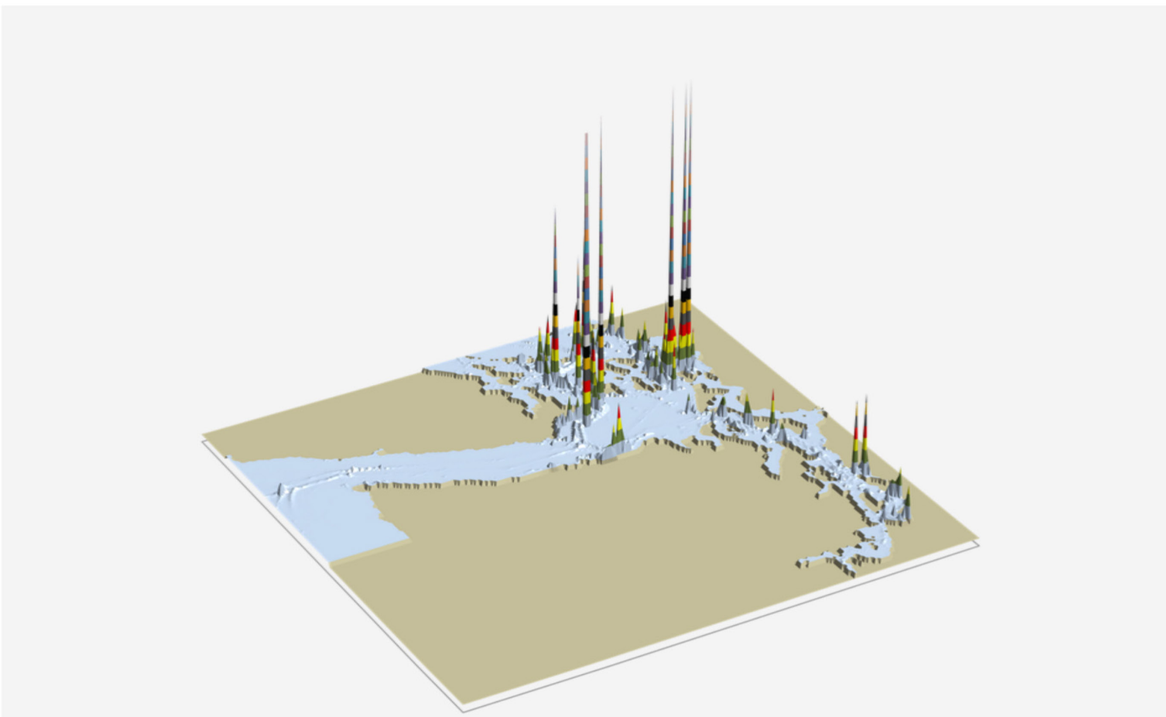
VTRA 2015 FINAL REPORT UPDATING THE VTRA 2010

A POTENTIAL Oil Loss Comparison of Scenario Analyses by four Spill Size Categories



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Prepared by Author(s):

Dr. Johan Rene Van Dorp

Professor Engineering Management and Systems Engineering

George Washington University (GW)

(202) 994-6638

dorpjr@gwu.edu

Dr. Jason Merrick

Professor Statistical Sciences and Operations Research

Virginia Commonwealth University (VCU)

(804) 828 5865

jrmerric@vcu.edu

Prepared for:

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Final Report

Vessel Traffic Risk Assessment (VTRA):

A POTENTIAL Oil Loss Comparison of Scenario Analyses by four Spill Size Categories

January, 2017

Approved by:

Signature: Date 1/9/2017

Johan Rene Van Dorp, George Washington University

Signature: Date 1/9/2017

Jason Merrick, Virginia Commonwealth University

Signature: Date 1-20-2017

Dale Jensen, Spills Program Manager, Washington State Department of Ecology

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This study was guided by a VTRA 2015 Working Group. The content of this document does not represent positions of the VTRA 2015 Working Group (or any of its members), or the Washington Department of Ecology.

Contact Information

Dr. Johan Rene Van Dorp
Professor Engineering Management and Systems Engineering
George Washington University (GW)
(202) 994-6638
dorpjr@gwu.edu

Dr. Jason Merrick
Professor Statistical Sciences and Operations Research
Virginia Commonwealth University (VCU)
(804) 828 5865
jrmerric@vcu.edu

Dale Jensen
Spills Program Manager
Washington State Department of Ecology
(360) 407-7450
dale.jensen@ecy.wa.gov

Scott Ferguson
Prevention Section Manager
Washington State Department of Ecology
(360) 407-7465
scott.ferguson@ecy.wa.gov

Brian Kirk
Marine Risk Management Lead & VTRA 2015 Contract Manager
Washington State Department of Ecology (Ecology)
(425) 649 7292
bkir461@ECY.WA.GOV

PREFACE

This report is submitted by Johan Rene van Dorp (George Washington University) and Jason R.W. Merrick (Virginia Commonwealth University), GW/VCU hereafter, on behalf of Washington State Department of Ecology. The content of the report describes a vessel traffic risk assessment (VTRA) conducted in 2016. The VTRA model has been updated during this VTRA study from the VTRA 2010 model using additional accident data from the period 1990 to 2015 and AIS passage line vessel count data from 2010 to 2015. To distinguish the study described herein from the previous VTRA studies (VTRA 2005 and VTRA 2010), it will be labeled VTRA 2015. Thus, the starting point for the VTRA 2015 study is the VTRA 2010 model with 2010 VTOSS data, as agreed upon in the scope of work between GW and Ecology.

This study has been funded by the Washington Department of Ecology through contract C1600131. Part I of the study utilized state funding from the Washington legislature; Part II of the study was funded by the United States Environmental Protection Agency under assistance agreement PC-00J90701 through the Washington Department of Fish and Wildlife. The VTRA 2010 study was funded by the Puget Sound Partnership. The update of the VTRA 2005 model to using VTOSS 2010 data was separately funded by the Makah Tribal Council. The VTRA 2005 Study was funded by BP. The VTRA 2005 study utilized the extensive technical work already completed by the George Washington (GW) University and Virginia Commonwealth University (VCU) in other funded maritime risk assessment (MRA) projects before that time. Specifically, The San Francisco Bay Exposure Assessment (2004), The Washington State Ferry Risk Assessment (1998) and The Prince William Sound Risk Assessment (1996).

The VTRA study area covers US/Canadian trans-boundary waters including: portions of the Washington outer coast, the Strait of Juan de Fuca and the approaches to and passages through the San Juan Islands, Puget Sound and Haro-Strait/Boundary Pass. The VTRA Study area is divided in 15 separate waterway zones outlined by the black border in Figure E-2 in the Executive Summary. One observes from Figure E-2 that the location of the Port of Vancouver, BC, falls outside the VTRA Study area boundary. The Strait of Juan de Fuca serves as the entrance to the VTRA Study area, for both US and CA port destinations, and is transited by approximately 8,300 deep draft vessels annually, including arrivals and departures, but excluding passenger vessel counts. Of these, about 5500 deep draft vessels travel to and from Canadian bound port destinations, i.e. including north and south bound transits, and about 3700 transit the entrance of the Puget Sound (at Admiralty Inlet), also including north and south bound transits.

The VTRA analysis tool evaluates the duration that vessels travel through the VTRA study area, referred to as vessel time exposure (VTE), by vessel type and the potential accident frequency and potential oil losses from a class of cargo focus vessels (bulk carrier, containerships and other cargo vessels) and a class of tank focus vessels (tankers, chemical carriers, articulated tug barges and oil barges). The inclusion of the-time-on-the-water element in the evaluation of exposure sets the VTRA methodology apart from count based approaches that focus on, for example, number of annual/monthly vessel transits, visits or calls. The value of a duration based approach versus a count based approach is that the former appropriately distinguishes between short and long transits in the evaluation of vessel traffic risk as well as differing vessel speeds. The VTRA Model methodology has been well documented and peer-reviewed in the academic literature and continuously improved over the course of the above maritime risk assessment projects. A reference list is provided at the end of this document.

A distinguishing feature of the VTRA 2015 study from the VTRA 2005 and VTRA 2010 Studies are evaluations of *estimated probabilities of at least one accident potentially occurring within a 10-year period per four potential oil loss categories*. Specifically, the following four POTENTIAL Oil Loss categories are being considered in the VTRA 2015 Study: (1) 0 m^3 – 1 m^3, (2) 1 m^3 – 1000 m^3, (3) 1000 m^3 – 2500 m^3, and (4) 2500 m^3 or more. These probability risk metrics relate directly to their estimated POTENTIAL accident frequencies per year and the length of the time period (i.e. a 10 year time period) over which these probabilities are estimated. Both the estimated probability of at least one accident per a period of time, on the one hand, and the POTENTIAL accident frequency per year, on the other hand, are considered absolute risk metrics. That being said, the evaluation of the probability risk metric demonstrate through the wording "probability" that however small the POTENTIAL accident frequency may be for a particular POTENTIAL Oil Loss category, a non-zero probability estimated using the VTRA 2015 Model supports that the occurrence of such a POTENTIAL event evaluated is not impossible and could in fact happen, however unlikely. The communication of such probability metrics per a specified period of time is advocated in [26]. That being said, the VTRA 2015 Study concentrates more on relative comparisons between risk metrics evaluated for different scenario analyses and less on the absolute values of their respective analysis results.

From the outset, this project has been guided by a VTRA 2015 Working Group. Meetings held with the VTRA 2015 Working Group provided GW/VCU a platform to obtain feedback from and access to the Washington State Department of Ecology, the United States Coast Guard, the Puget Sound Harbor Safety Committee, tribes, local governments, industry, non-profit groups in Washington State and British Columbia and other stakeholders in this maritime community. The VTRA 2010 and its update to utilizing VTOSS 2010 data were guided in a similar manner by an advisory committee of members drawn from this maritime/regulatory/tribal/stakeholder community. The sole purpose of this document and the analysis results described herein is to serve as an information source to this maritime/regulatory/tribal/stakeholder community.

E. EXECUTIVE SUMMARY

Vessels transiting the Salish Sea traverse waters bordering numerous communities en route to ports in both the US and Canada. The Salish Sea is a large (over 1000 square miles) and diverse water body physically characterized by passages that are broad and deep, as well as some narrow ones that are navigationally challenging with swift currents. In addition, it is a biologically rich ecosystem with significant natural resources these communities depend upon.

