between \$9,095,973 and \$9,173,011 in Scenario A and \$9,241,076 to \$9,269,746 in Scenario B. This translates into aquaculture damages for Scenario A of **\$99,204 to \$148,806** and **\$57,342 to \$86,012** for Scenario B.

b. Tourist Visitation Impacts

Impact Description

The tourism industry is an important economic driver in many coastal and island communities.^{44 50} Tourist activities—from dining and shopping to whale watching and hiking—inject money into regional and local economies and help to sustain a variety of supporting industries and associated employment. Trip-related expenditures on gas, lodging, restaurants, groceries, equipment, and guide services directly support local jobs, income, and public revenues, also referred to as *direct effects*. These expenditures also generate secondary effects, as employees of the above establishments spend their income on things like rent and food (*induced effects*) and business-to-business purchase (*indirect effects*).

The tourism industry is highly vulnerable to disasters,⁵¹ due to the fact that tourist activity is strongly tied to public perception of the safety and aesthetic quality of a place.⁵² Island communities, as attractive tourism destinations^{53 54} are particularly vulnerable to disasters and disturbances because of their considerable economic dependence on the tourism industry in comparison to local domestic industries.⁴⁴ Oil spills pose an especially large threat to island communities that depend on safe access to beaches and water, uninterrupted marine transportation, healthy marine wildlife, and overall positive public image to maintain a robust tourism industry.⁵⁵

Particularly for island communities such as San Juan County that are heavily dependent on seasonal visitation (May-September in the case of San Juan County), oil spills can be especially devastating if they align with the peak tourist season.²¹ Declines in tourist visitation and spending have been observed after several past oil spills, including *Exxon Valdez*, *Deep Water Horizon*, and *Ixtoc I*. Tourism declines have not only been observed for areas directly impacted by oil spills. For example, after *Deep Water Horizon*, tourist visitation decreased in coastal areas that were not directly impacted by the oil spill but were located nearby oiled shorelines,⁵⁶ and prospective tourists surveyed after the spill exhibited poor understanding of the exact geographic extent of areas impacted from the spill.⁵⁷ Misunderstanding by non-local travelers about the impacts of a spill can contribute to the negative perception held by tourists of the overall safety and aesthetic quality of a tourist destination affected by a spill.

Impact Estimation

Most studies of the tourism and recreation impacts of past oil spills have focused on *Exxon Valdez* and *Deep Water Horizon*. For *Exxon Valdez*, overall impacts to visitation and spending after the spill have been reported to have lasted anywhere from 9 months⁵⁸ to 24 months⁵⁹, with reductions in spending ranging from 8% in South-Central Alaska to 35% in Southwestern Alaska during the year of the spill.⁵⁸ For *Deep Water Horizon*, tourism spending was estimated to have declined by 12-25% in the first year after the spill, recovering to a 4-8% decline by the third year after the spill.⁵⁹ An analysis of US tourism impacts resulting from the *Ixtoc I* spill in the Gulf of Mexico found an estimated reduction in tourist spending of 7-10% over two years.⁶⁰ An analysis of tourism impacts across 5 international spills (including *Exxon Valdez*) estimated the average duration of tourism impacts after a spill to be 12-28 months.

Given that the *Deep Water Horizon* and *Ixtoc I* spills were significantly larger than our hypothetical spills, we defined the upper bound of our impact rate estimate as the average (21%) of the range of impact estimates of past spills (7-35%) and the lower bound as the lowest impact rate reported from past spills (7%). To estimate impact duration, for Scenario A we utilized the range durations (9-24 months) reported in studies of *Exxon Valdez*, given the relative similarities between Alaska and San Juan County in terms of seasonality of tourist visitation and activities. For Scenario B we scaled down the durations by a factor of three to reflect the smaller volume of oil assumed to wash up on shorelines in the smaller spill. **For the Scenario A, tourist spending is assumed to decline by 7-21% lasting for 9-24 months; for the Scenario B, we assumed a similar magnitude of 7-21% lasting for 3-8 months.**

Data and Methods

To estimate the overall economic value of tourism in San Juan County, we utilized county-level traveler spending data from 2017,ⁿ which includes trip-related spending (accommodations, food service, local transportation, retail sales, equipment, guide fees, etc) and associated direct effects (local earnings, employment, and local and state tax revenue) within San Juan County. We utilized the average annual percent change from 2010 to 2017 as an annual growth rate for each category (spending, earnings, revenue) and applied this growth rate to the baseline value across the 30-year time period, beginning in 2019. Monthly values for tourism spending, earnings, and tax revenue were estimated from the annual values based on San Juan Island National Historic Park 2011 Monthly Visitation data.^o We applied annual growth rates to each spill scenario, on top of the estimated impact rates described above. We assume a linear relationship between spending, earnings, and local tax revenue and therefore applied the impact rate (7-12%) to each category. We assume that the overall tourism industry is impacted equally regardless of geographic distribution of physical oil impacts, given the documented misperception among tourists of the geographic extent of past oil spill impacts⁵⁷ and the fact that the vast majority of tourist activities within San Juan County are dependent on access to or views of shorelines and marine waters.⁶¹ In other words, we assume that, in the event of an oil spill, a certain percentage of tourists would cancel their trips to San Juan County (regardless of the extent of oiled areas) instead of visiting the county and participating in alternative activities that do not involve accessing or viewing impacted shorelines and marine waters. Indirect and induced effects of reduced tourist spending were not modeled as part of this assessment due to data and resource limitations.

Results

	No-Spill Scenario	Scenario A		Scenario B	
	Total Value Over 30-Years	Total Damages Over 9 Months (low)	Total Damages Over 24 Months (high)	Total Damages Over 3 Months (low)	Total Damages Over 8 Months (high)
Tourist Visitation Impacts	\$44,777,269,674	\$21,096,238	\$161,466,255	\$8,644,889	\$59,241,307
Tourism Spending	\$33,972,999,667	\$15,928,288	\$121,929,033	\$6,527,149	\$44,728,952
Tourism Wages	\$10,016,417,831	\$4,872,646	\$37,263,695	\$1,996,730	\$13,683,100
Tourism Tax Revenue	\$787,852,176	\$295,303	\$2,273,527	\$121,010	\$829,255

The cumulative values across the 30-year period associated with travel to San Juan County in a no-spill scenario is nearly \$34 billion in traveler spending, \$10 billion in tourism-supported wages, and \$788 million in tourism-generated local tax. For the Scenario A, losses in total traveler spending, tourism-supported wages, and tourism-generated local tax amount to \$15.9 million to \$122.0 million, \$4.8 million to \$37.3 million, and \$295,303 to \$2.3 million, respectively, or **\$21.1 to \$161.5 million** of total tourism-related damages. For the Scenario B, damages for traveler spending, tourism-supported wages, and tourism-generated local tax amount to \$6.5 million to \$44.7 million, \$2.0 million to \$13.7 million, and \$121,010 to \$829,255 respectively, or **\$8.6 million to \$59.2 million** of total tourism-related damages.

ⁿ Source: Dean Runyan Washington State Travel Impacts and Visitor Volumes 2000-2017

^o Source: 2018 San Juan Visitor Study

c. Recreation Use Value

Impact Description

In San Juan County, as in many marine-dependent communities, popular recreation activities among tourists and locals alike depend on access to and views of natural shoreline and marine environments. Perceived safety and aesthetic quality of the local environment plays a major role in tourist visitation due to the benefits that visitors derived from interacting with the natural environment. In San Juan County, some of the most popular recreational activities for visitors and locals include fishing, shellfishing, boating, hiking, and wildlife viewing.⁶¹ Most all of the popular recreation activities for island visitors depend on access to clean beaches or water.

Past oil spills have caused short-term and long-term disruptions to coastal and marine recreation. Beach closures and marine transportation bans prevent people from partaking in recreation immediately after a spill; while degraded perceptions of aesthetic quality of the environment can impact recreation in the long-term. For example, after the *Exxon Valdez* spill, kayakers and campers surveyed reported to continue to avoid certain beaches in Prince William Sound due to perceived environmental degradation up to ten years after the spill event.⁵⁸

The non-market benefit that recreation provides tourists and locals alike is referred to as recreation use value or consumer surplus value. Use value is calculated by estimating a person's willingness to pay for recreation and subtracting the actual cost incurred. For example, if a visitor to San Juan County is willing to pay \$50 for a day permit to visit Lime Kiln State Park on San Juan Island and the permit only costs \$10, then the use value for that park visitor is \$40. Different types of recreation are associated with different use values, depending on the individuals and activities involved. The recreational benefits or use value provided by natural assets—or, in the case of San Juan County, by access to healthy shoreline and marine waters—is not accounted for within traditional economic indicators and is an important part of the overall damages generated by an oil spill.

Impact Estimation

Similar to our assumptions for tourist spending, we assume that tourist participation in recreation activities declines equally across all activities regardless of activity type or geographic impacts of physical oiling, based on the assumption that a) tourists' primary reason for planning a trip to San Juan County is to participate in some type of water- or shoreline-dependent activity that would be disrupted by an oil spill, and b) visitors who are deterred by an oil spill will cancel their trip to the Islands altogether despite the actual physical distribution of oiling in the islands. While local residents would also suffer a loss of use value caused by disruption to their regular recreational activities within the islands, we chose to omit impacts to local residents from this analysis due to uncertainties related to a) the percentage of local residents that would choose to refrain from recreation (and therefore suffer use value loss) as opposed to selecting unoiled recreation sites, and b) the extent to which residents' recreation sites are impacted by oil. We assumed the same impact rates for tourist recreation use values as the travel spending impacts—**a 7 to 21% loss of use value lasting 9-24 months for the Scenario A and 3-8 months for the Scenario B.**

Data and Methods

We utilized county-level estimates of recreation activity derived from Earth Economics' Economic Analysis of Outdoor Recreation in Washington State (2015) and the Economic Analysis of Outdoor Recreation at Washington's State Parks (2015). These activity values are reported as total person-days of recreation per land management type in 2015, broken down into the following land management categories: state parks, local/county parks, and public waters. For state parks visitation, we utilized 2017 visitation data (person-days) acquired through the Washington State Parks and Recreation Commission. We assumed that 85% of annual recreation person-days can be attributed to non-local tourist recreation, based on the average breakdown of local versus non-local visitors to attraction sites on the Islands.⁶¹ We estimated 2019 tourist visitation data from the 2015 and 2017 visitation data, using average annual percent change in Washington State population from 1998 to 2018.^p For the no-spill baseline scenario, we assumed the same annual growth rate in recreation visitation over the 30-year period of analysis. For the two spill scenarios, we applied the same growth rates to the annual visitation numbers in addition to discounting by the same 7-12% impact rate utilized for estimating tourist spending damages. Annual visitation (person-days) across the 30-year period for each scenario was then multiplied by average per-person-day consumer surplus values by land management type (see table 6 below) to arrive at a total estimated recreation use value for each scenario. The average use values from the Earth Economics' 2015 Washington State recreation reports are based on an overall average breakdown of local versus non-local visitation by land management type.^q

Table 6. Average Recreation Use Value by Land Management Type^r

Recreation by Land Management Type	2019 Projected Annual Visitation	Average Consumer Surplus Value Per Person-Day
State Lands		
State Parks	1,685,210	\$38
WA F&W Game Management Units	95,847	\$61
WA F&W Wildlife Management Areas	2,486	\$64
Public Waters		
Fishing	260,056	\$66
Motorized Boating & Sailing	248,724	\$26
Non-Motorized Paddle Sports	99,525	\$38
Scuba Diving	85,531	\$70
Local Parks		
County Parks	86,321	\$64
City Parks	379,814	\$64

^p Source: WA State Office of Financial Management.

^q Because non-local visitation is associated with a higher use value than local visitation (i.e. non-local visitors are likely to be willing to pay more for recreation on top of their direct expenses, as compared to local residents), and because the proportion of recreation visitation in San Juan County attributed to non-locals is significantly higher than other areas of the state, these average consumer surplus values are likely highly underestimating the true consumer surplus values associated with tourist recreation in San Juan County.

^r Source: Earth Economics 2015a and Earth Economics 2015b

Results

	No-Spill Scenario	Scenario A		Scenario B	
	Total Value Over 30-Years	Total Damages Over 9 Months (low)	Total Damages Over 24 Months (high)	Total Damages Over 3 Months (low)	Total Damages Over 8 Months (high)
Recreation Use Value	\$13,991,791,844	\$8,032,072	\$37,156,366	\$2,688,209	\$18,421,635

Total consumer surplus value over the 30-year no-spill baseline scenario is nearly \$14 billion. In Scenario A, San Juan County visitors see a loss between **\$8.0 million and \$37.2 million** in consumer surplus value associated with lost opportunities for recreation, and a loss of **\$2.7 million to \$18.4 million** in consumer surplus value for the Scenario B.

d. Property Value

Impact Description

Many residents are attracted to San Juan County for their proximity and access to the natural assets, including direct access to shorelines and marine waters as well as access to aesthetic benefits derived from waterfront views and views of marine and shoreline wildlife. The higher property values of waterfront and water-view homes in shoreline areas such as San Juan County are reflective of the value homeowners place on shoreline and marine resources.⁶²

The negative effect of environmental contamination on property values is well documented. Property values have been shown to decrease as a result of proximity to landfills, groundwater contamination, and toxic waste sites.⁶³ Environmental disamenities influence property values due to the anticipated costs of remediation, perceived or real hazards posed by contamination, and perceived impairment of aesthetic quality of the property location.⁶⁴ This loss in property value can materialize as an economic loss to a homeowner who sells his or her home as well as an economic loss to local governments in the form of reduced property taxes. Even if a person does not sell his or her home during the impact period, the homeowner still suffers a temporary loss in asset value.