The purpose of this vessel traffic risk assessment (VTRA) is to evaluate the combined potential changes in risk in light of a number of potential maritime terminal developments in various stages of their permitting processes potentially coming to fruition, and to inform the State of Washington, the United States Coast Guard, the Puget Sound Harbor Safety Committee, tribes, local governments, industry, non-profit groups in Washington State and British Columbia and other stakeholders in this maritime community of these potential changes in risk. The combined evaluated risk changes serves as an information source to these tribes and stakeholders to assist them as to what actions could be taken to mitigate potential increases in oil spill risk from large commercial vessels in the VTRA Study Area, should all or some of these terminal projects come to fruition. However, this study was not designed to measure the effectiveness of risk mitigation measures already in place.

Planned maritime terminal projects were grouped in a manner to form What-If Scenarios. A VTRA 2015 Working Group (see, Figure E-1) selected the maritime terminal projects included in the What-If Scenarios. The inclusion of these terminal projects in these What-If Scenarios ought by no means to be interpreted to imply that these maritime terminal projects may come to fruition. Rather, the inclusion of these terminal projects in this VTRA 2015 study ought to be seen as being part of a safety culture being practiced in this maritime community over many years of which the formation of the Puget Sound Harbor Safety Committee back in 1997 and its bi-monthly held meetings since then is a prime example. Summarizing, this study was conducted because study sponsors (Ecology), involved tribes and stakeholders want to ensure that the combined potential risks of maritime development projects in various permitting stages are better understood, should some or all come to fruition, so informed decisions and recommendations could be made by them about potential additional risk mitigation measures (RMMs) that would add to the continuous improvement efforts of the past.

The VTRA methodology has been developed over the course of close to twenty years of work in various maritime risk assessment projects. Specifically, the Prince William Sound Risk Assessment (1996), The Washington State Ferry Risk Assessment (1998), The San Francisco Bay Exposure Assessment (2004), the Vessel Traffic Risk Assessment 2005 (VTRA 2005)[1] and the Vessel Traffic

[1] The VTRA 2005 analysis in [12] was limited to vessel traffic risk evaluation associated with Tankers, ATBs and ITBs docking at the Cherry Point terminal.

Risk Assessment 2010 (VTRA 2010). The VTRA analysis methodology has been well documented and peer-reviewed in the academic literature and continuously improved over the course of these maritime risk assessment projects. A reference list is provided at the end of this document.

VTRA 2015 Working Group

Chair:

- Captain Stephan Moreno[2], Puget Sound Pilots

Federal, State and Tribal Leads [representing]:

- Scott Ferguson (alternate Brian Kirk or Sara Thompson), Washington State Department of Ecology
- US Coast Guard Sector Puget Sound – CAPT Joe Raymond (alternate CDR Matt Edwards)
- US Coast Guard District 13 - R.E. McFarland
- Makah Tribal Council - Chad Bowechop (alternate Keith Ledford or Jon Neel)

Core Working Group Members:

- Puget Sound Pilots - Jostein Kalvoy
- American Waterways Operators – George Clark, Charles Costanzo
- Marine Exchange of Puget Sound – John Veentjer
- Pacific Merchant Shipping Association – Mike Moore
- Western States Petroleum Association – Frank Holmes
- Washington Association of Counties – Jamie Stephens
- Washington Public Ports Association – James Thompson
- Tesoro - Ed Irish, Rob McCaughey
- BP - Scott McCreery, Carl Obermeier
- Puget Sound Partnership – Todd Hass
- Mulno Cove Consulting/Friends of the San Juans – Lovel Pratt
- Puget Soundkeeper – Chris Wilke
- Wave/Friends of the Earth – Fred Felleman

Figure E-1. Organizational Chart of the VTRA 2015 Working Group.

The VTRA 2015 Study Area is defined by the black border in Figure E-2 covering US/Canadian trans-boundary waters including: portions of the Washington outer coast, the Strait of Juan de Fuca and the approaches to and passages through the San Juan Islands, Puget Sound and Haro-Strait/Boundary Pass. It is worthwhile to note that while Canadian bound traffic passes through the VTRA 2015 Study Area, the Port of Vancouver is located north of the VTRA 2015 Study Area boundary. The VTRA 2015 Study Area is divided in 15 separate waterway zones outlined in Figure E-2. The VTRA 2015 Study Area includes an International Maritime Organization (IMO) approved Traffic Separation Scheme (TSS) that governs vessel traffic in the system and its approaches. It is

[2] Captain Moreno served as chair from November 2015 through August 2016.

actively managed by a joint US - Canadian Cooperative Vessel Traffic Service (CVTS). At the western entrance to the Strait of Juan de Fuca, it includes the extent of Prince Rupert radar coverage via a radar unit on Mt. Ozzard; approximately 60 miles out to sea, and extends throughout the Puget Sound region north to Vancouver, British Columbia, and south to Tacoma, Washington and Olympia, Washington. Radar is supplemented by Automatic Identification System (AIS) transponders, radio communications and advance notices for arriving vessels.

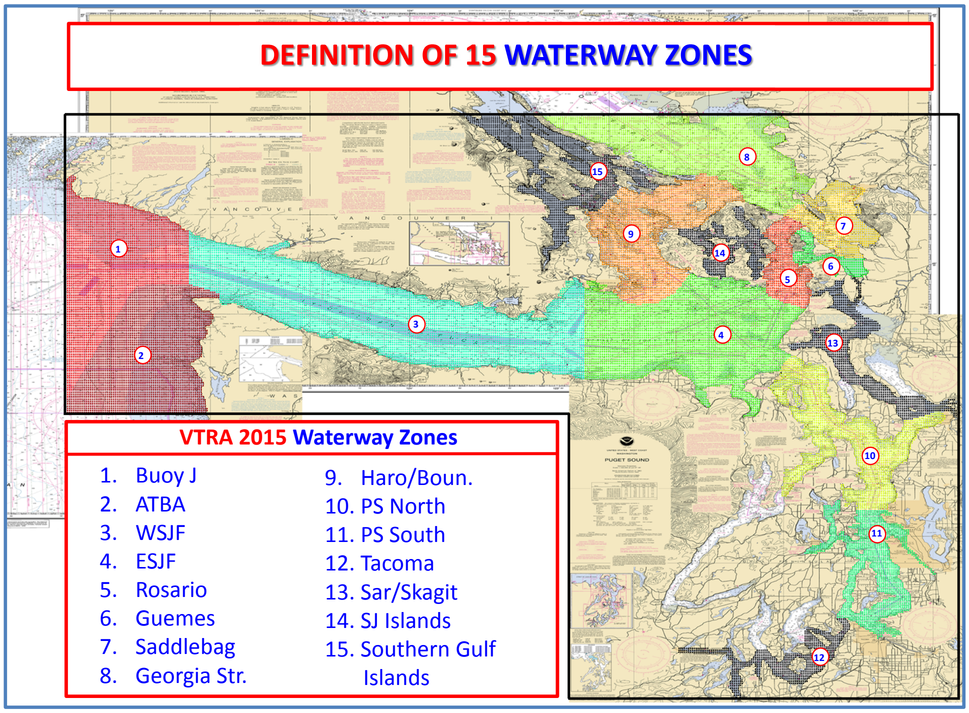

Figure E-2. Definition of 15 waterway zones and their descriptors in the VTRA 2010 Study Area.

For context, it is important to recognize that the VTRA Base Case 2015 Scenario analysis includes a series of risk mitigation measures. In addition to the previously mentioned IMO Traffic Separation Scheme and CVTS, vessels are subject to Port State Control and other vessel inspections regimes in both Canada and the United States to enforce international and federal standards. Pilotage is required in both the US and Canada and pilotage areas are comparable. Tug escorts for laden tankers are required and tugs are used to assist vessels into and out of the berths. Moreover, there are a number of risk mitigation measures that have been put in place internationally, federally and locally over the last several decades including double hulls for tankers, protectively located fuel tanks for non-tank vessels (still being phased in), a Puget Sound Harbor Safety Plan with Standards of Care, the implementation of AIS, a traffic procedure governing vessels transiting Turn Point at the boundary between Haro-Strait and Boundary Pass northeast of Victoria, BC, and a one-way zone regime in Rosario Strait. This list is not exhaustive.

Base Case Scenario Results

The Strait of Juan de Fuca serves as the entrance to these US and Canadian ports and facilities and is transited by approximately 8,300 deep draft vessels annually, including arrivals and departures. Of these transit entrances and departures, approximately nine cargo focus vessels (bulk carriers, container ships and other cargo vessels) enter and leave the Strait of Juan de Fuca daily totaling about 6500 transits annually. Similarly, approximately 1300 tank focus vessels (tankers, chemical carriers, articulated tug barges and oil barges) travel east and west annually (i.e. about 2 tank focus vessel per day enter and leave the Strait of Juan de Fuca in 2015).

Of these deep draft vessels transits, about 5500[3] deep draft vessels travel, including north and south bound transits, to the Port of Vancouver, British Columbia, and about 3700[4] transit the entrance of the Puget Sound (at Admiralty Inlet), also including north and south bound transits. Thus, in addition to the 8300 transits entering and leaving the Strait of Juan de Fuca, additional deep draft vessels transits occur internally as vessels shift locations. There are also tug and barge movements, ferry operations, fishing and recreational vessels throughout. For example, the US Coast Guard Vessel Traffic Service (VTS) alone handles approximately 230,000 transits annually with about 170,000 of those being Washington State Ferries meaning there are more than approximately 60,000 transits other than ferries handled by the USCG VTS. The Puget Sound Pilots assignments average at about 7,000 assignments annually which provide a good metric for how many deep draft vessel movements there are on the US side.

The VTRA 2015 analysis model evaluates the duration that vessels travel through the VTRA Study Area (referred to as Vessel Time Exposure, abbreviated VTE), by vessel type. The inclusion of the time-on-the-water element in the evaluation of exposure sets the VTRA 2015 methodology apart from other count based approaches that focus on, for example, number of annual/monthly vessel transits, visits or calls. The value of a duration-based approach versus a count-based approach is that the VTE approach appropriately distinguishes between short and long transits in the evaluation of vessel traffic risk as well as high and low vessel speeds. Figure E-3 and Figure E-4 are graphical depictions of VTE evaluated by the VTRA 2015 Model. Figure E-3 and Figure E-4 depict that of the total Base Case 2015 Scenario VTE, 24.2% (Figure E-3) is accounted for by focus vessels and 75.8% (Figure E-4) by non-focus vessels. Focus vessels are the vessels of primary interest in the VTRA 2015 study and are subdivided into tank focus vessels (tankers, chemical carriers, articulated tug barges and oil barges) and cargo focus vessels (bulk carriers, container ships and other cargo vessels). Non-focus vessels are represented in the VTRA 2015 as they can potentially collide with the focus vessel class or contribute to potential grounding of focus vessels (besides potential accidents amongst focus vessels themselves).

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[3] This number excludes passenger vessel counts
[4] This number excludes passenger vessel counts

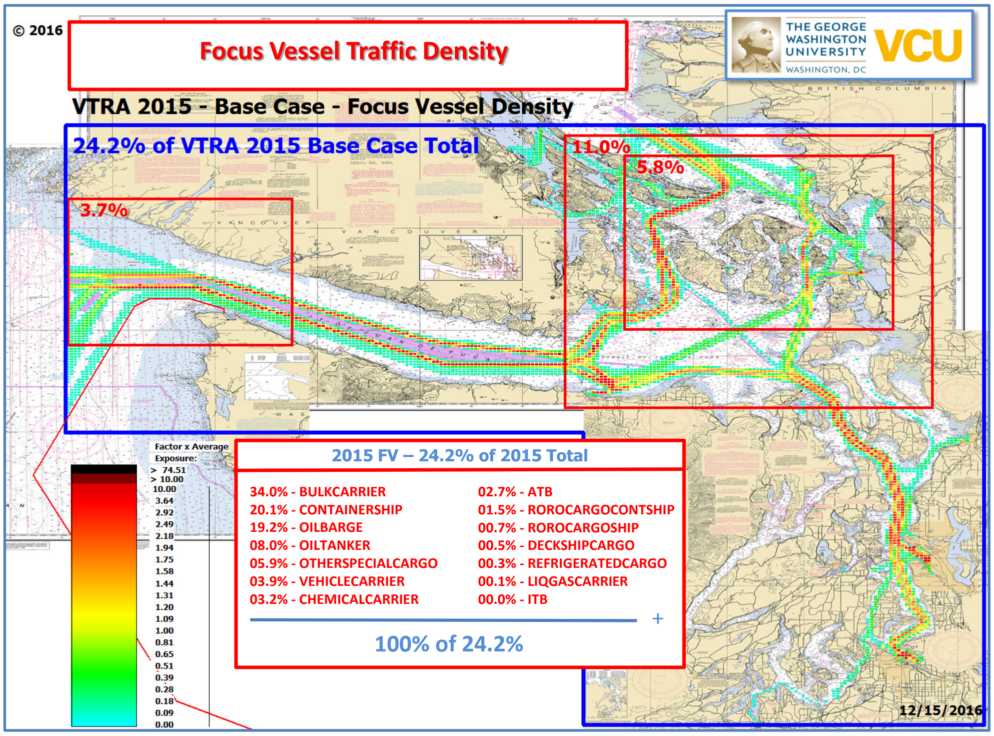

Figure E-3. 2D depiction of the traffic VTE for all focus vessels modeled in the Base Case 2015 Scenario.

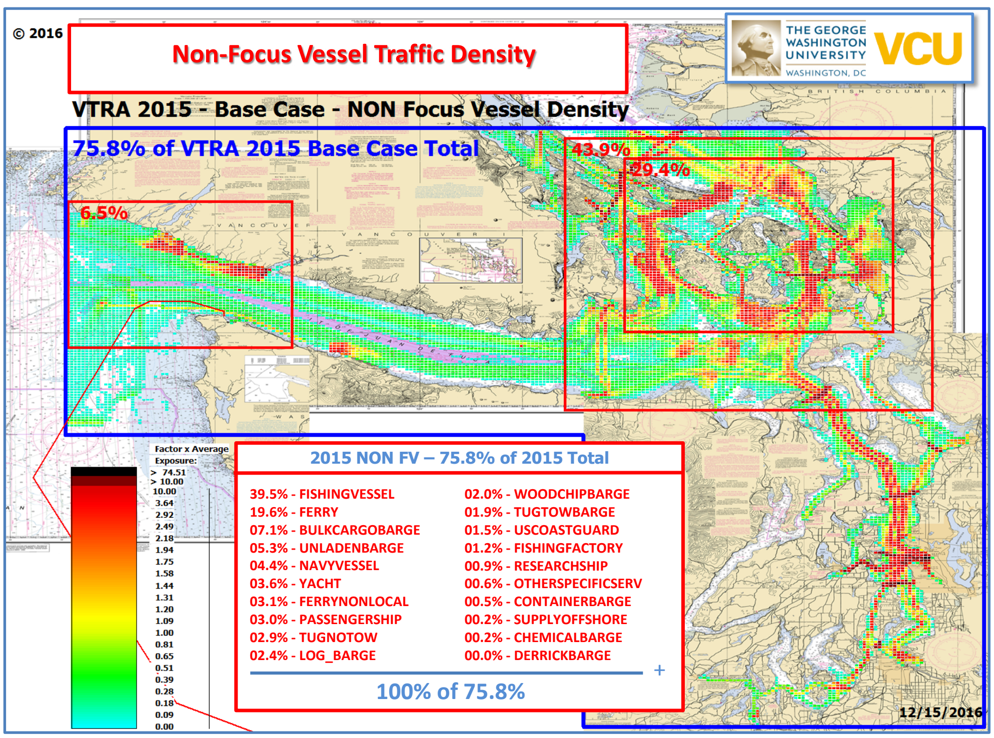

Figure E-4. 2D depiction of the traffic VTE for all non-focus vessel traffic modeled in the Base Case 2015 Scenario.

Totaling the VTE for tank focus vessels (oil barges – 19.2%, oil tanker – 8.0%, chemical carrier – 3.2%, ATB – 2.7%) we arrive at 33.1% in Figure E-3 of overall Base Case 2015 Scenario focus vessel VTE. Hence, about 19.2%/33.1% = 58.0% of the total tank focus vessel VTE is accounted for by oil barges that primarily travel within the VTRA Study Area in a north south direction and therefore many would not be captured as entrance counts to the Strait of Juan de Fuca. Totaling the VTE for cargo focus vessels in Figure E-3 we arrive at 66.9% of overall Base Case 2015 Scenario focus vessel VTE. Figure E-5 decomposes the VTE depicted in Figure E-3 into the VTE for cargo focus vessels @16.2% (Figure E-5A) of overall Base Case 2015 Scenario VTE and VTE for tank focus vessels @8.0% of overall Base Case 2015 Scenario VTE, together totaling the 24.2% of VTE depicted in Figure E-3.

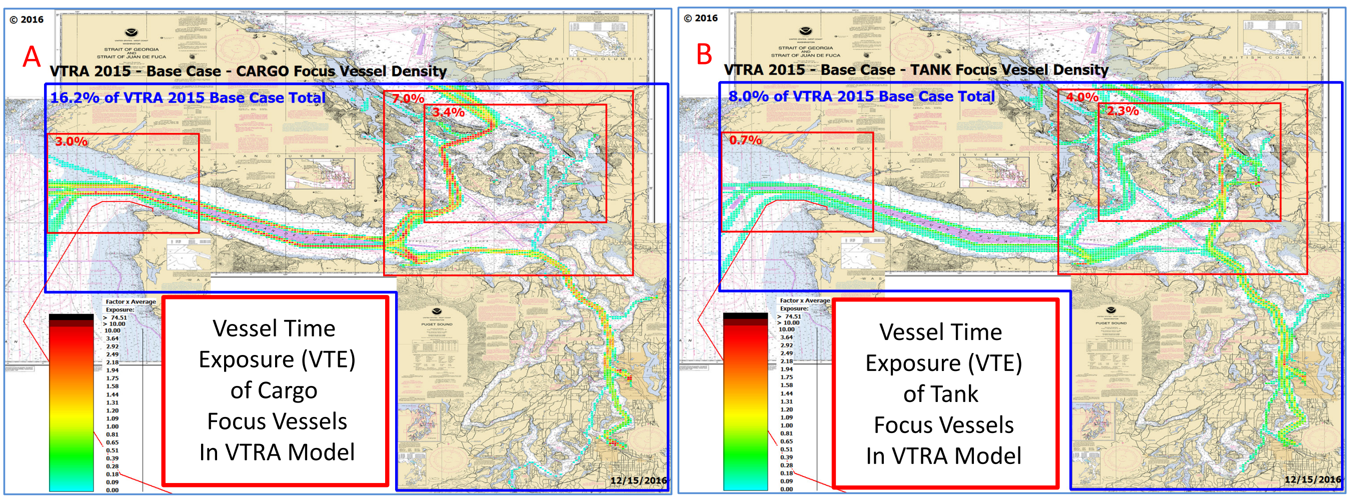

Figure E-5. 2D depiction of cargo focus vessel (A) and tank focus vessel (B) VTE components of Figure E-3 in the Base Case 2015 Scenario.

Analysis Observation 1: About 24.2% of the total modeled traffic time-on-the-water in the VTRA 2015 Model, called Vessel Time Exposure (VTE), is accounted for by focus vessels that are of primary interest within the VTRA 2015 Study. This 24.2% of Base Case 2015 Scenario VTE comprises of cargo focus vessels VTE (@16.2%) and tank focus vessels VTE (@8.0%). Thus, within the VTRA Study Area nearly a third of the total time that focus vessels are underway in the VTRA 2015 model is accounted for by focus vessels that carry oil products as cargo. The remaining about two thirds is attributed to focus vessels that carry other cargo (see Figure E-3 and Figure E-5).

Figure E-6 decomposes the VTE depicted for non-focus vessels modeled in the VTRA model depicted in Figure E-4 into four non-focus vessels VTE components being:

A. Fishing vessels and yachts (or recreational vessels) (@32.7% of Base Case 2015 Scenario VTE)
B. Ferry traffic (@17.2% of Base Case 2015 Scenario VTE)
C. Tug and tug tow barge traffic (excl. oil barges) (@17.0% of Base Case 2015 Scenario VTE)

D. Other non-focus vessel traffic (@8.9% of Base Case 2015 Scenario VTE)

When adding the 32.7%, 17.2%, 17.0% and 8.9% VTE's depicted in Figure E-6A, Figure E-6B, Figure E-6C and Figure E-6D one arrives at the 75.8% depicted in Figure E-4. While ferry traffic accounts for most of the transits handled by US Coast Guard Vessel Traffic Service (VTS) annually, one observes from Figure E-6B that their route length and location is relatively concentrated compared to the locations and distances that other non-focus vessels travel in the VTRA Study Area. Aside for vessel time exposure (VTE) accounting for those distances travelled and speed of the ferries in the VTRA Model, a large share of the VTE depicted in in Figure E-4 is accounted for by special events VTE depicted in Figure E-6A and that have been represented in the VTRA Model since the VTRA 2005 Study [12]. Special events in the VTRA Model involve movements of smaller vessels (less than 20 meters in length) that are not compelled to participate in the USCG VTS, such as whale watching activities, regatta events, and commercial and tribal (both Canadian and US) fishing openers. The darker regions in Figure E-6A depict the predominant locations of these special events in the VTRA model in terms of Base Case 2015 Scenario VTE.