Studies have demonstrated the direct negative effects of oil spills on property values.⁶⁸ Oil spills have also been shown to cause indirect effects to properties associated with oil spill areas but not directly impacted by oil, due to the effects of stigma and perceived risk associated with those homes.⁶⁴ Public perception of an environmental hazard is tied to a number of factors, including public trust in the government's ability to remediate or clean-up the hazard,⁶⁵ media coverage (tone and duration),⁶⁶ and community dynamics.⁶⁷ For example, values of property in close proximity to oil infrastructure (e.g. oil pipelines) have been shown to decline even in the absence of an actual oil spill. Anecdotal evidence also exists showing the stigma effects of marine oil spills on properties neighboring but not directly located on oiled areas.⁶⁸

Impact Estimation

Few studies have specifically examined the impacts of oil contamination to property values resulting from a marine oil spill. Property value impacts from remote spills (e.g. *Exxon Valdez*) are not well understood,

due to the remote location of the spill.⁶⁹ Data on the property market impacts of *Deep Water Horizon* are more readily available, given the relatively populated coastal areas of the Gulf region, as well as on the property value impacts of pipeline spills. Market-specific studies examining impacts to coastal properties after *Deep Water Horizon* report impacts ranging from a 16% decline in values specifically for properties with no residential structure⁷⁰, to a 10.1-13.5% reduction in value for condominiums in two coastal cities in Alabama for 3 months after the spill,⁷¹ to a 4-8% decline in home prices throughout the Gulf region recovering over five years.⁷² In the case of pipeline spills, values of nearby properties are typically impacted by 5-8% over 1-2 years.⁷³ In addition to the impacts of directly oiled properties, properties located near oiled areas may also suffer value loss as a result of stigma and the perceived risk of shoreline oiling, which is consistent with the larger literature on the property value impacts of environmental disamenities in general.^{65 66 67} A study examining *Deep Water Horizon* impacts to single-family residential properties in Hillsborough County, Florida, an area that was not directly contaminated with oil, found a 3.5% reduction in sales prices of properties within 2500m from shoreline, recovering after nine months.⁶⁹

In this analysis, we modeled impacts to property values for properties assumed to be directly oiled (waterfront parcels sharing a boundary with oiled shoreline), as well as all other properties located on islands assumed to be oiled in each scenario (Stuart, Spieden, Lopez, and San Juan Island in Scenario A, and Stuart and San Juan Island in Scenario B). This approach is based on the knowledge that buyers are attracted to the San Juan County housing market, including inland properties, due to the aesthetic and direct use value of nearby shorelines and marine areas, as well as the effect of stigma and perceived risk of shoreline oiling on property values of nearby waterfront properties.

We utilized an average value of the range of available impact rates (10%) to estimate the upper bound of impacts on directly oiled properties, and the lowest rounded impact rate as the lower bound (4%), to reflect the significant uncertainty associated with housing market behavior. Drawing on evidence after *Deep Water Horizon* of the impacts of perceived risk on non-oiled properties, we conservatively utilized the observed impact rate from non-oiled properties in Hillsborough County, Florida as the upper bound (3.5%), and 50% of this impact rate as the lower bound (1.75%), for inland and non-oiled waterfront properties located on islands assumed to be impacted by oiling elsewhere.

To estimate duration of impacts, for Scenario A, we similarly utilized the average value of the range of durations reported in available studies (30 months) as an upper bound and the lowest duration reported (3 months) as the lower bound. For Scenario B, we scaled the duration range down by a factor of three to reflect the smaller volume of oiled assumed to wash up on shore. **Using this approach, we assumed a 4-10% decline in asset value of oiled properties persisting for 3 to 30 months in scenario A, and persisting for 1 to 10 months in scenario B. For non-oiled properties located on islands assumed to experience some degree of shoreline oiling, we assumed a 1.75-3.5% decline in asset value persisting for 3 to 30 months (scenario A) and 1 to 10 months (scenario B).**

Data and Methods

We used 2015 San Juan County tax assessor parcel data⁵ to model property value impacts of direct and perceived risk of oil contamination. Appraised property values represent the government's estimation of taxable property value, which can serve as an indicator of asset value during a given time period. We subset the properties to include in the analysis into two groups: 1. all parcels within 500m landward of estimated oiled shorelines in each scenario (herein referred to as "waterfront properties"), and 2. all

⁵ Source: San Juan County Open Data

other parcels located on islands assumed to be impacted by shoreline oiling in each scenario. A 500m buffer was applied to the waterfront properties to conservatively account for the neighborhood effects of housing market disruptions from environmental hazards.⁷⁴

Under a no-spill baseline scenario, we applied an annual property value growth rate of 6%,^t to estimate the total value of the housing market over time if no spill were to occur. For each spill scenario, the total appraised value of oiled waterfront properties and non-oiled properties was discounted by 4-10% and 1.75-3.5% respectively. This approach estimates the total temporary loss of asset value across the San Juan County housing market during each scenario and does not include estimates of actual economic loss to homeowners who sell their homes during the period of impact (see Appendix D for a rough estimation of economic loss due to sales impacts in each scenario). In addition to modeling temporary declines in property values in the months after each hypothetical spill, we also estimated impacts to local property tax revenue^u due to these temporary losses, using the average levy rate in San Juan County, excluding state levies (\$4.19 per \$1000 in assessed value).^v

Results

	No-Spill Scenario	Scenario A		Scenario B	
	Total Value Over 30-Years	Total Damages Over 3 Months (low)	Total Damages Over 30 Months (high)	Total Damages Over 1 Month (low)	Total Damages Over 10 Months (high)
Total Property Value and Taxes	\$22,246,513,757	\$89,669,667	\$245,049,679	\$60,544,384	\$134,957,186
Property Value	\$22,153,763,183	\$89,295,815	\$244,028,014	\$60,291,961	\$134,394,520
Local Property Tax Revenue	\$92,750,574	\$373,852	\$1,021,666	\$252,423	\$562,666

In the no-spill scenario, assuming a 6% annual growth in property values, the estimated, total, appraised value over 30-years of all properties in San Juan County at risk of being impacted in either spill scenario is **\$22.2 billion**, and total marginal gains in annual local property tax revenue generated from these properties over 30 years is \$92,750,574. In the Scenario A, damages to these property values and associated local property tax revenue is **\$89.7 million to \$245 million**, and the estimated damages in Scenario B are **\$60.5 million to \$135.0 million**.

e. Ecosystem Services

Impact Description

^t Source: San Juan County Comprehensive Plan Appendix: Housing Needs Assessment 2017

^u According to local experts, in the event of property value decreases following an oil spill, the county and state would still collect the total amount of taxes due before values decreased, and the reduction in taxes collected from impacted properties would be shifted to other properties. We chose to still include this estimate as a tangible cost to the community, regardless of whether government or other property owners bear the cost. (L. Pratt, personal communication, November 2018)

^v Source: <https://www.sanjuanco.com/158/Tax-Levies-by-Tax-Code-Area>

Ecosystem services are the benefits people derive from nature. Functional ecosystems contribute both directly and indirectly to human well-being by providing natural water filtration, raw materials, flood-risk reduction, climate regulation, and more. Most ecosystem services are taken for granted or undervalued by society, leading to the degradation or destruction of natural assets. The shoreline and marine ecosystems of San Juan County provide benefits that would be impractical or even impossible to replace, including water quality, air quality, flood risk reduction, and habitat for threatened and endangered species. Once lost, these services that the county receives for free must be replaced with costly built solutions, which are often less resilient and shorter-lived. Understanding and accounting for ecosystem services reveals the true economic benefits of healthy ecosystems and the true economic damages that pollution events such as oil spills generate for communities like the San Juan County.

The severity of oil spill damage to marine and shoreline ecosystems depends on the type and quantity of oil spilled, season and weather, type of shoreline, and the waves and tidal energy in the spill area.⁷⁵ Oil can damage aquatic ecosystems through two main mechanisms: physical injury and biochemical injury.⁷⁶ Physical injury describes when plants or animals are coated or smothered with oil; biochemical injury refers to the poisonous effects of oil when it is ingested, inhaled, or absorbed by species. The primary chemical components responsible for oil's toxic characteristic are PAHs, which can persist in the environment for many years.⁷⁶

Marine and shoreline fauna such as invertebrates, fish, birds, and aquatic mammals can be harmed by oil through ingestion, inhalation, suffocation, and smothering.⁷⁷ Acute species loss and loss of species richness directly impacts ecosystem function and in turn ecosystem services.⁷⁸ Certain aquatic species such as benthic fauna (e.g. bivalves, anemones, hermit crabs) perform important ecosystem functions such as decomposition and nutrient transfer.⁷⁹ Marine and shoreline flora can be impacted by oil through direct coating and penetration of plant cover, roots, and rhizomes. Direct contact with oil can cause acute plant mortality.⁷⁹ Oiling of plant cover can result in necrosis while oiling of roots and rhizomes can impair nutrient uptake and re-sprouting.⁷⁹ Moreover, when the stomata and transpiration pathways of plants are blocked by oil, photosynthetic processes are disrupted.⁸⁰ Loss of vegetative biomass, root systems, and photosynthetic capabilities within critical aquatic ecosystems such as wetlands and estuaries can result in reduced ecosystem function and services, including impaired water filtration, flooding mitigation, carbon sequestration, and habitat provision.

Marine and shoreline ecosystems exhibit varying degrees of sensitivity to oil. For example, PAHs are more soluble in freshwater and estuarine water than saltwater⁸¹; making estuarine damage potentially more severe than damage that would occur in open ocean.^{79 82} Estuaries and wetlands, found in protected nearshore and intertidal areas, also exhibit high ecological productivity and are home to numerous critical activities such as spawning, rearing, migration, foraging, and nesting.⁸³ Shoreline characteristics also influence the relative sensitivity of shoreline areas, specifically exposure to wave and tidal energy, shoreline slope, and substrate type (grain size, mobility, burial), which influence the potential for natural removal of oil and duration of oil exposure.⁸⁴

The ecological impact and recovery rates of past oil spills in some cases is well documented. For example, a large volume of studies exists for major spills such as the *Exxon Valdez* Oil Spill and *Deep Water Horizon*. The majority of studies focus on impacts and recovery rates of specific marine species, with long-term monitoring data on wildlife recovery readily available for both *Exxon Valdez* and *Deep Water Horizon*. The impacts of oil spills to overall ecosystem function and productivity are much less understood.

Impact Estimation

Estimating impacts of oil spills to ecosystem services requires the ability to estimate the impacts to overall ecosystem health. Ecosystem health is defined inconsistently across the ecological literature.⁸⁵ Moreover, a wide range of ecological indicators are utilized in research and monitoring efforts depending on the management or scientific goal,⁸⁶ including vegetative biomass, biodiversity, and indicator species population levels. Because quantifying mortality and recovery rates of specific species is a standard part of the oil spill injury assessment process,⁸⁷ data on species-specific injuries (e.g. number of dead waterfowl, rates of recovery to pre-spill waterfowl population levels) resulting from past oil spills are readily available. According to the *Exxon Valdez* Oil Spill Restoration Plan Injured Resources and Services Report from 2014, after *Exxon Valdez*, recovery rates of intertidal species found on shorelines ranged from 3 years (rocky intertidal) to over 25 years (rockweed, barnacles, mussels, etc), while recovery rates for subtidal species (amphipods, snails, clams, sea urchins, crabs, etc) and fish species (salmon, herring, rockfish) that spawn in nearshore waters ranged from 10 to 21 years. Actual percent declines in populations as compared to pre-spill populations is not reported due to lack of pre-spill population monitoring, with the exception of impacts to salmon biomass, which was estimated to have declined by 43% after *Exxon Valdez* as compared to pre-spill levels.⁸⁸

While population levels of key species can serve as one indicator of ecosystem health, other indicators such as vegetative biomass can also serve as an indicator of overall ecosystem productivity. Studies examining past oil spill impacts to wetlands health estimated a 45% reduction in herbaceous aboveground biomass, recovering over 5 to 11 years after *Deep Water Horizon*⁸⁹, and a 100% reduction in heavily oiled wetland vegetation cover, recovering over 10 years after the much smaller Chalk Point spill.⁹⁰ Studies of past oil spill impacts to subaquatic vegetation (SAV) estimated that 47% of nearshore SAV was injured after the Refugio spill, recovering over 3 years, and eelgrass density was 24% lower in oiled areas for 2 years after the *Exxon Valdez* spill.⁹¹ However, eelgrass-dependent subtidal communities were still recovering 21 years after the spill,⁹² suggesting that vegetation biomass or density as an ecosystem health indicator may underestimate damages to certain ecosystem services such as habitat-supporting services.

Given the wide variation in reported ecosystem impacts from this diverse group of oil spills (ranging from 120,000 to 120 million gallons), we assigned conservative magnitudes and durations of oil spill impacts observed from past spills to our spill scenarios based on ecosystem type, utilizing the overall average magnitude and duration across all spills analyzed as our upper bound, and the lowest values as our lower bound, as a conservative approach: a **10-40% decline over 1-10 years**. Given the ample evidence from *Exxon Valdez* of the long-lasting ecological impacts to shoreline and marine ecosystems in the form of sub-lethal effects on marine fauna and submerged tar balls in benthic and shoreline sediments^{84 93}, we also assumed that, after the initial 1-10 year impact period, ecosystem services continue to function only at 99% of normal for an additional 20 years in the areas assumed to be oiled.^w We applied the same

^w The 30-year time period utilized for ecosystem impact estimates (initial impacts over 10 years, with additional long-term impacts over an additional 20 years) is based on the duration of the most severe ecological impacts observed from *Exxon Valdez*. In reality, it has only been roughly 30 years since the *Exxon Valdez* spill event occurred, and after 30 years, multiple species/habitats still have not recovered. Therefore, while a 30-year timeframe was chosen to conservatively model the long-term ecological impacts of the hypothetical spills for San Juan County, in reality the impacts will likely last longer than 30 years and some ecosystems could never fully recover, as is the case in some areas impacted by *Exxon Valdez*.

impact magnitude and duration to both scenarios, assuming that the same amount of damage occurs in each scenario wherever sea surface and shoreline oiling occurs. We also assumed that under the no-spill baseline scenario, ecosystems are fully healthy (providing the maximum amount of services) and that ecosystem health remains constant throughout the duration of the analysis period.^x

Table 7. Summary of Ecosystem Health Impact Rates from Past Oil Spills

Ecosystem Type	Sub-type	Ecosystem health indicator measured	Reported impact magnitude (% reduction from baseline)	Reported impact duration (# of yrs recovery after spill)	Oil Spill	Reference
Shoreline beach	Rocky intertidal communities	Species population level	n/a	3 years	<i>Exxon Valdez</i>	NOAA
Shoreline beach	Intertidal communities	Species population level	n/a	25 years	<i>Exxon Valdez</i>	EVOSTC 2014
Shoreline water	Wetland	Above ground vegetation biomass level	45%	5-11 years	<i>Deep Water Horizon</i>	Baker et al 2017
Shoreline water	Wetland	Above ground vegetation biomass level	10-100%	1-10 years	<i>Chalk Point</i>	Michel et al 2002
Marine water column and benthic	Subtidal species	Species population level	n/a	21 years	<i>Exxon Valdez</i>	EVOSTC 2014
Marine water column	Salmon	Species population level	43%	10 years	<i>Exxon Valdez</i>	EVOSTC 2014
Marine benthic	Subaquatic vegetation	Eelgrass chlorosis	47%	3 years	<i>Refugio</i>	Refugio Beach Oil Spill Trustee Council 2018
Marine benthic	Subaquatic vegetation	Eelgrass density	24%	2 years	<i>Exxon Valdez</i>	Dean and Jewett 2001
Average			40%	10 years		

Data and Methods

Earth Economics’ approach to ecosystem services valuation involves the following steps: 1. Identification and quantification of land cover classes within the study area; 2. Identification and valuation of ecosystem services; 3. quantification of the annual value of ecosystem services provided by land cover in the study area.