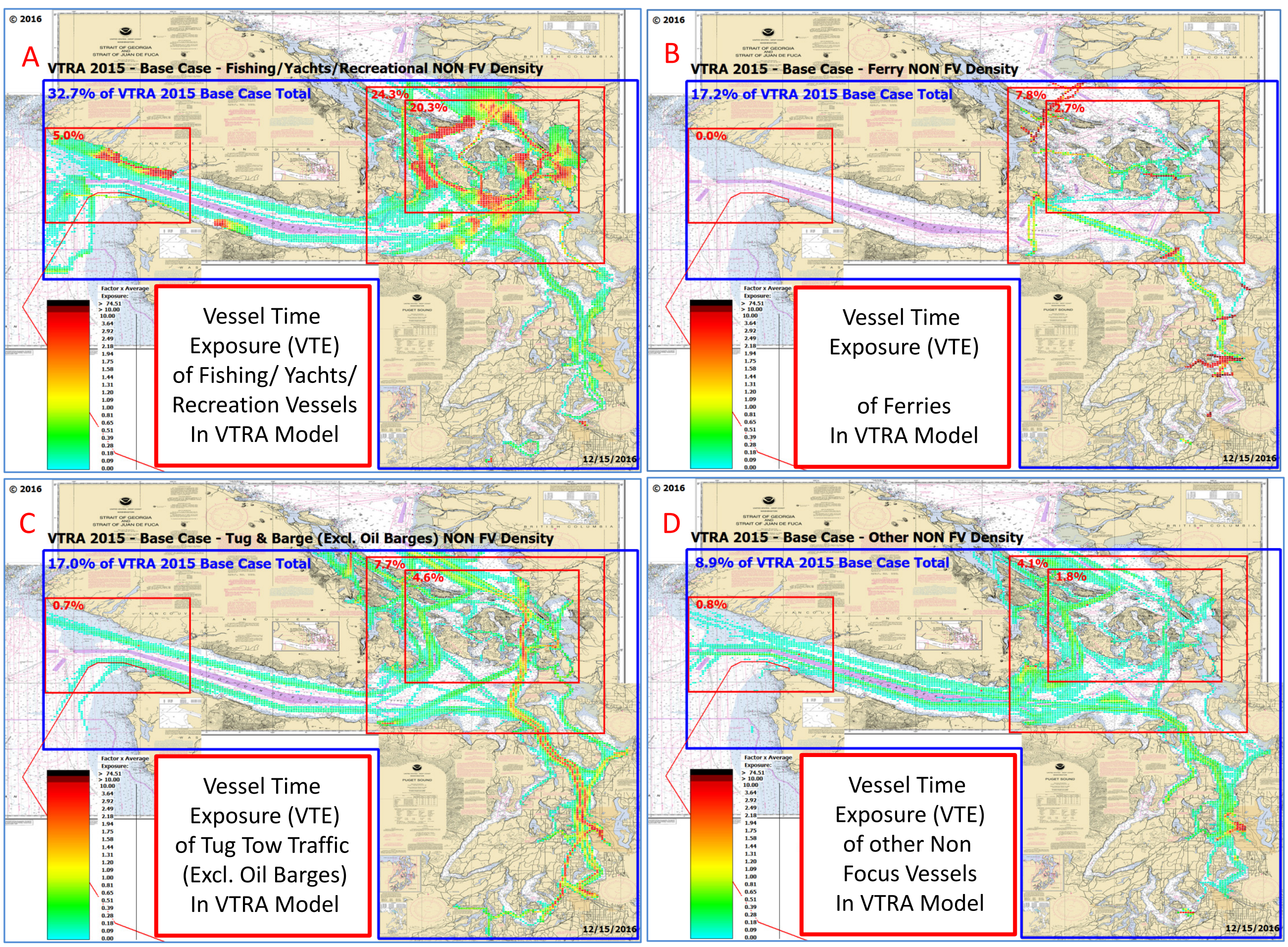

Figure E-6. 2D depiction of four Non-FV VTE Components of Figure E-4 in the Base Case 2015 Scenario.

Analysis Observation 2: About 75.8% of the total modeled traffic time on the water in the VTRA 2015 Model, called Vessel Time Exposure (VTE), is accounted for by non-focus vessel traffic that can potentially collide with focus-vessel traffic or contribute to potential grounding of focus vessels (See Figure E-4). This 75.8% of Base Case 2015 Scenario VTE comprises of movements of smaller vessels (less than 20 meters in length) VTE (@32.7%), ferries VTE (@17.2%), tug and tug-tow traffic (excl. oil barges) VTE (@17.0%) and other non-focus vessel VTE (@8.9%), see Figure E-6.

The VTRA 2015 analysis model represents the chain of events that could potentially lead to an oil spill and ends its evaluations with POTENTIAL volume of oil spilled in-the-water. Figure E-7 shows the accident causal chain.

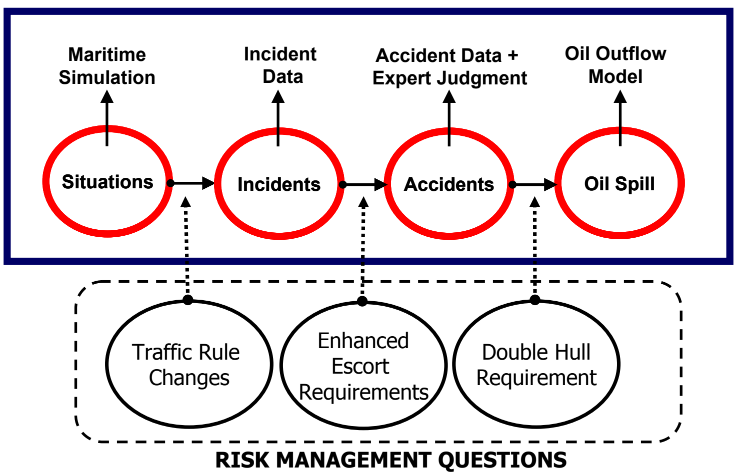

Figure E-7. A causal chain of events inter-connected by causal pathways. Risk management questions attempt to block these causal pathways.

A situation in which an accident could occur is called an accident exposure/situation. Maritime Transportation Systems (MTS) have accident exposures/situations simply from the movement of vessels within it. For each accident exposure, while the vessel is underway, incident and accident probability models are used to calculate the POTENTIAL Accident Frequency. This is not a prediction of an accident, but shows a relative propensity that an accident could occur in one situation versus another or the relative propensity for one type of accident versus another. The accident exposure and the potential accident frequency models are then combined with an oil outflow model to calculate potential oil loss. Throughout this report we shall use the terminology POTENTIAL to indicate that an accident exposure does not necessarily need to lead to an accident or oil loss, but may. As indicated by Figure E-7, the VTRA 2015 Analysis Tool does not evaluate the POTENTIAL fates and effects of a POTENTIAL Oil Loss beyond the POTENTIAL volume of oil spilled. That is, the VTRA Model's oil spill causal chain analysis ends with volume of POTENTIAL

Oil Loss in-the-water, should a POTENTIAL accident occur. The VTRA Oil Outflow model is described in [4] and modeled after the oil outflow model detailed in Special Report 259 [16] published by the Marine Board, Transportation Research Board of The National Academy of Sciences.

In terms of major oil spills over the past 25 years or so, defined as over 10,000 gallons ≈ 38 m^3 in the VTRA Study Area, the State of Washington and US Coast Guard records indicate one collision involving a fishing vessel and a cargo vessel spilling an estimated 361,000 gallons ≈ 1367 m^3 in 1991 near Cape Flattery and an oil barge grounding in 1994 near Anacortes on a transit from Vancouver, BC, resulting in an estimated 26,936 gallons ≈ 102 m^3 of diesel spilled. Even though this area has not experienced major oil spills in the past 20 years or so, the presence of tankers in an ever changing vessel traffic mix places the area at risk for large oil spills. While a previous GW/VCU analysis [3] of this area demonstrated significant risk reduction of oil transportation risk due to existing risk mitigation measures[5], the potential for large oil spills continues to be a prominent public concern heightened by proposed maritime terminal developments that are in various stages of their permitting processes.

Figure E-8 and Figure E-9 visualize graphically one of the VTRA 2015 analysis output formats in a manner that hopefully waterway users, regulators and the public can interpret. Figure E-8 and Figure E-9 are 3D visualizations of Base Case 2015 Scenario evaluated POTENTIAL Oil Loss within the VTRA Study Area and its geographic distribution. Figure E-8 depicts POTENTIAL Oil Loss for the Base Case 2015 Scenario (@100%), whereas Figure E-9 decomposes the POTENTIAL Oil Loss for the Base Case 2015 Scenario into POTENTIAL accidents with POTENTIAL Oil Loss in the following four categories:

A. 2500 m^3 or more POTENTIAL Oil Loss (@42% of Base Case POTENTIAL Oil Losses)
B. 1000 m^3 - 2500 m^3 POTENTIAL Oil Loss (@12% of Base Case POTENTIAL Oil Losses)
C. 1 m^3 - 1000 m^3 POTENTIAL Oil Loss (@45% of Base Case POTENTIAL Oil Losses)
D. 0 m^3 – 1 m^3 POTENTIAL OIL Loss (@0% of Base Case POTENTIAL Oil Losses)

The ability to separate POTENTIAL accidents by POTENTIAL Oil Loss category is a distinguishing feature of the VTRA 2015 study as compared to the VTRA 2010 and the VTRA 2005 studies. One observes from the Figure E-9 that the largest contributor to overall Base Case 2015 Scenario evaluated POTENTIAL Oil Loss is the 1 m^3 to 1000 m^3 POTENTIAL Oil Loss category and the second largest is the 2500 m^3 or more of POTENTIAL Oil Loss Category.

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[5] In [2] a 91.6% reduction in POTENTIAL oil loss was evaluated utilizing the VTRA 2005 model from all Tankers, Articulated Tug Barges (ATBs) and Integrated Tug Barges (ITBs) as a result of the implementation of the one-way zone regime in Rosario Strait, implementation of double hull tankers and the 2005 Escorting Regime.