Step 1. GIS was used to aggregate primary land cover datasets and create a better understanding of natural asset characteristics in nearshore and marine environments. The National Wetland Inventory, NOAA’s 2011 Coastal Change Analysis Program (C-CAP) data, and Puget Sound Eelgrass Monitoring Data^y were used to generate the marine and nearshore ecosystem classifications for this valuation. Areas classified as “open water” in the C-CAP dataset were extracted to establish marine water column areas. Marine areas were further classified into nearshore waters (<20m depth) and deep marine waters (>20m depth) using bathymetric data from NOAA (2017). Next, wetland areas classified as “estuarine and marine wetlands” in the National Wetland Inventory dataset were extracted and overlaid on top of the nearshore and marine waters to further refine ecosystem classes within the nearshore areas. Lastly, eelgrass

^x In reality, several marine ecosystem health indicators for the Salish Sea suggest that overall ecosystem health is declining (EPA 2018).

^y Source: Washington State Department of Natural Resources

population areas were utilized from the Puget Sound Eelgrass Monitoring Data layer to further characterize the benthic ecosystems in nearshore and marine areas. While shoreline land cover classes present in San Juan County include forest, grassland, shrub, pasture, and barren land, we conservatively only included marine waters, eelgrass, and tidal wetlands areas in our analysis, assuming that shoreline vegetation such as trees and shrubs would largely not come into contact with oil due to the presence of bluffs and steep slopes throughout the Islands’ shoreline.

We assumed that eelgrass and water column ecosystems within the nearshore (<20 m deep) zone have higher sensitivity to oil due to higher PAH concentrations per cubic unit of water column (and thus applied the higher bound of the 10-40% over 1-10 years impact rate ranges), and that eelgrass and water column ecosystems in deep waters (>20 m) have lower sensitivity to oil due to lower PAH concentrations (and thus applied the lower bound of the 10-40% over 1-10 years impact rate ranges)² (see table 8). We assumed that all estuarine and marine wetlands are highly sensitive to oiling and applied the upper bounds of the impact magnitude and duration ranges. Though sea surface oiling is assumed to impact an area much larger than the geographic boundaries of San Juan County administrative borders, we utilized the county borders to delineate the extent of deep-water ecosystems that reside within the county. See Figure 3 for a map of nearshore and marine ecosystem classifications utilized.

Step 2. For each land cover type (tidal wetlands, marine water column, and marine subaquatic vegetation), the ecosystem services provided by that land cover were identified. We then valued these services using the benefit transfer method (BTM). BTM is a well-established approach within the field of ecological economics for indirectly estimating the values of ecological goods and services by utilizing existing data on ecosystem services from other areas and applying them to a study area, in this case, San Juan County. We identified peer-reviewed studies that value ecosystem services in locations similar to San Juan County using a variety of well accepted valuation methods. Each value estimate in these studies is then transformed into a dollars-per-acre-per-year format to ensure “apples-to-apples” comparisons, as these estimates are transferred to the study site. Table 9 reports which ecosystem services could be valued for each land cover type, based on available data.^{aa}

Table 8. Impact Magnitude and Duration Assumptions for Ecosystem Services, by Ecosystem Category

Ecosystem Category	Sensitivity	Intermediate Term Impact		Long Term Impact	
		Magnitude	Duration	Magnitude	Duration
Tidal wetlands	High Sensitivity	40%	Years 1-10	1%	Years 11-30
Marine benthic zone (eelgrass)	Low Sensitivity (>20m water column)	10%	Year 1	1%	Years 2-21
	High Sensitivity (<20m water column)	40%	Years 1-10	1%	Years 11-30
Marine water column	Low Sensitivity (>20 m water column)	20%	Year 1	1%	Years 2-21
	High Sensitivity (<20m water column)	40%	Years 1-10	1%	Years 11-30

² The Ecological Impact Assessment submitted as part of the Trans Mountain Pipeline Expansion Application (Stantec et al 2013) utilized a similar bathymetry-based method for delineating sensitivity levels of marine ecosystems.

^{aa} Though up to 21 ecosystem services are provided by any given ecosystem, several ecosystem services associated with marine and coastal ecosystems were not valued in this analysis due to lack of available peer-reviewed studies examining similar sites. Given the data gaps for this benefit transfer analysis, it is expected that the valuation provided here is an underestimate of the full value of the ecosystem.

Step 3. The sum of all annual estimates for the ecosystem services provided per acre by each land cover type was then scaled by the extent of corresponding land cover classes within the study area to calculate the total annual contribution of ecosystem services within the study area. The annual contributions of all land cover types were then combined to calculate the total annual value contributed by ecosystem services to the local economy.

Table 9. Ecosystem Services Included in San Juan County Analysis, by Land Cover Type

Ecosystem Service	Tidal Wetlands	Benthic Zone (Eelgrass)	Water Column (Marine Waters)
Air Quality			X
Carbon Sequestration	X	X	X
Disaster Risk Reduction	X		
Energy and Raw Materials	X		X
Habitat	X	X	X
Soil Formation			
Water Storage	X		
Water Quality	X		X

Figure 4. Nearshore and Marine Ecosystem Classifications in San Juan County

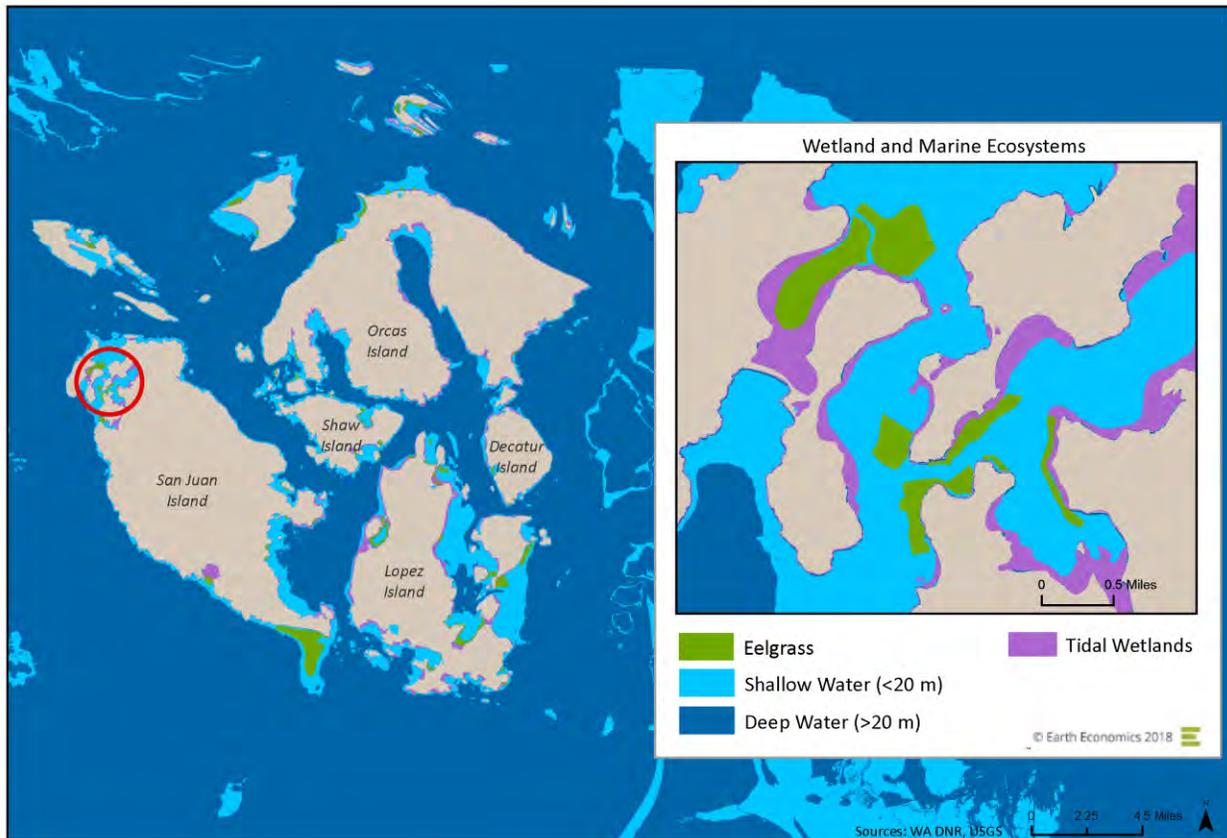


Table 10. Baseline Annual Ecosystem Services by Ecosystem Type (\$/Acre/Year)

Ecosystem Service	Tidal Wetlands		Benthic Zone (Eelgrass)		Water Column (Marine Waters)	
	Low	High	Low	High	Low	High
Carbon Sequestration	\$27	\$27	\$222	\$222	\$121	\$121
Disaster Risk Reduction	\$1,699	\$7,756			\$17	\$2,335
Energy and Raw Materials	\$8	\$25				
Habitat	\$279	\$418	\$318	\$318		
Water Storage	\$25	\$25				
Water Quality	\$259	\$646			\$17	\$17
Total	\$2197	\$8897	\$540	\$540	\$123	\$218

Results

	No-Spill Scenario	Scenario A		Scenario B	
	Total Value Over 30-Years	Total Damages Over 21 Yrs (low)	Total Damages Over 30 Yrs (high)	Total Damages Over 21 Yrs (low)	Total Damages Over 30 Yrs (high)
Ecosystem Services	\$1,466,699,928 to \$3,427,331,178	\$22,465,043	\$63,585,734	\$12,275,287	\$30,267,625

The total economic value of ecosystem services in a no-spill scenario associated with healthy tidal wetlands, benthic eelgrass, nearshore water column, and marine water column amounts to \$1.4 billion to \$3.4 billion over 30 years. In Scenario A, total damages to services provided by shoreline and marine ecosystems are estimated at **\$22.5 million to \$63.6 million**, and Scenario B damages are estimated at **\$12.3 million to \$30.3 million**.

8. Additional Impacts and Considerations

Due to lack of data, methodological constraints, and limitations of scope, the damage estimations for the two San Juan County oil spill scenarios did not include a number of known impacts of oil spills, including impacts to local government services, marine transportation, marine infrastructure, human health, education and scientific research, and whale watching. Moreover, this analysis only examined a small subset of ecosystem types due to data and methodological limitations. The following section describes the significance of these economic impact categories in detail and our limitations for integrating them into this analysis.

a. Impacts to Local Government Operations and Services

Local residents, communities, and municipalities are on the front lines of oil spill events. While local, state, and federal governments all play a role in response and recovery, local municipalities are the hardest hit by oil spills. The total costs incurred by local governments in disaster response and recovery, including impacts to public services due to resources being diverted toward disaster management, is not well understood.⁹⁴ Total clean-up cost estimates from past spills (e.g. *Exxon Valdez* and *Prestige*), which

includes some of the direct costs incurred by local governments, range from \$3746 to \$15,270 per bbl of oil spilled.⁹⁵

Local governments play a significant role in staging response activities. This includes finding adequate space for housing and office space for response-workers, providing and maintaining communication systems and networks, managing volunteers, among other administrative needs. Local governments will also be responsible for evacuation procedures, including the implementation of fire, police, emergency services, and other first responders to ensure adequate support for immediate threat to life and property. Long-term recovery costs can include direct and indirect costs from disaster recovery. Local governments may be in charge of funding for research and assessment of damages, subsequent recovery planning efforts, and technical assistance programs to support local communities in recovery and mitigation strategies. There are also direct payouts for financial relief to residents and communities impacted and expenditures on mitigation and preparedness for future events. Additional costs and losses include losses in tax revenue, opportunity costs of diverting government staff resources from existing projects and services, damages to municipal property, costs for permitting and regulatory oversight, and legal costs for potential litigations.⁹⁴ The impacts of an oil spill on local government and on the government-supported services on which the community depends would be significant for San Juan County, where the capacity to respond and recover are exacerbated by geographic location and lack of immediate support from adjacent municipalities.

b. Impacts to Marine Infrastructure, Transportation and Island Industries

An oil spill could cause physical damage to marine infrastructure, including boats, docks, and marina facilities. Boats that come into contact with oil would require a cleaning procedure, depending on which parts of the boat come into contact with oil (e.g. engine).⁹⁶ An assessment of socioeconomic cost modeling exercise as part of Washington Department of Ecology's Final Cost-Benefit and Least Burdensome Alternative Analyses (2012) estimated the cost of oil cleaning per boat to be \$200 for diesel cleaning, \$500 for heavy fuel oil cleaning, and \$300 for crude oil cleaning.⁹⁷ Recreational boating is popular activity throughout San Juan County; Roche Harbor is a historic resort located on San Juan Island that accommodates 20,000 guest boats (excluding permanently moored boats) every year, many of which are high-value yachts.^{bb} Oiling in Roche Harbor alone would likely generate significant cleaning costs for boats and harbor infrastructure.

Marine transportation would also be disrupted in the event of an oil spill. After a spill occurs, all vessels, including cargo vessels and passenger vessels, are banned from transiting oiled waters, until waters are deemed safe by the Coast Guard for travel.²⁴ Disruption to marine transportation would result in a number of economic damages, including operational costs incurred by rerouted vessels that must transit waters for longer than originally planned, loss of income at ports and marinas in the form of lost spending (moorage fees and fuel purchases), lost wages of port/marina workers,⁹⁷ and lost income to passenger vessels (ferries, cruise ships) that must cancel trips during the period of disruption.²⁰

San Juan County residents, visitors, and commercial industries are highly dependent on regular service from Washington Department of Transportation (WDOT) ferries and private water taxis. An oil spill occurring in San Juan County waters transited by ferries would disrupt Island communities and businesses. Due to the dependence of San Juan County residents and businesses on regular ferry service

^{bb} Roche Harbor Resort Marina, personal communication, October 2018.

for transportation and goods, ferries would likely be granted limited access to Islands within a few days of a spill, transiting oiled waters if needed and undergoing routine de-oiling to minimize public health risks to passengers and damages to ferry infrastructure.^b However, even ferry service disruptions lasting a couple days can have tangible economic impacts to island communities. For example, temporary disruption of regular ferry services in the summer of 2017 resulted in lost wages and/or overtime pay for construction companies and suppliers, and lost revenue at grocery stores, hotels, and guide companies.⁹⁸ In the event of an oil spill, losses in wages and income to Island residents and businesses due to disrupted ferry service would be expected.

Impacts to marine transportation were not included in the damage estimation due to data and methodological limitations. We were unable to obtain complete economic data on port/marina and vessel operations. In addition, our use of county-level traveler expenditure data (Dean Runyan 2018) to estimate tourism-related impacts partially accounts for loss of port/marina/passenger vessel income and wages; incorporating economic data on port/marina and vessel operations would result in double-counting.

c. Impacts to Human Health

Human health is a critical aspect of well-being, influencing stress levels, productivity, and life satisfaction. An oil spill in San Juan County has the potential to impact human health across the entire county over multiple years. Oil spills are associated with physical and psychological effects, including increased anxiety and depression, headaches, vision impairment, and respiratory impacts. Research has shown that exposure to oil (liquid, solid, or gas form) can increase cancer risks and depress central nervous system (CNS) function.⁹⁹ There are many examples of negative health impacts and outcomes from oil spill events. Following the Sea Empress oil spill in 1996, residents in exposure areas had higher anxiety and depression, worse mental health, and an increase in self-reported headaches, sore eyes, and respiratory irritation, as compared to unexposed populations.¹⁰⁰ After the Prestige oil spill in Spain, academic achievement, measured through test scores, decreased among local communities.¹⁰¹ Residents involved in the Hebei Spirit oil spill clean-up were 6.5 times as likely to have high stress levels and nearly 10 times as likely to be depressed.¹⁰² A catastrophic oil spill would also cause displacement, which can exacerbate psychological effects. This result means that an oil spill, no matter the magnitude or geographic scope, will impact residents and tourists throughout San Juan County. Not only that, but mental, physical/physiological, and genotoxic effects may persist for years after exposure.¹⁰³ Even a small oil spill in San Juan County could result in negative impacts that last years after the event. The negative impact to health from oil spills in San Juan County could be drastic, leading to physical and mental impacts that could continue for years after the spill event and clean up.

d. Impacts to Education and Scientific Research

Natural systems provide important opportunities for education and science. The number of youth education programs that exist throughout San Juan County is a testament to the value that shoreline and marine settings provide in fostering knowledge and awareness of the natural world. Camp Orkila, an outdoor education facility on Orcas Island, educates more than 6,000 youth annually through their outdoor environmental education program, and several thousand more through their summer camp operations. Other outdoor education programs are active throughout the county, including the Youth Conservation Corps of the San Juan Islands, which education 50 youth annually and provided a total of 5300 education hours in 2018.¹⁰⁴ College and graduate students engaged through Friday Harbor Labs also

gain educational value through research, field work, and mentorship opportunities in the fields of marine biology, oceanography, and fisheries. Damages to the safety and aesthetic quality of shoreline and marine ecosystems utilized by education programs throughout San Juan County would hamper the quality and potentially the quantity of such programs, though quantifying the impacts of hypothetical oil spills to the educational value provided by these programs is difficult.

Educational programs also exist within San Juan County that are not explicitly dependent on access to shorelines or marine waters but are dependent on visitation by out-of-county school groups. The Whale Museum is a major educational facility located in Friday Harbor on San Juan Island that engaged with over 200 school groups involving over 5000 students in 2017 alone. A spring-time oil spill event impacting shorelines and marine waters into the next school year would likely result in cancellations or re-scheduling of school trips, potentially resulting in a decline in educational value derived from contact-hours. For reference, the educational value of one contact-hour of education within Washington state public school systems is estimated at \$3.64 per pupil-hour.¹⁰⁵

San Juan County are also home to a large number of ecological monitoring research programs, coordinated and managed through the University of Washington Friday Harbor Labs. The marine waters and shorelines provide a unique opportunity for conducting world-class marine research, and over one hundred researchers visit Friday Harbor Labs each year to conduct a vast array of research projects, ranging from restoration ecology, to long-term monitoring of oceanic change, to crustacean neurobiology.¹⁰⁶ In any given year, the total dollar value of active grants supporting scientific research through Friday Harbor Labs is significant. While an oil spill event would likely generate new research opportunities related to injury assessments and ecological recovery monitoring, some loss in value associated with disruption to existing long-term research grants can be assumed.

e. Southern Resident Killer Whales and the Whale Watching

The Southern Resident Killer Whales (SRKWs) are a cultural icon of the Pacific Northwest and draw visitors from around the world. The San Juan Islands in particular are known for orca sighting opportunities, making whale watching a central component of the county's recreation and tourism economy. A recent study conducted by Earth Economics values the economic contribution of boat- and land-based whale watching in San Juan County.¹⁰⁷ Relying on whale watching participation estimates provided by the National Marine Fisheries Service and the International Fund for Animal Welfare, as well as the results of an expenditure survey conducted by Earth Economics, we found that individuals who participate in boat- or land-based whale watching in San Juan County spend over \$120 million on trip related expenses in the county each year.

In addition to valuing San Juan County's whale watching economy as a whole, our survey design allows us to estimate the economic damages that would occur if the SRKW population were to collapse. Using sightings data to predict the decrease in orca whale sighting days near the San Juan Islands, we asked survey respondents to predict their behavior, should their chances of seeing an orca whale decrease by the proportion that is expected if the SRKWs become extinct, roughly 50%. In this alternative scenario, a significant portion of whale watching participants said they would no longer choose to visit San Juan County, equating to a loss of \$68 million of expenditures in the county every year.

The results of that report clearly demonstrate the significant economic benefit of a healthy SRKW population to San Juan County. A report recently published by the SRKW Task Force² also pointed to new

findings that suggest a catastrophic oil spill could kill between 12.5 and 50% of the SRKW population.¹⁰⁸ In this assessment we took an overall conservative approach and did not assume SRKW extinction, or mortality to specific species in general, as an impact in San Juan County spill scenarios. Instead, we estimate an overall decline in tourist spending (7-21%) for the San Juan County spill scenarios based on actual lost tourist visitation and spending observed from past oil spills in areas where whale watching is a component of the local economy (e.g. Prince William Sound region). The 7-21% decline in tourist spending assumed for San Juan County therefore includes an assumed temporary decline in whale watching, though this likely underestimates the true economic losses that would occur given the significant contribution of whale watching to San Juan County's tourism economy.

f. Impacts to Specific Species and Habitat

We know from past events that the ecological impacts of oil spills are severe and long-lasting and can result in acute mortality and long-term sub-lethal impacts to a wide range of marine and terrestrial species. The shorelines and waters of San Juan County are home to critical habitat for salmon, orcas, porpoise, sea lions, river and sea otters, rockfish, and over 100 species of marine birds.¹⁰⁹ The subaquatic vegetation found throughout San Juan County waters, including eelgrass and bull kelp, provide critical food and shelter for a wide range of marine life. The diverse ecosystems found in the county provide irreplaceable cultural value to residents and visitors, support a robust tourism industry, and provide critical ecosystem services to island communities.

Our approach to valuing ecosystem services of marine and terrestrial ecosystems assigns economic values to services provided by specific ecosystem types, grouped into broad categories, such as tidal wetlands, estuarine waters, marine waters, subaquatic vegetation, etc. Our ability to value benefits from specific ecosystem types depends on availability of relevant and transferrable economic valuation studies from other sites throughout the region and the world. For example, while we were able to value certain benefits provided by eelgrass, the analysis excludes benefits derived from other subaquatic vegetation types such as bull kelp, purely due to limited availability of transferrable studies valuing bull kelp. As such, the ecosystem service values provided above underestimate the total benefits provided by ecosystems throughout the county.

Oil spill impacts to specific species are often monetized in terms of their estimated replacement cost and requires making assumptions about the number of animals that would be harmed in a hypothetical oil spill. We did not draw such assumptions for this assessment and instead estimated an overall decline in ecosystem health in San Juan County waters of 10-40%. Replacement costs, in addition to other costs associated with response, clean-up, and recovery, is an important element of oil spill damage estimation and is beyond the scope of this analysis.

9. Limitations, Future Research, Conclusion

Limitations and Areas for Further Research

This assessment utilized the best available data to estimate hypothetical oil spill damages across five key categories. In cases where sufficient data existed to estimate damages, a conservative approach was taken to ensure that users of this report can utilize the values with high confidence. In other cases, key impact categories or key aspects of impacts were omitted altogether due to a lack of sufficient data and limited resources. As exhibited in Table 2, a significant range of short- and long-term impacts can be

expected to arise from even a moderate oil spill near San Juan County; this assessment took into consideration a narrow subset of the full potential impacts to San Juan County communities. Moreover, an oil spill in Haro Strait/Boundary Pass would generate significant impacts beyond San Juan County, including significant stretches of British Columbia shoreline on Vancouver Island and the Gulf Islands, as well as areas of the Olympic Peninsula, Whidbey Island and potentially other areas within Washington State. We suggest the following opportunities for future research on this topic:

1. *Quantify local business dependence on ferry service and implications of oil spills.* Given the county's dependence on regular ferry service for transportation of people and goods, an assessment of the economic consequences of prolonged ferry disruption (incl. lost wages, lost revenue, overtime pay, costs of emergency grocery resupply) due to an oil spill is warranted.
2. *Expand tourist spending impact analysis to include full economic effects (indirect and induced effects).* The full economic impact of reduced tourist spending, which was not examined in this analysis, includes the ripple effects throughout the local economy that a removal of tourist dollars would generate for San Juan County. This includes indirect effects (reduction of sales to businesses where tourist expenditures are made) and induced effects (sales of goods and services purchased by employees of directly and indirectly affected businesses). Conducting a full economic impact assessment of lost tourist spending would provide a more complete picture of damages associated with declined tourism.
3. *Conduct primary valuations for important ecosystem services not yet documented.* Many ecosystem services were excluded from this analysis due to lack of available peer-reviewed primary valuation studies. For example, studies on the value of ecosystem services provided by non-vegetated benthic zones by important subaquatic vegetation such as bull kelp, and by intertidal beach, are scarce. These ecosystems provide critical ecosystem services to San Juan County and are excluded from this assessment purely due to lack of existing valuation studies.
4. *Include terrestrial landcover classes (trees, shrubs, grasses) that may be impacted by shoreline oiling through finer resolution shoreline landcover data.* This ecosystem service valuation excluded all non-aquatic landcover classes which effectively excluded the vast majority of shoreline (the majority of shoreline, based on 30x30 meter resolution landcover data, is made up of trees and shrubs). These omitted landcover classes could be integrated into the assessment with the use of higher resolution landcover data or through estimating likelihood of landcover oiling by analyzing shoreline slope as an estimator of presence of bluffs.
5. *Conduct primary valuations (travel cost survey) to estimate lost recreation use value to local residents.* Local residents of San Juan County would invariably suffer from lost recreation use value in the event of an oil spill. Quantifying the specific decline in use value associated with residents either a.) refraining from any shoreline or water-based recreation or b.) choosing less preferred recreation sites, would best be quantified through a travel cost survey specifically targeting local recreation users of shorelines and waters likely to be impacted by an oil spill.
6. *Expand valuation to include social impacts, including impacts to human health, social services, and passive use value.* A more comprehensive damages assessment could include social impacts, such as human health in terms of dislocation and medical costs, and social costs of disrupted social services due to diversion of local government resources to clean-up and response. Passive use or existence value describes the value associated with the county's natural assets derived by

individuals that do not directly utilize or benefit from those assets, such as households throughout the United States. A contingent valuation survey, such as the survey conducted by Carson et al. 2003 after Exxon Valdez, would shed light on the benefit people receive from knowing that the natural resources of San Juan County exist.

7. *Expand oil spill damage estimates to include the entire Salish Sea region.* While this assessment improves our understanding of how an oil spill would impact San Juan County, an oil spill in Haro Strait/Boundary Pass would have widespread impacts to tourism, recreation, properties, and ecosystems through coastal and shoreline areas in the Salish Sea, including the northern coast of the Olympic Peninsula, a large expanse of shoreline on Vancouver Island, and potentially Anacortes and other shorelines of Washington's Skagit County. Moreover, it is assumed that, in both spill scenarios, oil would spread to the Strait of Juan de Fuca, which would require significant re-routing of marine vessels given the high vessel traffic in the area. As oil spills in this region would likely require an international response, understanding the full economic costs of an oil spill in Haro Strait/Boundary Pass to all Salish Sea communities, including those in other parts of Washington State and in Canada, is worthwhile.

Conclusion

This assessment examined a sub-set of the economic, social, and environmental impacts of an oil spill in the Salish Sea and estimated damages to San Juan County associated with two spill scenarios: a 4-million-gallon diluted bitumen spill and a 1-million-gallon heavy fuel oil spill, both occurring in Haro Strait/Boundary Pass. Spill scenarios were defined based on the best available data on vessel traffic, oil carrying capacity, and oil spill trajectory models for the Haro Strait/Boundary Pass region. Estimated impacts of oil spills across five key impact categories (commercial fishing and aquaculture, tourist visitation, recreation use value, property value, and ecosystem services) were derived from observed impacts from past crude and heavy fuel oil spills in North America.