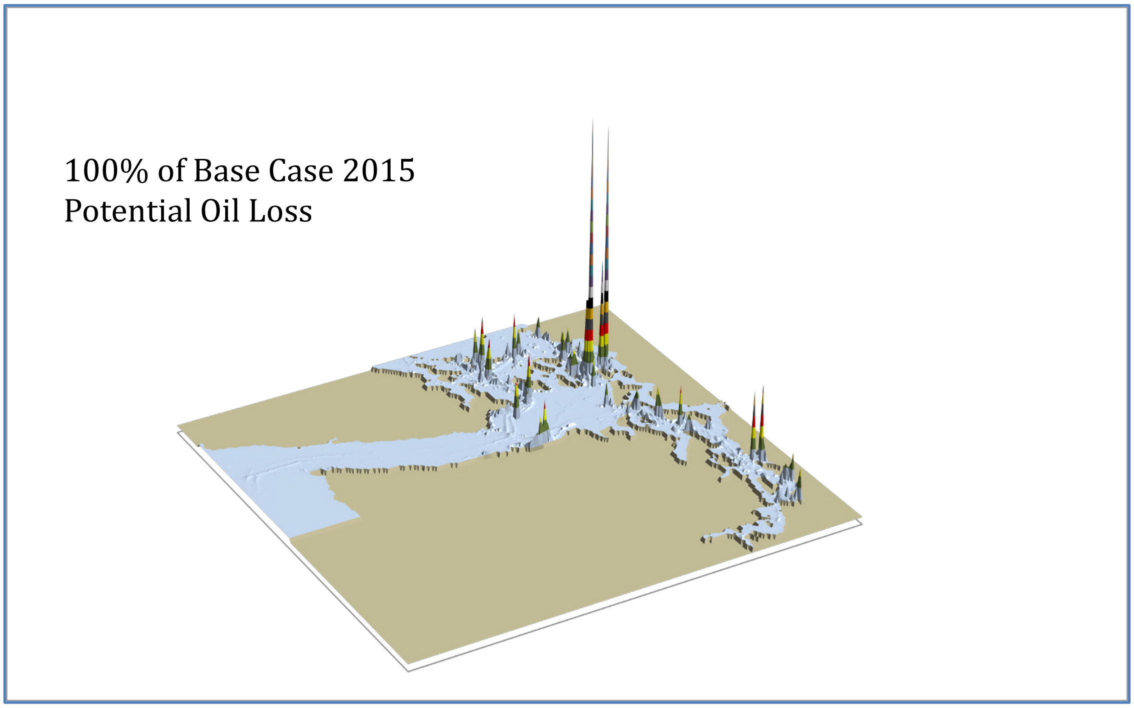

Figure E-8. 3D Geographic profile of Base Case 2015 Scenario POTENTIAL oil loss.

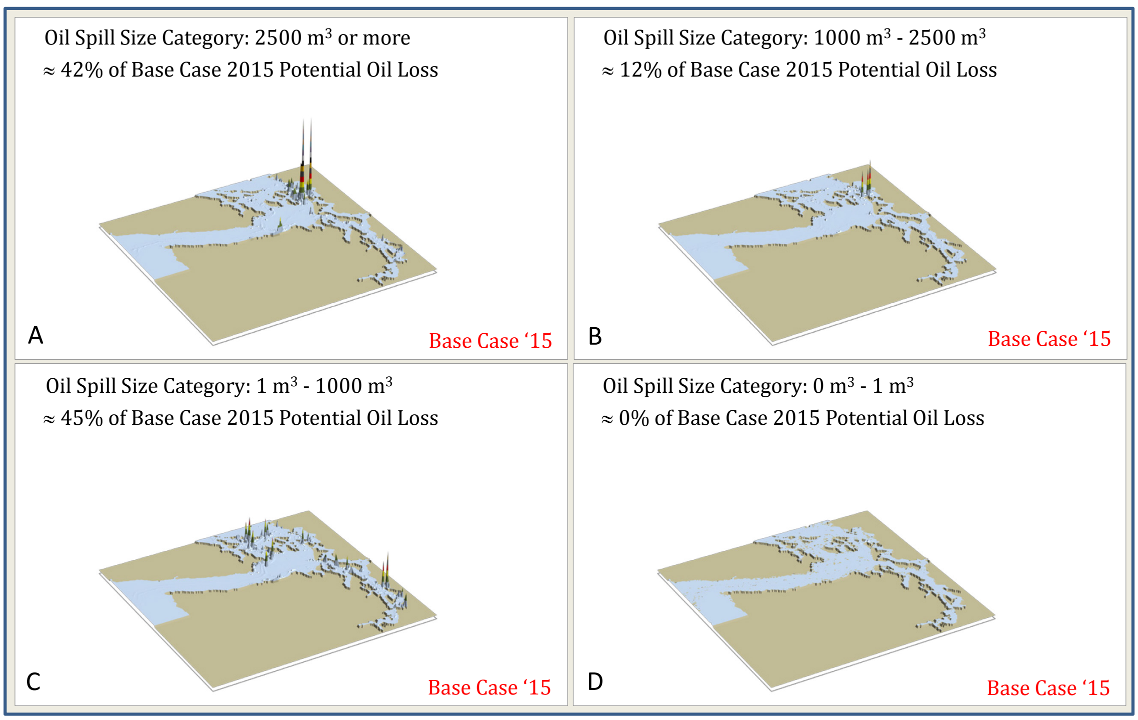

Figure E-9. Components of 3D Geographic profile of Base Case 2015 Scenario POTENTIAL oil loss. A: 42% in Oil Spill Size Category of 2500 m^3 or more; B: 12% in Oil Spill Size Category of 1000 m^3 -2500 m^3; C: 45% in Oil Spill Size Category of 1 m^3 -1000 m^3; D: 0% in Oil Spill Size Category of 0 m^3 -1 m^3.

Analysis Observation 3: Within the VTRA Study Area, the VTRA 2015 Model evaluates that the largest contributing POTENTIAL Oil Loss category is the 1 m^3 - 1000 m^3 POTENTIAL Oil Loss category @45% of Base Case 2015 Scenario POTENTIAL Oil Losses (see Figure E-8). The remainder is split between the 2500 m^3 or more of POTENTIAL Oil Loss Category (@42%), the 1000 m^3 - 2500 m^3 POTENTIAL Oil Loss Category (@12%) and the 0 m^3 – 1 m^3 POTENTIAL Oil Loss category (@0%).

In contrast, 98.2% of the POTENTIAL Accident Frequency evaluated by the VTRA 2015 model for the Base Case 2015 Scenario is accounted for by the 0 m^3 – 1 m^3 POTENTIAL Oil Loss category of which its contribution to Base Case 2015 Scenario POTENTIAL Oil Loss is about 0%. The remaining 1.79% of POTENTIAL Accident Frequency is split over the other three POTENTIAL Oil Loss categories above 1 m^3, with 1.76% in POTENTIAL Accident Frequency attributable to the 1 m^3 - 1000 m^3 POTENTIAL Oil Loss category.

It is important to note in this context that overall the Base Case 2015 Scenario was calibrated to about 4.4 accidents per year evaluated using available accident data to the VTRA 2015 study from 1990 – 2015 and provided in Appendix B. The Base Case 2015 Scenario accident frequency was calibrated separately to (1) the number of accidents available to the VTRA 2015 study over the time period 1995-2015 falling in the 0 m^3 – 1 m^3 oil loss category within the VTRA Study area and (2) two accidents available over the time period 1990-2015 falling in the oil loss category of above 1 m^3 within the VTRA Study area, one involving a cargo focus vessel and the other involving a tank focus vessel. Specifically, and using this available accident data to the VTRA 2015 study from 1990 – 2015, the Base Case 2015 Scenario was calibrated to nine accident frequency calibration points for spills within the spill size category 0 m^3 -1 m^3, and one accident frequency calibration point for spills within the spill size category of 1 m^3 and above. For spills between 0 m^3 -1 m^3, these nine calibration points represent the number of accidents per year for cargo focus vessels, tank focus vessels (excluding oil barges), and oil barges and by the accident type (allisions, groundings, and collisions)[6]. Adding these nine calibration points in the 0 m^3 -1 m^3 spill size category one arrives at a total number of accidents per year in this spill size category of close to 4.31, of which 2.96 are cargo focus vessel accidents, 0.34 are tank focus vessel (excluding oil barges) accidents, and 1.00 accident per year is from oil barges. In addition, the 2015 Base Case scenario is calibrated to an additional $2/26 \approx 0.08$ accidents per year of spills greater than 1 m^3 across all focus vessel categories. Thus in total, one arrives at 4.39 accidents per year for all spill sizes from available accident data to the VTRA 2015 study from 1990 – 2015. Comparing the average number of accidents per year in these two spill size categories, one evaluates about 98.2% (4.31/4.39) of accidents per year in the 0 m^3 -1 m^3 spill size category, and about 1.8% (0.08/4.39) of accidents per year in the spill size category larger than 1 m^3. Hence, these percentages are consistent with

[6] The specific accident frequency calibration points are provided in Figure 2-6 and Figure 2-7. See the discussion on pages 59-67 in Chapter 2 of this report.

the POTENTIAL Accident Frequency percent contributions evaluated in the Base Case 2015 Scenario above for the 0 m^3 -1 m^3 POTENTIAL Oil Loss category (@98.2%) and for the POTENTIAL Accident Frequency of POTENTIAL spill sizes larger than 1 m^3 (@1.8%).

Analysis Observation 4: About 98.2% of the POTENTIAL Accident Frequency evaluated by the VTRA 2015 model in the Base Case 2015 Scenario is accounted for by the 0 m^3 – 1 m^3 category of which its contribution to Base Case 2015 Scenario POTENTIAL Oil Loss is about 0%. The remaining 1.8% of POTENTIAL Accident Frequency is split over the other three VTRA POTENTIAL Oil Loss categories 1 m^3 - 1000 m^3, 1000 m^3 -2500 m^3 and 2500 m^3 or more. Overall the Base Case 2015 Scenario was calibrated to about 4.4 accidents per year.

These percentages highlight the dichotomy and challenges for risk management of POTENTIAL Oil Loss, i.e. the objective of both (1) the prevention of accidents with lower POTENTIAL accident frequencies but higher POTENTIAL consequences and (2) the prevention of accidents with higher POTENTIAL accident frequencies but lesser POTENTIAL consequences. Needless to say, one's focus ought to be on the prevention of all POTENTIAL accidents. The information about their contribution to POTENTIAL consequences in terms of POTENTIAL Oil Loss categories, however, may be useful in the selection of a portfolio of risk mitigations that attempts to address all POTENTIAL Oil Loss categories.