Damages from Scenario A were estimated at **\$142.3 million to \$509.9 million**, while damages from Scenario B amounted to **\$84.3 million to \$243.2 million**. While both estimates exhibit a significant gap between the lower and upper bounds, the full range for each scenario—inclusive of the upper bounds—should be taken as *underestimates* of the true cost of a spill, given a) the negative directional biases embedded in our methodologies and use of data and b) the exclusion of multiple critical impacts, including short-term impacts to marine transportation, infrastructure, and public health and the long-term impacts to cultural resources and activities of tribes and local communities. Clean-up cost estimates were also omitted from this analysis. Future investments in oil spill prevention and response should take into consideration the full range of economic, social, and environmental costs that an oil spill would generate for communities throughout the Salish Sea region that depend on and benefit from the region's rich ecosystems.

Appendix A: Scenario Parameters, References, and Confidence Levels

SCENARIO A			
Parameter	Type	Reference	Confidence Level
Junction of Haro Strait and Boundary Pass (Turn Point)	Spill Location	Van Dorp and Merrick 2016, WDOE 2018, Nuka Research 2015, Tetra Tech 2013	High – multiple references indicate this as a high-risk location
4 million gallons	Spill Volume	Gunton and Broadbent 2015, Tetra Tech 2013	High – this volume is used as the credible worst case discharge (CWCD) for the oil spill modeling studies that supported the Trans Mountain Expansion Application
Diluted Bitumen	Spill Material	WDOE 2018, Nuka Research 2015, Nuka Research 2013	High – this oil type is shown in multiple references to be a high-risk material for the region and for Haro Strait/Boundary Pass specifically
Occurs in late spring (May)	Season	Bjarnason et al 2015, Thorne 2010	High – spring as an ecologically and economically sensitive time of year discussed in multiple references
No response efforts	Spill Response	Nuka Research 2015, Tetra Tech 2013, WDOE 2012	Low – The Tetra Tech 2013 Models for Trans Mountain utilized for this assessment assume no response (e.g. floating oil recovery) efforts, to allow for pure modeling of oil spill trajectory; however, multiple other references include response effort assumption, and the likelihood of no response efforts is low. A study examining maximum floating oil recovery capacity at Turn Point (Nuka 2015) identified a max recovery capacity of 1.6 million gallons under ideal response conditions.
70% (2.8 mil gal) of oil wash up on shore	Weathering	Tetra Tech 2013	High – based on assumptions utilized in Tetra Tech 2013 Trans Mountain oil spill models
1246 square miles total, 232 square miles within San Juan County administrative borders	Sea surface and water quality oiling	Tetra Tech 2013 Trans Mountain oil spill modeling results: >60% probability, 16,500 m ³ (4.2 mil gal) diluted bitumen spill	<p>Medium – derived from spill model results that modeled 4 million gallons of dilbit; utilized >60% probability results to align with oiling extent assumptions utilized in ecological impact estimates in Trans Mountain Ecological Risk Assessment. Utilizing the >60% probability results is a conservative approach – the true extent of oiling could be as severe as the 20% probability results as shown Appendix C Map 1.</p> <p>While the original oil spill model examined a similar spill scenario (volume and material), manually reconstructing the model results to estimate oiling extent is a crude approach that introduces error.</p>
72 miles within San Juan County	Shoreline oiling	Tetra Tech 2013 Trans Mountain oil spill modeling results: >60% probability, 16,500 m ³ (4.2 mil gal) diluted bitumen spill	<p>Medium – derived from spill model results that modeled 4 million gallons of dilbit; utilized >60% probability results to align with oiling extent assumptions utilized in ecological impact estimates in Trans Mountain Ecological Risk Assessment.</p> <p>While the original oil spill model examined a similar spill scenario (volume and material), manually reconstructing the model results to estimate oiling extent is a crude approach that introduces error.</p>

SCENARIO B			
Parameter	Type	Reference	Confidence Level
Turn Point at the junction of Haro Strait and Boundary Pass	Spill Location	Van Dorp and Merrick 2016, WDOE 2018, Nuka Research 2015, Tetra Tech 2013	High – multiple references indicate this as a high-risk location
1 million gallons	Spill Volume	WDOE 2012, Etkin and French-McCay 2005	Medium – Oil spill economic cost modeling for WA Dept. of Ecology in 2012 modeled 25,000 bbl for a worst-case discharge of heavy fuel oil, which is roughly equivalent to 1 million gals. However, references identify the max. fuel carrying capacity (and worst case discharge) for a cargo vessel as 2 million gal. Cargo vessels also do not operate fully fueled while transiting Salish Sea, further complicating a likely worst-case discharge.
Heavy fuel oil (Bunker C)	Spill Material	WDOE 2012, Nuka Research 2013, Nuka Research 2014	High – this oil type is shown in multiple references to be a high-risk material for the region
Occurs in late spring (May)	Season	Bjarnason et al 2015, Thorne 2010	High – spring as an ecologically and economically sensitive time of year discussed in multiple references
No response efforts	Spill Response	Nuka Research 2015, Tetra Tech 2013, WDOE 2012	Low – The Tetra Tech 2013 Models for Trans Mountain utilized for this assessment assume no response (e.g. floating oil recovery) efforts, to allow for pure modeling of oil spill trajectory; however, multiple other references include response effort assumption, and the likelihood of no response efforts is low. A study examining maximum floating oil recovery capacity at Turn Point (Nuka 2015) identified a max recovery capacity of 1.6 million gallons under ideal response conditions.
90% (900,000 gal) of oil washes up on shore	Weathering	NOAA	Medium – based on known evaporation behavior of heavy fuel oil, but degree of sinking, dissolution, or other weathering processes not considered
763 square miles total, 181 square miles within San Juan County administrative borders	Sea surface and water column oiling	Tetra Tech 2013 Trans Mountain oil spill modeling results: areas with >90% probability sea surface oiling, 16,500 m ³ (4.2 mil gal) diluted bitumen spill	<p>Low – derived from manually reconstructed spill model results that modeled 4 million gallons of dilbit; utilized >90% probability results to differentiate from likely trajectory of a Scenario A spill of 4x the volume of oil. Based on sea surface oiling areas published in Trans Mountain Ecological Risk Assessment 2013 for a 4-mil-gal and 2-mil-gal dilbit spill, the geographic extent of oiling decreases approx. 11% with a 1-mil gal reduction in spill volume. The geographic extent of the >90% probability contour line is roughly similar to what we would expect the area of oiling to be for a 1-mil gal dilbit spill (878 square miles), adjusted downwards to account for likely smaller oiling extent of a heavy fuel oil spill as compared to dilbit.</p> <p>This is a very crude approach to estimating sea surface oiling extent and is the best available option without the ability to generate oil spill trajectory models for this specific spill volume and material.</p> <p>The oiling extent assumption used for Scenario A (>60% probability results) is an overall conservative approach – oiling for Scenario A could be as severe as the 20% probability results as displayed in Appendix C Map 1. As such, oiling extent assumption for Scenario B, which is directly based on Scenario A assumptions (scaled down based on spill volume), is similarly conservative.</p>
30 miles of shoreline are oiled within San Juan County	Shoreline oiling	Tetra Tech 2013 Trans Mountain oil spill modeling results: areas with >90% probability shoreline oiling, 16,500 m ³ (4.2 mil gal) diluted bitumen spill	Low – derived from spill model results that modeled 4 million gallons of dilbit; utilized >90% probability results to differentiate from likely trajectory of a Scenario A spill of 4x the volume of oil; see Appendix A Scenario A table for detailed justification of selection <90% probability results. This is a very crude approach to estimating sea surface oiling extent and is the best available option without the ability to generate oil spill trajectory models for this specific spill volume and material.

Appendix B: Scenario Impact Estimate Sources

Impact Assumptions for San Juan County Hypothetical Spill Scenarios

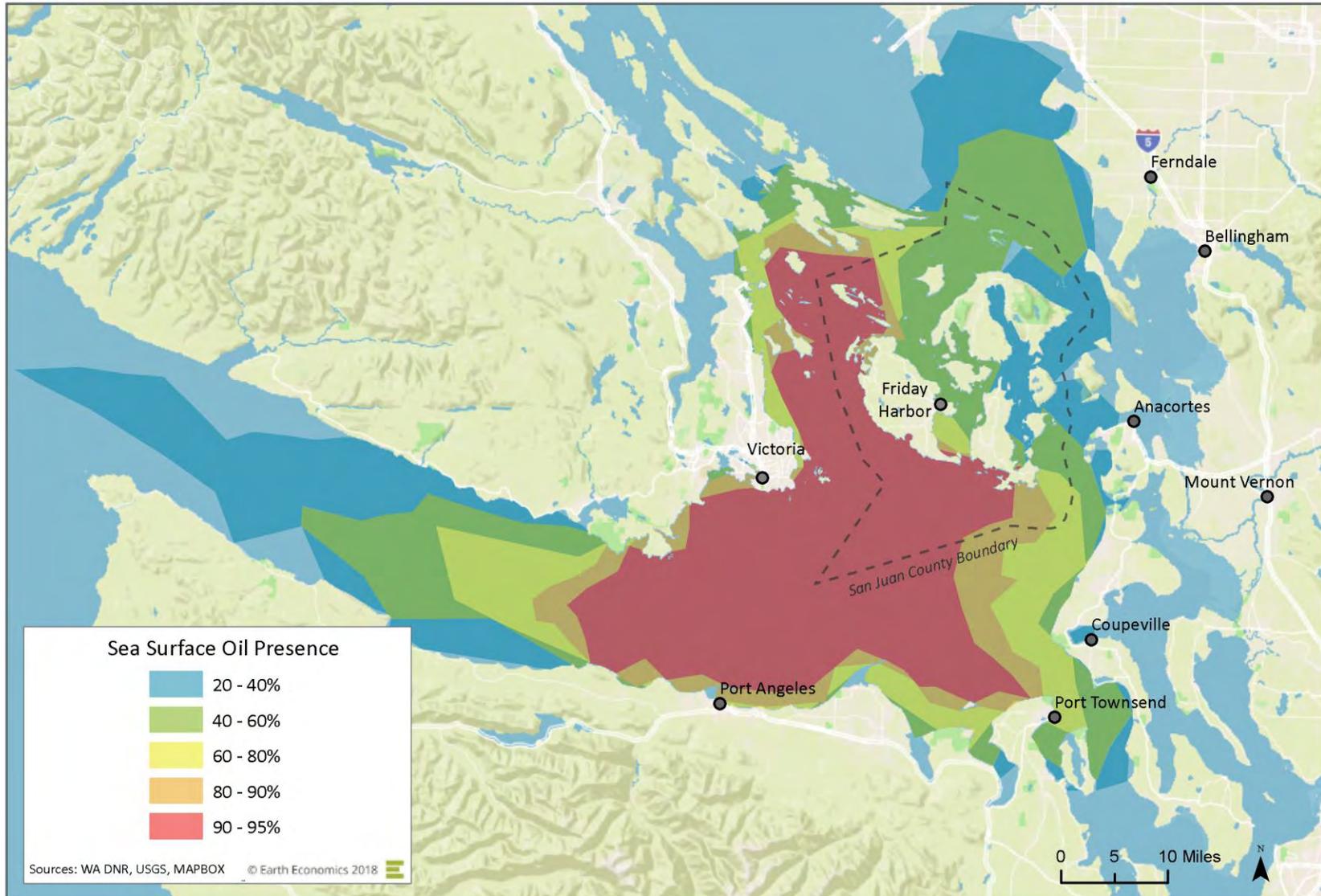
Oil Spill	Location	Year	Volume Spilled	Season	Material Spilled	Volume of Oil on Shorelines	Commercial Fishing	Tourism and Recreation Use Value	Property Values	Ecosystem Health
Scenario A	Turn Point	2019	4 million	May	Diluted bitumen	2.8 million gallons (70%)	4-12 months	7-21% decline over 9 to 24 months	4-10% decline (oiled) and 1.75-3.5% decline (nearby) over 3-30 months	10-40% decline over 1-10 years, 1% decline over additional 20 years
Scenario B	Turn Point	2019	1 million	May	Heavy fuel oil	900,000 gallons (90%)	1-3 months	7-21% decline over 3 to 8 months	4-10% decline (oiled) and 1.75-3.5% decline (nearby) over 1-10 months	10-40% decline over 1-10 years, 1% decline over additional 20 years

Impact Magnitudes and Durations from Past Oil Spills

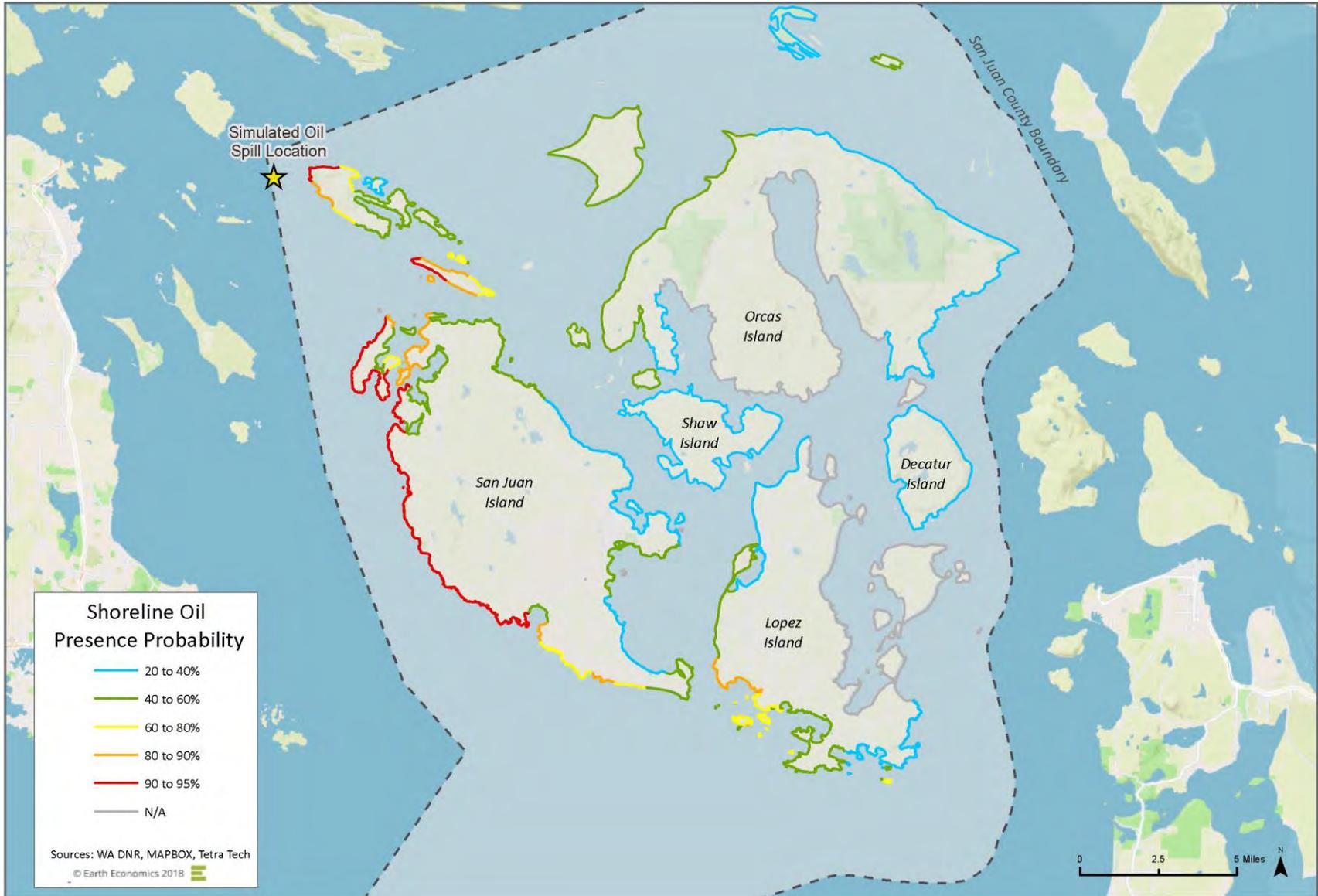
Oil Spill	Location	Year	Volume Spilled	Season	Material Spilled	Volume of Oil on Shorelines	Commercial Fishing	Tourism and Recreation	Property Values	Ecosystem Health
<i>Deep Water Horizon</i>	Gulf of Mexico	2010	134 million	April	Crude oil		Closed for 1-12 months	12-25% decline in Y1; 4-8% in Y2-3	4-16% decline over 3-60 months (oiled) 3.5% decline over 9 months (nearby)	45% reduction in herbaceous live aboveground biomass in wetlands, sustained over 3 years, recovering over 2-8 years
<i>Exxon Valdez</i>	AK	1989	11 million	March	Crude oil	4.4 million gallons (40%)	Closed for 9-24 months	8-35% decline in Y1; recovering over 2-3 years		Shoreline, nearshore, and marine species recovery rates 3-25+ years; Salmon pop declined by 43%
<i>Refugio</i>	CA	2015	142,000	May	Crude oil		Closed for 1 month			47% of nearshore sub-aquatic vegetation (surfgrass, seaweed) impacted in Y1, recovered to 10% by Y2
<i>Ixtoc I</i>	Gulf of Mexico	1979	126 million	June	Crude oil			7-10% decline over 2 years		
<i>Bouchard 120</i>	MA	2003	98,000	April	No. 6 heavy fuel oil		Closed for 6 months			
<i>Chalk Point</i>	MD	2000	126,000	April	No 6. heavy fuel oil and No 2. fuel oil		Closed for 2.5 weeks		11% decline over 6 months (oiled)	100% reduction in shoreline (wetland) ecosystem services, recovered over 10 years
<i>Cosco Busan</i>	CA	2007	54,000	November	Bunker heavy fuel oil		Closed for 3 weeks	49-53% reduction over 1 month		

Appendix C: Additional Maps

Map 1. Reconstructed Sea Surface Oiling Probability Map from Trans Mountain Stochastic Oil Spill Model Results (4.2 Million Gal Diluted Bitumen Spilled in March-May). Scenario A (4 Mil Gal Diluted Bitumen) and Scenario B (1 Mil Gal Heavy Fuel Oil) sea surface oiling assumptions are based on 60-95% and 90-95% probability contours in Trans Mountain model results, respectively.

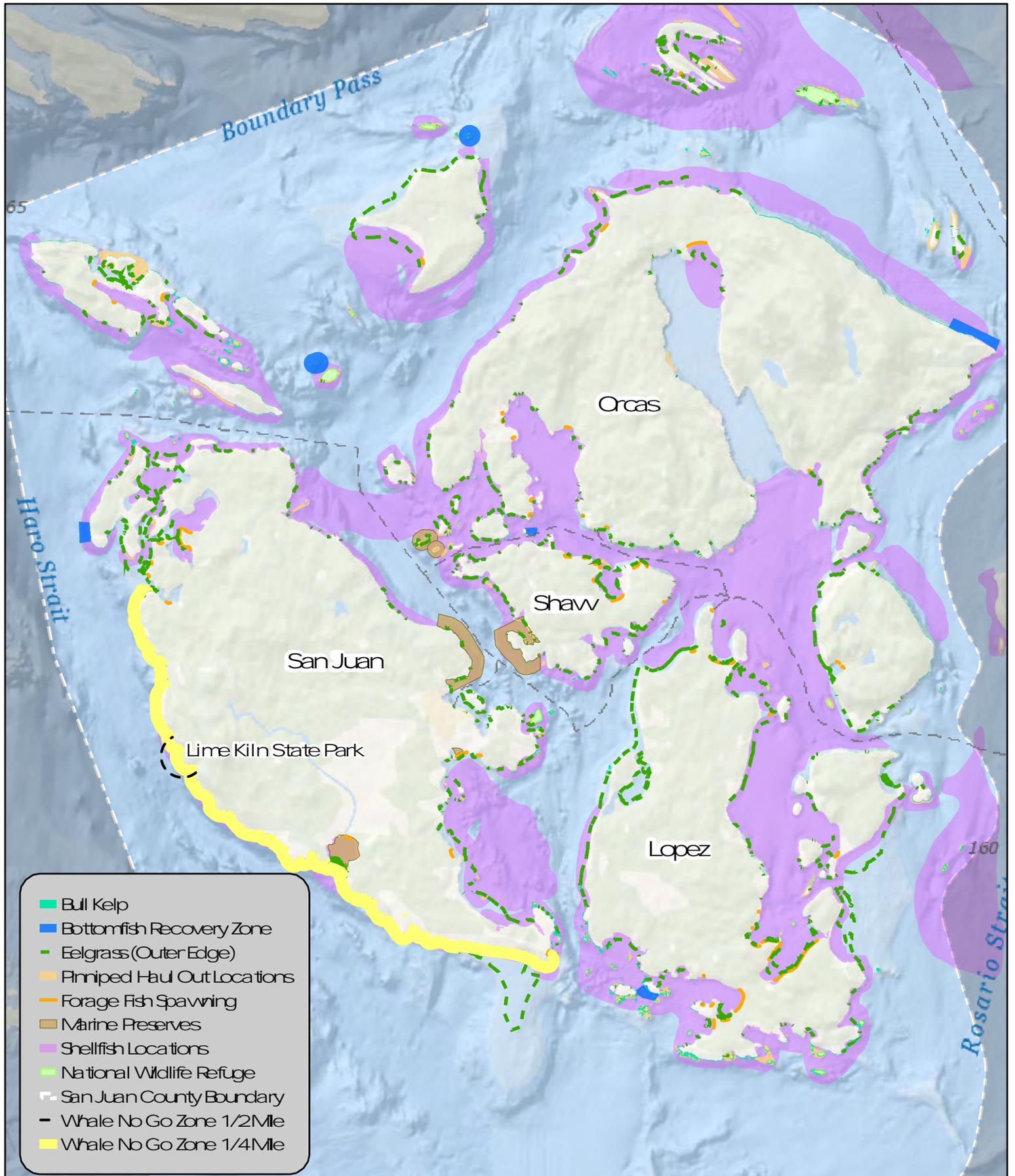


Map 2. Reconstructed Shoreline Oiling Probability Map from Trans Mountain Stochastic Oil Spill Model Results (4.2 Million Gal Diluted Bitumen Spilled in March-May). Scenario A (4 Mil Gal Diluted Bitumen) and Scenario B (1 Mil Gal Heavy Fuel Oil) shoreline oiling assumptions are based on 60-95% and 90-95% probability shoreline oiling estimates in Trans Mountain model results, respectively.



Map 3. Designated Commercial Fishing and Aquaculture Sites.





Sources: Esri, GEBCO, NOAA, National Geographic, Garmin, HERE, Geonames.org, and other contributors, Esri, Garmin, GEBCO, NOAA NGDC, and other contributors



This map is derived from San Juan County's Geographic Information System (GIS). It is intended for reference only and is not guaranteed to survey accuracy. The information represented on this map is subject to change without notice.

San Juan County Marine Stewardship Area



Appendix D: Estimated Property Sales Impacts

Overview and Purpose

In this analysis we quantified property value impacts as the temporary loss of marginal property value gains during the period of impact in each spill scenario, as compared to expected growth in property values based on a 6% annual growth rate. This approach captured the overall effect on the housing market and the costs associated with adjustments in property tax revenue. This approach did not specifically account for the actual lost economic value to homeowners who choose to sell their homes during the period of impact after an oil spill. We offer the following exercise to illustrate the potential economic costs to homeowners in the event of an oil spill in San Juan County. However, the following sales impacts estimates cannot be directly added to the property values impact estimates presented above, due to double counting issues.

Methods and Data

We used San Juan County property sales data from 2013 to 2017 to estimate the total value of properties sold—and economic loss to sellers due to reduced property values—in the months following a hypothetical oil spill. In each spill scenario, we assumed that the total value of homes sold in each month after the hypothetical spill (May) is 40% less than the total value of homes sold on average in the same month, from 2013 to 2017, assuming that either a) a significant subset of property owners would choose to ride out housing market disruptions and wait to sell their homes until after property values recover, or b) a significant subset of property owners would be unable to sell their homes due to reduced demand.^{cc}

Average value of sales by property group for each month of the year were derived from 2013-2017 monthly sales data. Properties were grouped as follows: 1) oiled waterfront properties (within 500m landward of oiled shorelines) in Scenario A, 2) non-oiled waterfront and inland properties on impacted islands in Scenario A (San Juan, Lopez, Stuart, Spieden), 3) oiled waterfront properties (within 500m landward of oiled shorelines) in Scenario B, and 4) non-oiled waterfront and inland properties on impacted islands in Scenario B (San Juan, Stuart). The total value of properties assumed to be sold in each group was discounted by the same impact rates as utilized in the property values damage estimates above (4-10% for properties within 500m of oiled shoreline; 1.75-3.5% for all other properties located on affected islands), to arrive at a total economic loss to all homeowners who sold their homes after a spill.

Results

	Full Value of Sales on Impacted Islands in No-Spill Scenario	Economic Loss from Sales on Impacted Islands During Impact Period
Scenario A		
<i>Low (decline for 3 months)</i>	\$43,619,277	\$602,330
<i>High (decline for 30 months)</i>	\$406,141,109	\$11,602,067
Scenario B		
<i>Low (decline for 1 month)</i>	\$16,704,799	\$210,563
<i>High (decline for 10 months)</i>	\$133,878,067	\$3,002,790

Assuming a 40% decline in sales volume after a spill than would otherwise occur based on average monthly sales activity, property sellers would lose a total of **\$602,330 to \$11.6 million** in the 3-30 months of property value decline in Scenario A, and a total of **\$210,563 to \$3 million** in the 1-10 months of property value decline in Scenario B. This does not account for the economic impacts associated with sales that did not occur that otherwise would have in a no-spill scenario, including opportunity costs to sellers and economic losses to realtors and the construction industry.

^{cc} This assumption is based on observed declines in sales volume after two different spill events, Chalk Point (2000) and Deep Water Horizon, as reported in Simons, R. et al 2001 and Winkler et al 2013.

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San Juan County Emergency Response Towing Vessel Cost Evaluation

Prepared for

San Juan County

December 2018

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Abbreviations

ERTV	Emergency response towing vessel
MRC	Marine Resources Committee
OFM	Office of Financial Management
RMM	Risk mitigation measure
SJC	San Juan County
WSMC	Washington State Maritime Cooperative

Executive Summary

This report provides cost estimates and other considerations for the long-term stationing of an emergency response towing vessel (ERTV) capable tugboat in or near San Juan County (SJC) in Washington. Positioning an ERTV to respond to a distressed vessel in Haro Strait and Boundary Pass has been recommended as a priority oil spill prevention risk mitigation measure by the Washington Department of Ecology, Puget Sound Partnership boards, and SJC through its Marine Resources Committee. The annual costs are evaluated for three alternative standby positions for the ERTV tug. The tug can be either permanently moored at a harbor in SJC, permanently on standby at sea (underway), or a combination of the two. SJC marinas experience seasonal traffic related to tourism and may not be able to accommodate a large tug during the summer months.

Annual costs of maintaining an ERTV in SJC are estimated to range from \$4.4 to \$6.3 million, as summarized in Table ES-1. The lowest cost of the three alternative methods is permanent moorage in a harbor, at \$4.4 to \$6.2 million. This scenario is consistent with the Neah Bay ERTV configuration and organization. When the ERTV is operated permanently underway there are no marina fees, but total cost increases by an estimated \$109,000 due to increased consumption of diesel for electrical generators. A vessel which is moored only during the winter has partial savings on marina fees and an increase in diesel consumption. Compared to the case where the ERTV is permanently moored, the estimated cost of seasonal mooring is \$65,000 more. Each scenario includes six training sessions per year, at three hours each.

Table ES-1. Summary of Cost Alternatives

Rate	Permanently Moored	Permanently Underway	Seasonally Moored
	Annual Cost (\$)		
Low Daily Rate	4,351,000	4,460,000	4,416,000
High Daily Rate	6,176,000	6,285,000	6,241,000

Source: The Glostén Associates (2018) and Northern Economics, Inc.

The typical daily charter rate for a tug with ERTV capabilities ranges from \$11,500 to \$16,500 per day. This rate includes labor, operations and maintenance, profit, insurance, taxes, and the cost of provisions. Not included within these rates are marina fees and fuel surcharges for running the tug's engines and electrical generators. Table ES-2 shows the relative portion of each cost component relative to total cost.