What-If Scenario Results

Informed by Vessel Time Exposure (VTE), the VTRA 2015 analysis tool evaluates POTENTIAL Accident Frequency and POTENTIAL Oil Loss for tank focus vessels (tankers, chemical carriers, articulated tug barges and oil barges) and cargo focus vessels (bulk carriers, container ships and other cargo vessels). The Base Case 2015 Scenario analysis serves as a reference point to evaluate potential relative risk changes due to selected maritime terminal developments grouped in What-If Scenarios. Each What-If Scenario involves adding cargo focus vessels and tank focus vessels to the VTRA 2015 model. Subsequently, the model evaluates potential risk changes in terms of POTENTIAL Vessel Time Exposure, POTENTIAL Accident Frequency and POTENTIAL Oil Loss for the VTRA Study Area as a whole and by the fifteen VTRA waterway zones depicted in Figure E-2. Utilizing the VTRA 2015 Model, the following five What-If Scenarios were modeled in this study and evaluated for POTENTIAL risk increases from the Base Case 2015 Scenario:

(1) **US232:** A collection of terminal projects adding an estimated 232 focus vessels (32 tankers, 197 ATBs and 3 bulk carriers) to the VTRA 2015 modeled Base Case 2015 Scenario traffic with these 232 focus vessels travelling predominantly through US Waters.
(2) **KM348:** The Westridge Marine Terminal/Kinder Morgan pipeline expansion project adding an estimated 348 tankers to the VTRA 2015 modeled Base Case 2015 Scenario traffic with these 348 focus vessels travelling predominantly through Canadian (CA) Waters.

(3) **CA1020:** A collection of terminal projects adding an estimated 1020 focus vessels (629 bulk carriers, 368 container ships and 23 tankers) to the VTRA 2015 modeled Base Case 2015 Scenario traffic with these 1020 focus vessels travelling predominantly through Canadian (CA) Waters.

(4) **USKMCA1600:** The combination of US232, KM348 and CA1020 What-If Scenarios (632 bulk carriers, 368 container ships, 403 tankers and 197 ATBs) while these 1600 focus vessels travel through US and Canadian (CA) Waters.

(5) **USKMCALN2250:** The combination of the USKMCA1600 What-If Scenario (632 bulk carriers, 368 container ships, 403 tankers and 197 ATBs) with a collection of terminal projects adding an additional estimated 650 LNG vessels to the VTRA 2015 modeled Base Case 2015 Scenario traffic with these 2250 focus vessels travelling through US and Canadian (CA) Waters. **The VTRA 2015 Model, however, does not contain a model for the potential consequences of an accident with an LNG Tanker. Thus, LNG Tankers for the purposes of the VTRA 2015 study are minimally modeled for traffic impact as cargo focus vessels only. Hence, risk metrics evaluated for the USKMCALN2250 What-If Scenario ought to be considered lower bounds of those risk metrics.**

Bunkering support for the various terminal projects was also modeled in the VTRA 2015 What-If Scenarios. Specifically, 49, 17, 111, 177 and 207 oil barge bunker trips were added as part of the US232, KM348, CA1020, USKMCA1600 and USKMCALN2250 What-If Scenario definitions. Thus the number at the end of each What-If Scenario descriptor/name reflects the total number of focus vessels that are added to the Base Case 2015 Scenario while excluding from that number in the What-If Scenario name the number of bunkering support transits modeled for those What-If Scenarios. Or, in other words, the total number of focus vessels added to the Base Case 2015 Scenario is higher than the ending number of the What-If Scenario name, since oil barges are part of the focus vessel group.

Four of the five above What-if Scenarios were compiled by the VTRA 2015 Working Group from their selected maritime development projects[7], specifically the US232, KM348, USKMCA1600 and USKMLN2250 What-If Scenarios above. The CA1020 What-If Scenario analysis is included in this report by GW/VCU since the US232, KM348 and the CA1020 What-If Scenarios together combine to form the USKMCA1600 What-If Scenario. It is worthwhile to note that there is about a 10-fold difference or more in the number of tankers and ATBs that are being added to Base Case 2015 Scenario for the US232 (32 tankers and 197 ATBs) and KM348 (348 tankers) What-if Scenarios, on the one hand, and the CA1020 What-If Scenarios (23 tankers), on the other hand. That being said, the CA1020 What-If Scenario adds about 997 cargo focus vessels, whereas the KM348 What-If Scenario adds no cargo focus vessels and the US232 scenario only adds 3 cargo focus vessels.

[7] A list of maritime terminal projects is included in the main body of the report.

Summarizing, the portfolio of focus vessels added to the Base Case 2015 Scenario for the What-if Scenario CA1020 is quite different from the portfolio of focus vessels added to the Base Case 2015 Scenario for the US232 and the KM348 What-If Scenarios. Moreover, the CA1020 What-If Scenario adds about 4.4 times (=1020/232) as many focus vessels as the US232 What-if Scenario, not including the added bunkering operations in this 4.4 factor, and about 2.9 times (=1020/348) as many focus vessels as the KM348 What-If Scenario, not including the added bunkering operations in this 2.9 factor.

Analysis Observation 5: There is about a 10-fold difference or more in the number of tankers and ATBs that are being added to Base Case 2015 Scenario for the US232 (32 tankers and 197 ATBs) and KM348 (348 tankers) What-if Scenarios, on the one hand, and the CA1020 What-If Scenarios (23 tankers), on the other hand. That being said, the CA1020 What-If Scenario adds about 997 cargo focus vessels to the Base Case 2015 Scenario, whereas the US232 scenario only adds 3 bulk carriers and the KM348 What-If Scenario adds no cargo focus vessels. The USKMCA1600 What-If Scenario combines the US232, KM348 and CA1020 What-If Scenarios.

Figure E-10 depicts POTENTIAL Oil Loss evaluated for the USKMCA1600 What-If Scenario (the combination of the above US232, KM348 and CA1020 What-If Scenarios). Similar figures as Figure E-10 are included for the other What-If Scenarios in the main body of this report.

Figure E-10 illustrates an estimated 1.85 relative increase in overall POTENTIAL Oil Loss compared to the Base Case 2015 Scenario without additional risk mitigation. This too demonstrates that the VTRA 2015 study concentrates more on relative comparisons between What-If scenarios or between POTENTIAL Oil Loss categories and less on the absolute values of their respective analysis results. Figure E-11 decomposes the overall POTENTIAL Oil Loss for the combined What-If Scenario USKMCA1600 into POTENTIAL accidents across four POTENTIAL Oil Loss categories considered in the VTRA 2015 analysis model, i.e. those with:

A. 2500 m^3 or more POTENTIAL Oil Loss (@91% of Base Case POTENTIAL Oil Losses)
B. 1000 m^3 - 2500 m^3 POTENTIAL Oil Loss (@21% of Base Case POTENTIAL Oil Losses)
C. 1 m^3 - 1000 m^3 POTENTIAL Oil Loss (@73% of Base Case POTENTIAL Oil Losses)
D. 0 m^3 – 1 m^3 POTENTIAL OIL Loss (@1% of Base Case POTENTIAL Oil Losses)

Hence, in contrast to the Base Case 2015 Scenario analysis results, the 2500 m^3 or more POTENTIAL Oil Loss category is now the largest contributor to overall POTENTIAL Oil loss (@91%) increased by a multiplicative factor of 2.17 (= 91%/42%) and now the second largest contributor to overall POTENTIAL Oil Loss is the category 1 m^3 - 1000 m^3 (@73%) instead, increased by a multiplicative factor of 1.61 (= 73%/45%). These three different multiplicative factors, i.e. 1.85 for the Total POTENTIAL Oil Loss for the entire VTRA Study Area, 2.17 for the POTENTIAL Oil Loss Category 2500 m^3 or more and 1.61 for the POTENTIAL Oil loss category 1 m^3 - 1000 m^3, demonstrate that POTENTIAL Oil Loss risk does not increase uniformly (i.e. by the

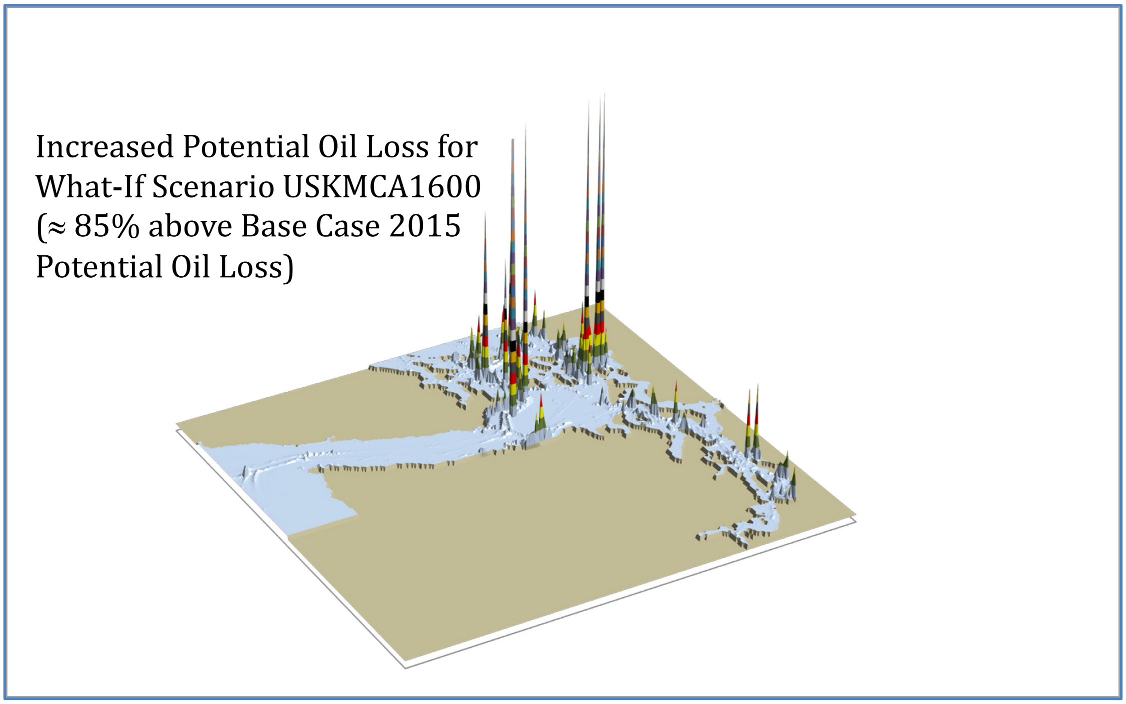

Figure E-10. 3D Geographic Profile of USKMCA1600 What-If Scenario POTENTIAL Oil Loss.