Table ES-2. Proportion of Annual ERTV Costs by Category

Cost Category	Percentage of Total Annual Cost (%)
Labor	50
Maintenance and Operations (including depreciation)	25
Profit	10-15
Insurance	5-10
Taxes/Provisions/Marina Fees	3-6

Source: The Glostén Associates (2018)

The estimates provided in Table ES-1 are sensitive to annual labor wages, which is the primary difference between the low and high daily charter rates used to calculate cost. Vessels capable of ERTV services may require a crew of up to seven, but as few as four. Additionally, the crew members can be unionized or non-unionized, which significantly affects their wage rates. These two factors alone

account for most of the variation in the estimate. Due to the business confidential nature of the information collected for this analysis, data have been aggregated and details withheld to protect the information. The estimates presented here are based on stationing the tug at a domestic port. If the tug were stationed at a location outside of the U.S., the actual cost could vary.

1 Introduction

San Juan County (SJC) is located in the Salish Sea, bounded by Haro Strait and Boundary Pass to the west, Rosario Strait to the east, Georgia Strait to the north, and Strait of Juan de Fuca to the south. While renowned for its remoteness and pristine natural beauty, the county is situated among major commercial shipping routes that connect ports in Washington and British Columbia and are vulnerable to the threat of oil spills caused by incidents involving both cargo vessels and oil tankers (Figure 1). Oil tanker traffic is projected to increase significantly with planned and ongoing expansions to port activities, which will in turn increase the risk of large oil spills in the region. Protection against a catastrophic oil spill is the highest environmental priority for SJC, as ranked by the Local Integrating Organization comprising local governmental, non-governmental, academic, and tribal representatives.

At its October 2016 Salish Sea Oil Spill Risk Mitigation Workshop, the Washington Department of Ecology solicited input on potential additional marine oil spill prevention risk mitigation measures (RMMs) from a diverse group of governmental, non-governmental, and tribal participants. The output of this workshop was a prioritized list of nine RMMs. Among the priorities is a measure that would reduce spill risk at particularly vulnerable locations. The measure would pre-position a fit-for-purpose multi-mission emergency response towing vessel (ERTV) based on best achievable technology for Boundary Pass and Haro Strait on the northwest and west sides of SJC. The recommended implementation strategy is to develop a strong case statement and a cost/benefit business model, drawing upon the success of the Neah Bay ERTV. This cost evaluation directly supports such a cost/benefit business model (Ecology 2016).

The scope of this project also is consistent with the recommendations made in the SJC Marine Resources Committee's (MRC) 2015 and 2017 Marine Managers Workshops. It implements recommendations made by the MRC, approved by the Local Integrating Organization and adopted to the 2016 Action Agenda for Puget Sound. It is a central strategy of the San Juan Islands Action Area Ecosystem Protection and Recovery Plan to promote additional oil spill prevention measures and justify additional oil spill prevention financing for an ERTV positioned near Haro Strait/Boundary Pass to regulators and elected officials (AAOG 2017). The Puget Sound Partnership Ecosystem Coordination Board and Leadership Council have formally encouraged elected officials to support the ERTV and other high priority risk mitigation measures. Additionally, the Governor's Southern Resident Orca Task Force has recommended the ERTV for this area (Task Force 2018).

This cost evaluation is based on the current operation of an ERTV at Neah Bay on Washington's Olympic Peninsula at the entrance of the Strait of Juan de Fuca, an important maritime shipping route for both the State of Washington and Canada. In 1999, Washington leaders first developed the use of the emergency rescue tug at Neah Bay, which was only funded to operate during the harsh winter months (Ecology 2018). In 2008, year-round funding was established and in 2010 the state legislature created an industry-funded program to maintain the ERTV permanently in Neah Bay (RCW 88.46.130, 2016; WAC 173-182-242, 2013). The ERTV is funded by fees paid from all vessels over 300 gross tons traveling through Washington State waters to Washington ports. The first year-round contract for ERTV services at Neah Bay was awarded to Crowley in 2008. The current provider is Foss Maritime, which has held the contract for eight years.

Minimum requirements for the ERTV (according to State of Washington RCW 88.46.135) are as follows:

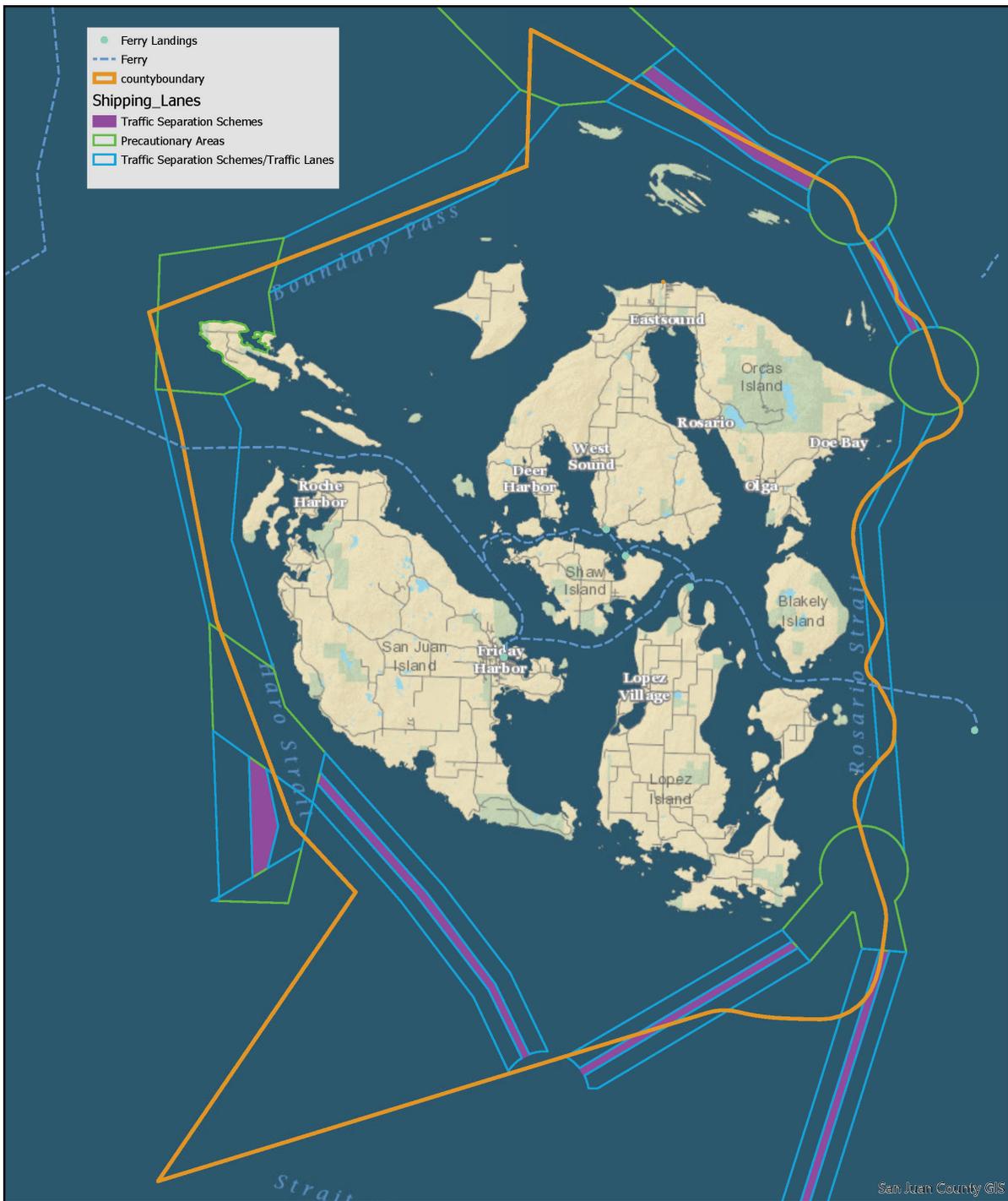
- Able to be underway within twenty minutes of a call to deploy
- Be available to deploy 24/7 and remain deployed for up to 48 hours
- Bollard pull of 70 short tons
- Capable of towing a disabled vessel of 180,000 dead weight metric tons
- Must have equipment to perform the following functions:
 - Ship anchor recovery hook and line throwing gun
 - Damage control patching
 - Vessel dewatering
 - Air safety monitoring
 - Digital photography

Since establishment, the ERTV has been deployed 68 times (Ecology 2018). It is an important tool in the prevention of ship groundings and ultimately oil spills. SCJ contracted Northern Economics, Inc. to provide an estimate for a similar ERTV that would be positioned to respond to distressed vessels in the Haro Strait, Boundary Pass, and a broader geographic area which includes Rosario Strait. The cost estimates summarized in this report cover a range of scenarios and alternatives.

The Washington Department of Ecology recently submitted a draft report on vessel traffic safety which included a review of the Neah Bay ERTV and its activity in the Strait of Juan de Fuca since implementation (Ecology 2018). The report recommended that a joint effort between U.S. and Canadian stakeholders, including tribes and First Nations, would be the best method for implementing additional standby tugs in the Haro Strait region. For the purposes of this report, cost estimates are based on domestic ports. An alternative to permanently stationing the tug within a harbor is to maintain the tug underway/offshore 24/7. This analysis considers the alternatives of maintaining an ERTV moored in Roche Harbor or Friday Harbor, underway 24/7, or a seasonal combination of the two. Deer Harbor Marina is not able to accommodate a vessel of the typical ERTV length (Broman 2018).

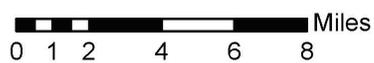
Figure 1 shows shipping lanes and marinas in SJC.

Figure 1. Shipping Lanes and Marinas



This map is derived from San Juan County's Geographic Information System (GIS). It is intended for reference only and is not guaranteed to survey accuracy. The information represented on this map is subject to change without notice.

Shipping Lanes and Marinas



Source: SJC GIS (2018)

2 Approach and Methodology

The cost estimates provided in this report are limited to the operation and maintenance of an ERTV in preparation for emergency response. There are no estimates of response costs included here, since the costs will vary depending on the circumstances and all costs would be billed to the owner of the distressed vessel when the ERTV responds to a call.

The Neah Bay ERTV provides a baseline for developing a cost estimate for an ERTV based at a harbor in SJC. The Neah Bay vessel is moored at the marina year-round and pays fees to the Makah Tribe for the use of its facilities. Another possibility is for the tug to be on standby at sea (underway) permanently. Marinas in SJC become busy in the summer with seasonal traffic, so it may be more practical to station the ERTV offshore during the summer months. In the case of the Friday Harbor Marina, there is not enough room to accommodate a vessel during the summer (Long 2018). Permanent offshore stationing is the most expensive of the scenarios because it costs more to generate the vessel's own electricity than to pay for metered shore power. This report presents low and high cost estimates for each of the discussed alternatives: permanent moorage in a marina, permanent offshore standby, and seasonal moorage in a marina.

There are five main sources of cost to maintaining an ERTV: labor wages, maintenance and operations (including depreciation), contractor profit, insurance, and fuel surcharges plus various other small fees. Northern Economics contracted with The Glosten Associates, a naval architectural and marine engineering firm, to provide rough order-of-magnitude estimates for a range of charter rates and electrical service loads. Northern Economics also reached out to marine shipping service companies to discuss the costs of obtaining and operating an ERTV and to understand the factors that affect costs.

3 Neah Bay ERTV Cost Estimates

The ERTV which has been stationed year-round at Neah Bay since 2008 is the primary basis for cost estimation of an ERTV in SJC. The ERTV at the Port of Neah Bay is maintained in the Makah Marina, which is owned and operated by the Makah Tribe.

The tugs stationed at Neah Bay have varied over time in age and length, while still meeting the minimum state law requirements. In general, the ERTVs at Neah Bay have been in the range of 100 to 130 feet but have been as large as 150 feet.¹ Tugs meeting ERTV requirements usually have four to six crew members, who live onboard the vessel and work in alternating six-hour shifts. When moored in the harbor, the tug is connected to an electrical meter on the shoreline to draw power. The water and wastewater systems are self-contained on the vessel.

The tug is on standby 24/7 and must be prepared to respond to distressed vessels in the area. If the ERTV is called to assist a vessel, the vessel owner is billed for the service and additional expenses (e.g. time and fuel) are no longer the burden of the Washington State Maritime Cooperative (WSMC). The contractor is required to provide another tug meeting ERTV requirements while the stationed tug is responding to a call. If the stationed tug is expected to be away for more than 24 hours, the replacement tug is stationed in Neah Bay.

When the ERTV is away from the harbor, it consumes diesel for a generator to produce electricity which is significant source of operating cost. The largest single component of cost for stationing an ERTV is labor, at about 50 percent of the total annual cost.

The tug stationed at Neah Bay has some additional fuel costs that are not anticipated at the locations evaluated in SJC. At Neah Bay, tidal fluctuations sometimes prevent the tug from being able to leave the harbor. During especially low tides, the draft of the tug is larger than the depth of water at the harbor entrance. Approximately 10 times per month, the tug must leave the harbor prior to low tide and remain outside the harbor until the tide rises again. This is to prevent the tug from being trapped within the bay should the tug be dispatched to a distressed vessel. The additional expense of fuel during these trips is passed on to the WSMC. This additional cost is not expected at Roche Harbor or the Friday Harbor Marina; however, the tug must make some trips outside the harbor for training exercises. The analysis assumes that the tug will conduct six training exercises per year, each lasting three hours, regardless of its stationed location.

¹ Vessel length is the basis for marina moorage. It is not an indicator of vessel capability or towing capacity.

4 Cost Estimates for San Juan County

Cost estimates for the long-term stationing of an ERTV in SJC are based on three generalized scenarios: permanent standby in an SJC harbor, standby when the ERTV is permanently underway, or standby while stationed in a harbor during the winter and underway during the summer.

An informal industry survey conducted by The Glosten Associates was used to obtain day charter rates for a tug capable of ERTV services. A tug with rated bollard pull of 80–100 short tons and with an appropriate winch package ranges from \$11,500 to \$16,500 per day. In addition to the daily rate, fuel consumption for engines and electrical generators are passed on as a surcharge² and moorage fees must be paid to the harbor for use of their facilities.

4.1 ERTV Permanently Moored at a Domestic Harbor

Northern Economics reached out to Roche Harbor, Friday Harbor Marina, and Deer Harbor to obtain rates for moorage, metered electricity, and liveaboard fees. Deer Harbor currently does not have facilities to accommodate a vessel up to 130 feet. The Friday Harbor Marina provided monthly rates but noted that they did not have room for the ERTV during the summer months when recreational marine activity is greatest. Moorage rates for Roche Harbor were obtained from their website, but as a popular summertime resort destination they may not have room for the ERTV during the summer.

For the scenario where an ERTV is permanently moored at an SJC harbor, this report presents an average rate for moorage fees which is based on data obtained. For a 130-foot vessel, all-in marina fees would cost approximately \$35,000 annually. Table 1 provides a breakdown of costs for the low and high day rates, and their associated percentages of total annual cost.

Table 1. Cost Estimate Summary for Permanently Moored ERTV in SJC

Cost Category	Low Daily Rate (annual \$)	High Daily Rate (annual \$)	Percent of Total (%)
Labor	2,160,000	3,070,000	50
Operations, Maintenance, Depreciation, Profit, Insurance, Taxes, Provisions, and Misc.	2,073,000	2,953,000	48
Fuel Surcharge (training exercises and generator)	83,000	119,000	2
Marina Fees	35,000	35,000	1
Annual Total	4,351,000	6,176,000	100

Source: The Glosten Associates (2018), Long (2018), Roche Harbor (2018), and Northern Economics, Inc.

4.2 ERTV Permanently Underway

As an alternative to mooring the ERTV at a marina, the tug could be underway offshore 24/7. The vessel must return to shore for crew changes and for supplies, but it would remain at sea for the remainder of the time and the main engines would not be running. In this case, there would be no marina fees, but the vessel would incur additional expenses from the use of its electrical generator, which would increase the overall cost. The cost of metered shore-based power is less expensive than purchasing diesel for generators. Despite the savings on marina fees, the underway alternative would be more costly than

² Diesel consumption for locomotion is approximately 200 gallons per hour, and consumption for electricity (when underway) is 75 to 100 gallons per day. A marine diesel price of \$2.50/gal was used in the estimates.

permanent mooring by approximately \$109,000 per year. This represents an increase of two to three percent over permanent mooring. Table 2 provides a breakdown of costs for the low and high day rates, and their associated percentages of total annual cost.

Table 2. Cost Estimate Summary for Permanently Underway

Cost Category	Low Daily Rate (annual \$)	High Daily Rate (annual \$)	Percent of Total (%)
Labor	2,160,000	3,070,000	49
Operations, Maintenance, Depreciation, Profit, Insurance, Taxes, Provisions, and Misc.	2,139,000	2,952,000	47
Fuel Surcharge (training exercises and generator)	161,000	263,000	4
Marina Fees	0	0	0
Annual Total	4,460,000	6,285,000	100

Source: The Glosten Associates (2018) and Northern Economics, Inc.

4.3 ERTV Seasonally Moored and Underway

Harbors in SJC have seasonal traffic related to tourism, fishing, and resorts at some marinas. A 130-foot tugboat is difficult to accommodate and maintain at a harbor during the summer months. An alternative to maintaining the ERTV permanently underway is mooring the vessel only during the winter. The vessel would be underway from May to September. The cost estimate is based on the vessel spending 60 percent of the year moored and 40 percent of the year underway. Table 3 provides a breakdown of costs for the low and high day rates, and their associated percentages of total annual cost.

Table 3. Cost Estimate Summary for Seasonally Moored ERTV in SJC

Cost Category	Low Daily Rate (annual \$)	High Daily Rate (annual \$)	Percent of Total (%)
Labor	2,160,000	3,070,000	49
Operations, Maintenance, Depreciation, Profit, Insurance, Taxes, Provisions, and Misc.	2,105,000	2,945,000	47
Fuel Surcharge (training exercises and generator)	130,000	205,000	3
Marina Fees	21,000	21,000	0
Annual Total	4,416,000	6,241,000	100

Source: The Glosten Associates (2018), Long (2018), Roche Harbor (2018), and Northern Economics, Inc.

5 Other Potential Costs

The crew size, rate of fuel consumption (for both the engine and generator), and capital expenses all vary with individual tugboats. The ERTV requirements described in RCW 88.46.135 can be met by tugs of substantially different lengths and crew sizes because towing capabilities are primarily based on engine output and configuration. For example, the ERTV at Neah Bay has used crews of four to six and has varied in length from 100 to 130 feet. The estimates provided in this report considered vessels with a crew of four to seven people.

The three alternatives presented in Section 4 vary with respect to fuel surcharges and marina fees, which make up a small portion of the variation in total cost. The largest source of both total cost and uncertainty in cost are the labor wages of the tugboat crew. At 50 percent of the total annual cost, ERTV labor wages are approximately \$2.2 to \$3.1 million per year. There are several factors that influence variation in labor wages and help to explain the difference in the provided range of daily rates. The most significant factor is wage rates of unionized versus non-union workers. Similarly, state prevailing wages tend to increase non-union wage rates. The lowest wage rates are for non-union workers where state prevailing wages do not apply. The cost estimates presented in this report also do not account for inflation. Wage rates rise over time with a typical inflation rate of 3 to 3.5 percent annually. A long-term contract rate will likely factor in those increases.

It may be possible to negotiate discounted marina fees for a long-term service contract. Northern Economics' cost estimates are based on published annual rates or rates provided by harbormasters.

Another consideration is the age of a tug and its ability to meet emissions requirements. California is well known for its clean air initiatives, which have forced some marine shipping companies to repower their old tugs to meet new emissions standards. If the State of Washington were to follow this trend it might affect the ERTV(s) in Washington. If an older tug is renovated to meet the state ERTV requirements, it could be impacted by changes to air quality initiatives. These changes may require capital in the future to repower the vessel and be accounted for through increased daily charter rates.

6 Summary

The typical daily charter rates for a tug with ERTV capabilities is \$11,500 to \$16,500 per day. This rate includes labor, operations and maintenance, profit, insurance, taxes, and the cost of provisions. Not included in these rates are marina fees and fuel surcharges for running the tug's engines and electrical generators.

The lowest cost of the three alternative methods is permanent moorage in a harbor, estimated at \$4.3 to \$6.1 million. This scenario is consistent with the Neah Bay ERTV configuration and organization. When the ERTV is operated permanently underway, there would be no marina fees, but the total estimated cost would increase by \$109,000 due to increased consumption of diesel for electrical generators. A vessel that is moored only during the winter would have partial savings on marina fees and an increase in diesel consumption. Compared to the case where the ERTV is permanently moored, the estimated cost of seasonal mooring is \$65,000 more. Each of the scenarios accounts for six training sessions per year, lasting for three hours each.

Table 4. Summary of Cost Alternatives

Rate	Permanently Moored	Permanently Underway	Seasonally Moored
	Annual Cost (\$)		
Low Daily Rate	4,351,000	4,460,000	4,416,000
High Daily Rate	6,176,000	6,285,000	6,241,000

Source: The Glosten Associates (2018) and Northern Economics, Inc.

7 Limitations

An ERTV positioned for Haro Strait and Boundary Pass would be similar to the Neah Bay tug in specifications and in annual cost. Costs for maintaining the Neah Bay ERTV prior to 2011 are publicly available, because the program was funded by the State of Washington (tax dollars). From 2008 to 2009 the standby tug cost \$3.65 million per year (nominal dollars), and from 2009 to 2011, the standby tug cost \$3.6 million per year (nominal dollars) (OFM 2018a, 2018b). Since 2011 the Neah Bay ERTV has been funded by private industry, and the costs are considered business confidential information.

Similarly, the information used as the basis for analysis in this report was provided by private companies in the shipping industry, to which Northern Economics promised confidentiality of detailed costs. The information is therefore aggregated and summarized in this cost evaluation.

An ERTV positioned in or near SJC would be subject to a bidding process and rely on a contractor to provide the service. There is some uncertainty associated with future contracts negotiated through bidding, and the range of estimates presented in this evaluation attempts to capture the potential range of actual costs.

Costs estimates in this report are based on U.S. port locations. A cost estimate of an ERTV based at a port outside of the U.S. could vary substantially from the estimates provided in this report. Moorage fees, fuel prices, taxes, and wage rates would depend on the tug's standby location.

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Appendix: Glosten Associates Rough Order-of-Magnitude ERTV Estimates



San Juan ERTV – ROM Cost Estimate

16 November 2018

TO: Mike Fisher
FROM: Peter S. Soles
JOB/FILE NO. 18127.01

Introduction

Northern Economics, Inc. contracted Glosten to prepare annual cost estimates for stationing an Emergency Response Towing Vessel (ERTV) in San Juan County, Washington for the purpose of responding to vessel loss-of-propulsion events and other marine incidents on an emergency callout basis. It is assumed, consistent with standard industry practice, that ERTV services would be contracted through a marine towing or salvage company, with costs based on a fixed day rate for the contract period plus surcharges for fuel and shoreside electricity. This memorandum serves to provide a rough order of magnitude (ROM) cost for this service and identify basic requirements for a suitable ERTV berth.

Summary of Findings

Primary cost drivers for a permanently deployed ERTV include: crew size and union affiliation (i.e. union vs. nonunion); the age, size, horsepower, and outfit of the tug itself; and fuel consumption. Taking the above variables into consideration, current day rates for a modern ERTV with a rated bollard pull of 80-100 short tons, outfitted with an appropriate winch package and gear for emergency towing, are estimated to fall in the range of \$11,500 to \$16,500 per day, equating to a base annual cost of \$4.20M to \$6.02M. Fuel and shoreside power costs, which would likely be billed as a surcharge, are estimated between \$83,000 and \$119,000 annually, assuming shoreside power is available, and between \$161,000 and \$263,000 annually for the alternative case, in which the vessel must run one onboard generator continuously. Annual cost totals for both cases are presented in the table below.

Table 1 Estimated total annual costs

Day Rate (\$/day)	Case 1 (with shore power)		Case 2 (no shore power available)	
	Low Ship Service Load	High Ship Service Load	Low Ship Service Load	High Ship Service Load
Low (\$11,500)	\$4,280,787	\$4,316,065	\$4,358,169	\$4,459,805
High (\$16,500)	\$6,105,787	\$6,141,065	\$6,183,169	\$6,284,805

Berthing costs are not included in this cost estimate, as rates are highly variable depending on location (not provided), facilities, ERTV funding mechanisms, and other factors. That noted, a suitable berth is critical for a dependable and cost-efficient ERTV program. Basic requirements for a suitable berth for an ERTV include:

- Adequate underkeel clearance (UKC) (>10% of draft) at all heights of tide
- Unrestricted passage in and out of the harbor at all heights of tide (i.e. no controlling depths $<1.1 \times$ vessel draft)
- Minimum overhead clearance of approximately 50' at all heights of tide
- Direct shoreside access (connected walkways) for crew changes and resupply of provisions/consumables
- Shoreside connections for sewage pump-out and fresh water fill
- Guaranteed berthing space for tug approximately 130' LOA
- Adequate dock strength to support a tug approximately 130' LOA
- Suitable mooring points for a tug approximately 130' LOA
- Shoreside power connection (ideally)
- Stores crane accessible on pier, such that equipment, replacement parts, provisions, etc. can be lifted on/off the vessel (ideally)

Methodology

Cost estimates were based on a recently constructed (<5 years old) towing vessel with a rated bollard pull in the 80-100 short ton range. This is consistent with other ERTVs deployed regionally; but it is noted that an ERTV with less bollard pull may be adequate in the partially-protected waters of Haro Strait, Rosario Strait, and Boundary Pass. No analysis was done to determine actual performance requirements for an ERTV in this area.

It is assumed that a marine towing company would charge for services on a standard day rate basis (365 days/year), with additional surcharges for fuel and shoreside power used. Day rates are assumed to be made up of the following operating and fixed costs:

- Labor (wage and fringe): ~50%
- Operations and maintenance (including depreciation): ~25%
- Provisions/commissary: ~1-3%
- Insurance: ~5-10%
- Taxes: ~1-3%
- Profit: ~10-15%

Day rates were estimated based on recent project experience and an informal and confidential survey of local marine towing companies.

For estimation of fuel and power consumption costs, it was assumed that fuel/power consumed at berth and during routine drills would be passed on as a surcharge; but fuel usage during emergency callouts would be billed directly to the subject vessel owner/operator. Drills were assumed to take place six times annually, each lasting for three hours with main engines run at an average of 75% load. Main engine sizing was based on a twin-screw arrangement designed to produce 100 short tons of bollard pull at maximum continuous rating.

Two cases were assumed for calculation of fuel and power consumption at berth: one in which the availability of a shoreside power connection allows onboard generators to be secured –i.e. not running– at all times, except during drills and routine start-ups (Case 1); and another in which the absence of a shoreside power connection requires the vessel to run an onboard generator at all times (Case 2).

In both cases, a high and low ship service load was calculated to contrast variability in possible fuel costs. The high ship service load was assumed as 150 kW (70% load of a large 215 kW

generator), while the low ship service load was assumed as 100 kW (85% load of a smaller 120 kW generator). Costs presented assume an average annual price of \$2.50/gallon for marine diesel. For Case 1 (with shore power), Puget Sound Energy rate sheet Schedule 25 was used to calculate electricity cost and demand charge. A breakdown of annual energy costs for Case 1 is presented below.

Table 2 At-berth energy cost Case 1

	Fuel Cost (\$)	Electricity Cost (\$)	Total Cost
Low ship service load (100 kW)	\$12,520	\$70,767	\$83,287
High ship service load (150 kW)	\$12,729	\$105,836	\$118,565

Note that fuel costs shown in Table 2 are the result of routine drills, as discussed above. It is assumed the vessel is connected to shoreside power the remainder of the time, with onboard generators secured.

Conclusion

It is emphasized that total annual costs presented here are closely linked to crew size and union affiliation, and the assumed age, size, and horsepower of the tug. Selection of a smaller tug with a rated bollard pull of 60 short tons, for example, could result in a significant reduction in annual costs without compromising the intended function of the ERTV. To avoid unnecessary costs to the entities that fund an ERTV, regardless of location, it is imperative that clear mission objectives are defined early in the process and a formal analysis carried out to determine required performance characteristics of the tug to be deployed.