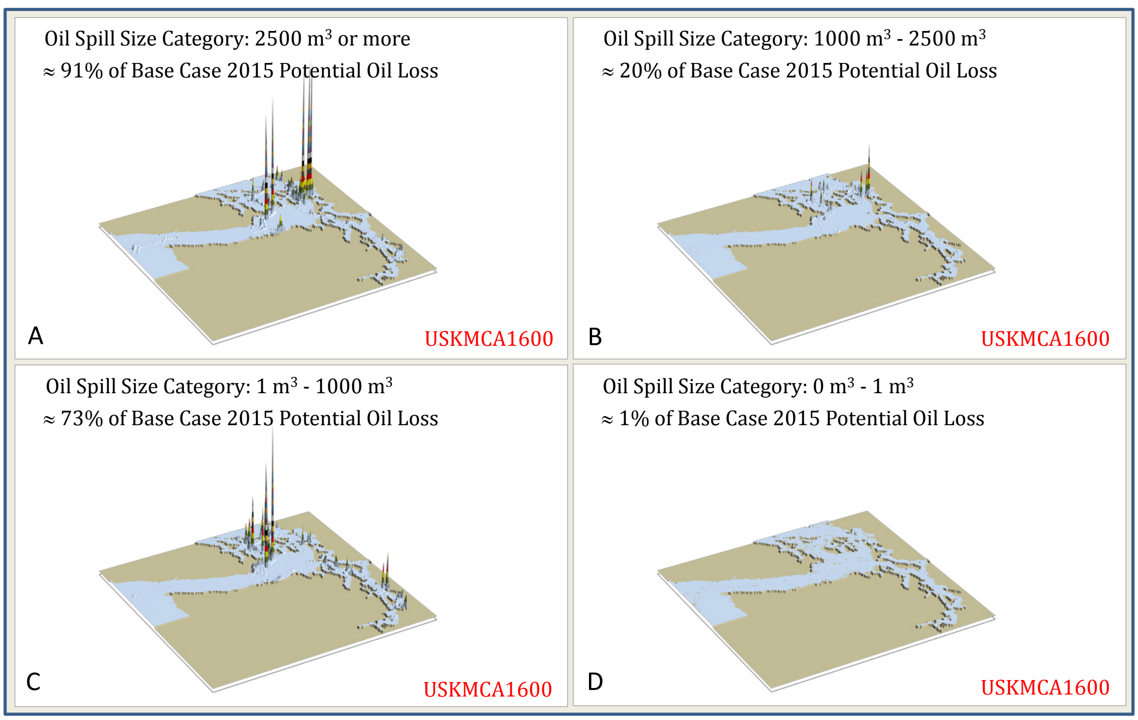

Figure E-11. Components of 3D Geographic Profile of What-If USKMCA1600 Scenario POTENTIAL Oil Loss. A: 91% in Oil Spill Size Category of 2500 m^3 or more; B: 20% in Oil Spill Size Category of 1000 m^3 -2500 m^3; C: 73% in Oil Spill Size Category of 1 m^3 -1000 m^3; D: 1% in Oil Spill Size Category of 0 m^3 -1 m^3

same relative factor) across the four POTENTIAL Oil Loss categories above, should all terminal projects in the USKMCA1600 Scenario come to fruition.

Analysis Observation 6: Should the maritime terminal projects in a What-If Scenario come to fruition POTENTIAL Oil Loss risk does not change by the same relative factor across the four POTENTIAL Oil Loss categories: 2500 m³ or more, 1000 m³ - 2500 m³, 1 m³ - 1000 m³ or 0 m³ – 1 m³. While for the USKMCA1600 Scenario a relative factor 1.85 increase is evaluated in terms of Base Case 2015 Scenario POTENTIAL Oil Loss across the VTRA 2015 Study Area, relative factor increases 2.17, 1.61 and 1.56 were evaluated within the 2500 m³ or more, the 1 m³ - 1000 m³ and the 1000 m³ - 2500 m³ POTENTIAL Oil Loss categories.

Figure E-12 depicts a by-waterway-zone comparison of POTENTIAL Oil Loss evaluated for the USKMCA1600 What-If Scenario to those evaluated for the Base Case 2015 Scenario.

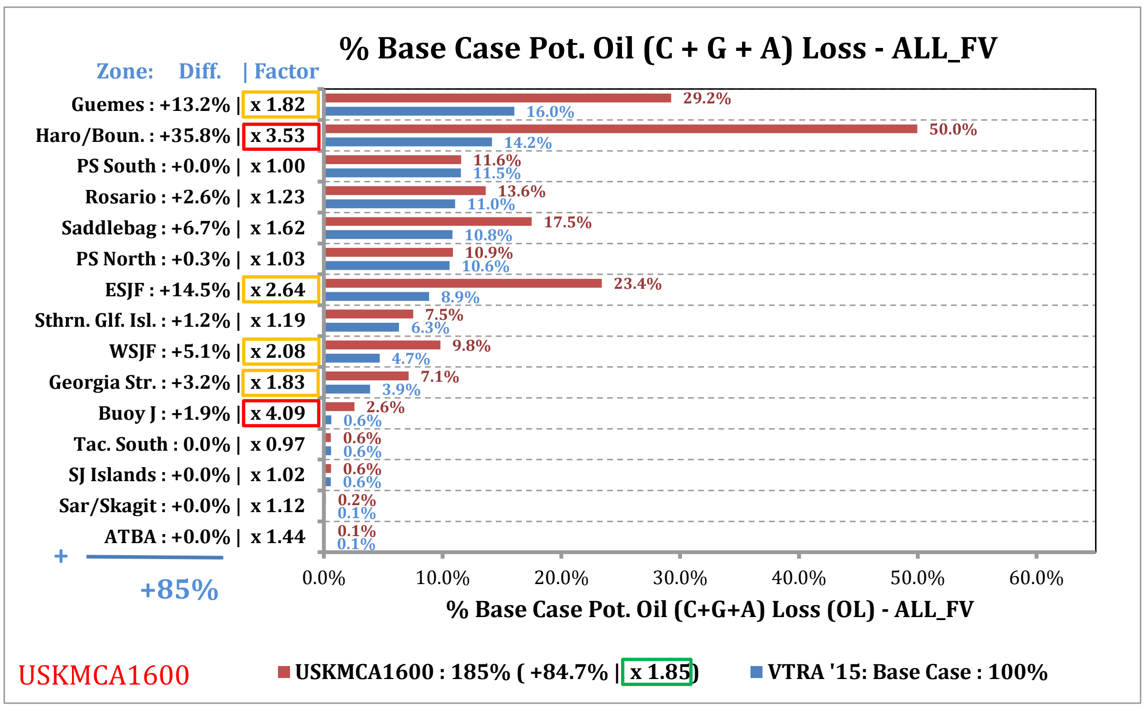

Figure E-12. Relative comparison of POTENTIAL Oil Loss by-waterway-zone. Blue bars show the percentage by waterway zone for the Base Case 2015 scenario, red bars show the percentage for What-If Scenario USKMCA1600 in terms of base case percentages. Absolute differences by waterway zone and relative multipliers by waterway zone are provided in the y-axis labels.

Similar to the POTENTIAL Oil Loss Categories themselves, one observes from Figure E-12 that POTENTIAL Oil Loss by-waterway-zone does not increase by the same relative factors across the fifteen waterway zones depicted in Figure E-2, should all terminal projects in the USKMCA1600 Scenario come to fruition. Figure E-12 shows that while system-wide POTENTIAL Oil Loss increases by about +85% (i.e. by about the evaluated relative factor 1.85 for the VTRA study area) in the USKMCA1600 What-If Scenario (green highlight in Figure E-12), larger relative factors are observed for the following specific waterway zones[8] (orange and red highlights in Figure E-12):

- Buoy J (× 4.09)
- Haro-Strait/Boundary Pass (× 3.53)
- East Strait of Juan de Fuca (× 2.64)
- West Strait of Juan de Fuca (× 2.08)
- Georgia Strait (× 1.83)
- Guemes (× 1.82)

Thus the waterway zones above experience a relative factor increase in POTENTIAL Oil Loss that is about the same or higher than the relative factor increase in POTENTIAL Oil Loss 1.85 for the entire VTRA Study Area, should all the terminal projects in the USKMCA1600 What-If Scenario come to fruition.

Analysis Observation 7: The Buoy J and Haro-Strait/Boundary Pass waterway zone specific increases in POTENTIAL Oil Loss was evaluated to be larger than a relative multiplier 3.5 (red highlights in Figure E-12), should all maritime terminal developments in the What-If Scenario USKMCA1600 come to fruition.

Similar to making a by-waterway-zone comparison in terms of overall POTENTIAL Oil Loss, such by-waterway-zone comparisons can also be made within a POTENTIAL Oil Loss Category. In the VTRA 2015 study those by-waterway-zone comparisons are made in terms of what is called an absolute risk metric not utilized in the prior VTRA 2005 and VTRA 2010 studies, specifically *the estimated probability of one or more accidents potentially occurring over a 10-year period per potential oil loss category*. The evaluation of these probability risk metrics is also a distinguishing feature of the VTRA 2015 study compared to the VTRA 2010 and VTRA 2005 studies. These probability risk metrics relate directly to their evaluated POTENTIAL accident frequencies and the length of the time period over which these probabilities are estimated[9]. Both the probability of at least one accident per a period of time, on the one hand, and the POTENTIAL accident frequency per year, on the other hand, are considered absolute risk metrics. That being said, the evaluation of the probability risk metrics demonstrate through the wording “probability” that however small the POTENTIAL accident frequency may be for a particular POTENTIAL Oil Loss category, non-zero probabilities evaluated using the VTRA 2015 Model supports that the occurrence of these POTENTIAL events evaluated is not impossible and could in fact happen, however unlikely. The communication of such probability metrics per a specified period of time is advocated in [26]. As stated earlier, however, the VTRA 2015 Study concentrates more on relative comparisons

[8] See Figure E-2 for the geographical depiction of these waterway zones in the VTRA 2015 Model.

[9] These estimated probabilities $\hat{p}$ have a direct relationship $\hat{p}(\hat{f}|t) = 1 - e^{-\hat{f}\times t}$ to their estimated annual POTENTIAL accident frequencies $\hat{f}$, where t equals the length of the time period. Thus $\hat{p}(\hat{f}|t)$ increases when the length of the time period t increases and for a large enough POTENTIAL accident frequency $\hat{f}$ and a long enough time period t, $\hat{p}(\hat{f}|t)$ can mathematically attain an estimated value of 1.

between risk metrics evaluated for the five What-If scenarios and the Base Case 2015 Scenario and less on the absolute values of their respective analysis results.

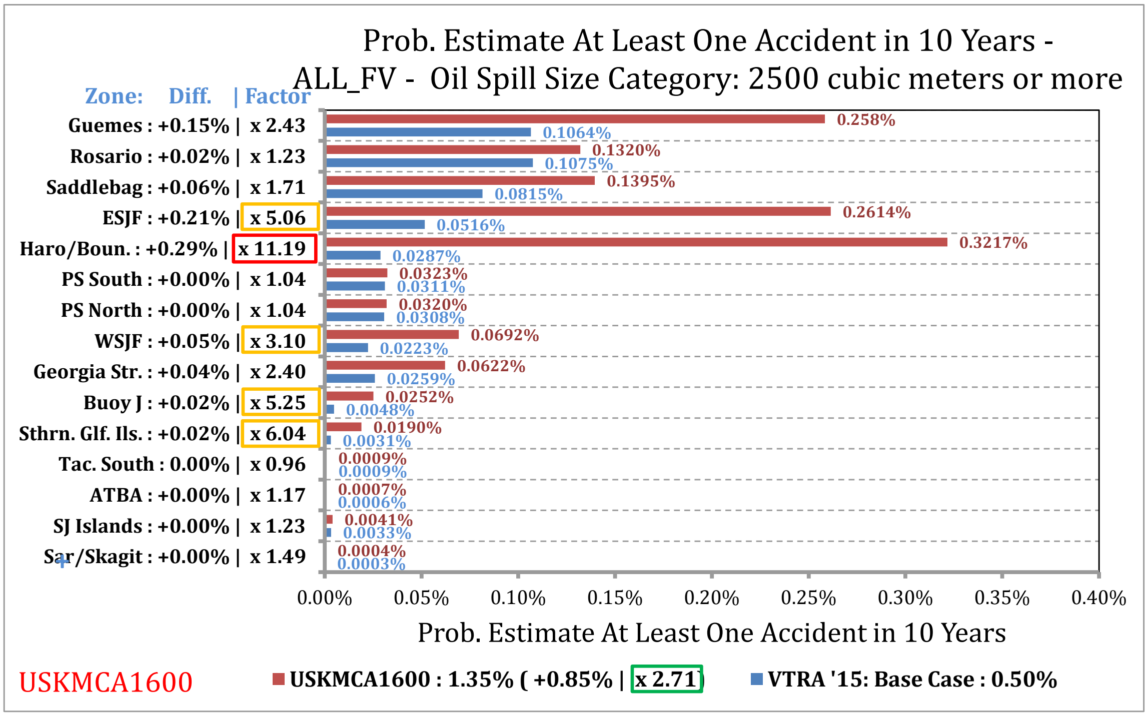

Figure E-13. Relative comparison of the probability of one or more accidents within 10-year period in the Oil Spill Size category 2500 m³ or more by waterway zone. Blue bars show these probabilities by waterway zone for the Base Case 2015 scenario, red bars show these probabilities for What-If Scenario USKMCA1600 in terms of base case percentages. Absolute differences by waterway zone and relative multipliers by waterway zone are provided in the y-axis labels.

These probability risk metrics per a specific period of time, as defined above, are also evaluated for the VTRA Study Area as a whole by POTENTIAL Oil Loss category. For the Base Case 2015 Scenario, a 0.50% probability is estimated for the POTENTIAL occurrence of at least one accident in the VTRA Study Area over a 10-year period within the POTENTIAL Oil Loss category 2500 m^3 or more. For the USKMCA1600 What-If Scenario this estimated probability increases to 1.35%, a relative factor 1.35%/0.50% ≈ 2.71 increase. Figure E-13 above demonstrates that while system-wide the estimated probability of at least one accident over a 10-year time period within the POTENTIAL Oil Loss category 2500 m^3 or more increases by this relative factor 2.71 (green highlight in Figure E-13) in the USKMCA1600 What-If Scenario, larger relative factors are observed for the following specific waterway zones (orange and red highlights in Figure E-13):

- Haro-Strait/Boundary Pass (× 11.19)
- Southern Gulf Islands (× 6.04)
- Buoy J (× 5.25)
- East Strait of Juan de Fuca (× 5.06)
- West Strait of Juan de Fuca (× 3.10)

Analysis Observation 8: The estimated probability of one or more accidents in the VTRA Study Area over a 10-year period within the POTENTIAL Oil loss category 2500 m³ or more increased from an estimated 0.50% for the Base Case 2015 Scenario to an estimated 1.35% for the USKMCA1600 What-if Scenario (i.e. an increase by a relative factor of 2.71, green highlight in Figure E-13). For the Haro-Strait/Boundary Pass waterway zone its estimated probability of one or more accidents in the VTRA Study Area over a 10-year period within the POTENTIAL Oil loss category 2500 m³ or more was evaluated to increase by a relative multiplier larger than a factor 11.0 (red highlight in Figure E-13), should all maritime terminal developments in the What-If Scenario USKMCA1600 come to fruition.

In Figure E-14 below, the by-waterway-zone comparison of the estimated probability of at least one accident within a 10-year time period in the POTENTIAL Oil Loss category 1000 m³ - 2500 m³ is provided.

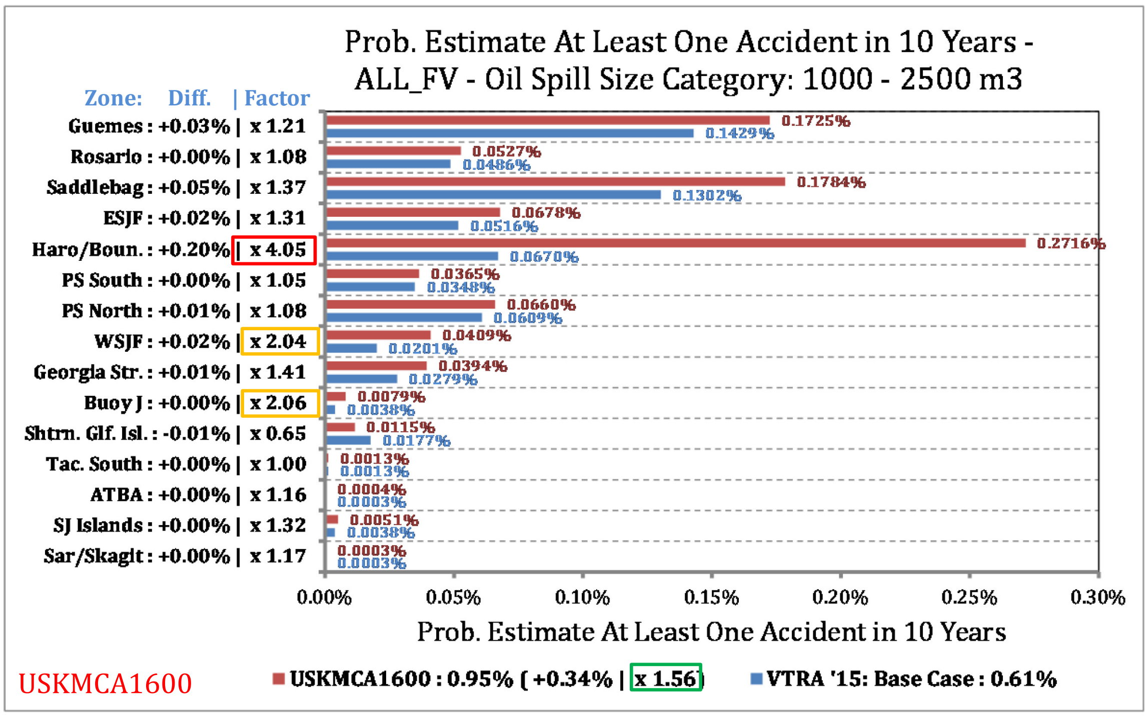

Figure E-14. Relative comparison of the probability of one or more accidents within 10-year period in the Oil Spill Size category 1000 m³ - 2500 m³ by waterway zone. Blue bars show these probabilities by waterway zone for the Base Case 2015 scenario, red bars show these probabilities for What-If Scenario USKMCA1600 in terms of base case percentages. Absolute differences by waterway zone and relative multipliers by waterway zone are provided in the y-axis labels.

While the relative multiplier 1.56 (green highlight in Figure E-14) for this probability is smaller than the relative multiplier (2.71) for the 2500 m³ or more category in Figure E-13, the probability for an accident of this type over a 10-year period is estimated at 0.61% for the Base Case 2015 Scenario. Recall from Figure E-11 that the 1000 m³ - 2500 m³ POTENTIAL Oil Loss category was estimated to contribute about 12% to the overall 2015 POTENTIAL Oil Loss evaluated for the Base

Case 2015 Scenario. Figure E-14 demonstrates that while system-wide the estimated probability of one or more accidents over a 10-year period within the POTENTIAL Oil Loss category 1000 m^3 - 2500 m^3 increases by this relative factor 1.56 (green highlight in Figure E-14) in the USKMCA1600 What-If Scenario, larger relative factors are observed for the following specific waterway zones (orange and red highlights in Figure E-14) for this particular POTENTIAL Oil Loss category:

- Haro-Strait/Boundary Pass (× 4.05)
- Buoy J (× 2.06)
- West Strait of Juan de Fuca (× 2.04)

Analysis Observation 9: The estimated probability of one or more accidents in the VTRA Study Area over 10-year period within the 1000 m^3 - 2500 m^3 POTENTIAL Oil Loss category increased from an estimated 0.61% for the Base Case 2015 Scenario to an estimated 0.96% for the USKMCA1600 What-if Scenario (i.e. an increase by a relative factor of 1.56). For the waterway zone Haro-Strait/Boundary Pass its estimated probability of one or more accidents in the VTRA Study Area over 10-year period within the 1000 m^3 - 2500 m^3 POTENTIAL Oil Loss category increased by a relative multiplier larger than 4.0 (red highlight in Figure E-14), should all maritime terminal developments in the What-If Scenario USKMCA1600 come to fruition.

In Figure E-15, the by-waterway-zone comparison of the probability of one or more accidents within a 10-year period in the 1 m^3 - 1000 m^3 POTENTIAL Oil Loss category is provided. While the relative multiplier 1.06 (green highlight in Figure E-15) for this probability is smaller than the relative multiplier (2.71) for the 2500 m^3 or more category in Figure E-13, the probability for an accident of this type in the VTRA Study area over a 10-year period is estimated at 54.2% for the Base Case 2015 Scenario[10].

Recall from Figure E-11 that the 1 m^3 - 1000 m^3 POTENTIAL Oil Loss category was evaluated to contribute the most (45%) to overall POTENTIAL Oil Loss evaluated for the Base Case 2015 Scenario. Figure E-15 demonstrates that while system-wide the probability of one or more accidents over a 10-year period within the POTENTIAL Oil Loss category 1 m^3 – 1000 m^3 increases by this factor 1.06 (green highlight in Figure E-15) in the USKMCA1600 What-If Scenario, larger relative factors are observed for the following specific waterway zones (orange and red highlights in Figure E-15) for this particular POTENTIAL Oil Loss category:

- Buoy J (× 1.64)
- Haro-Strait/Boundary Pass (× 1.50)
- East Strait of Juan de Fuca (× 1.39)
- West Strait of Juan de Fuca (× 1.23)
- Guemes (× 1.16)

[10] A probability of 50% is typically assigned to the probability of heads or tails in a coin toss experiment.

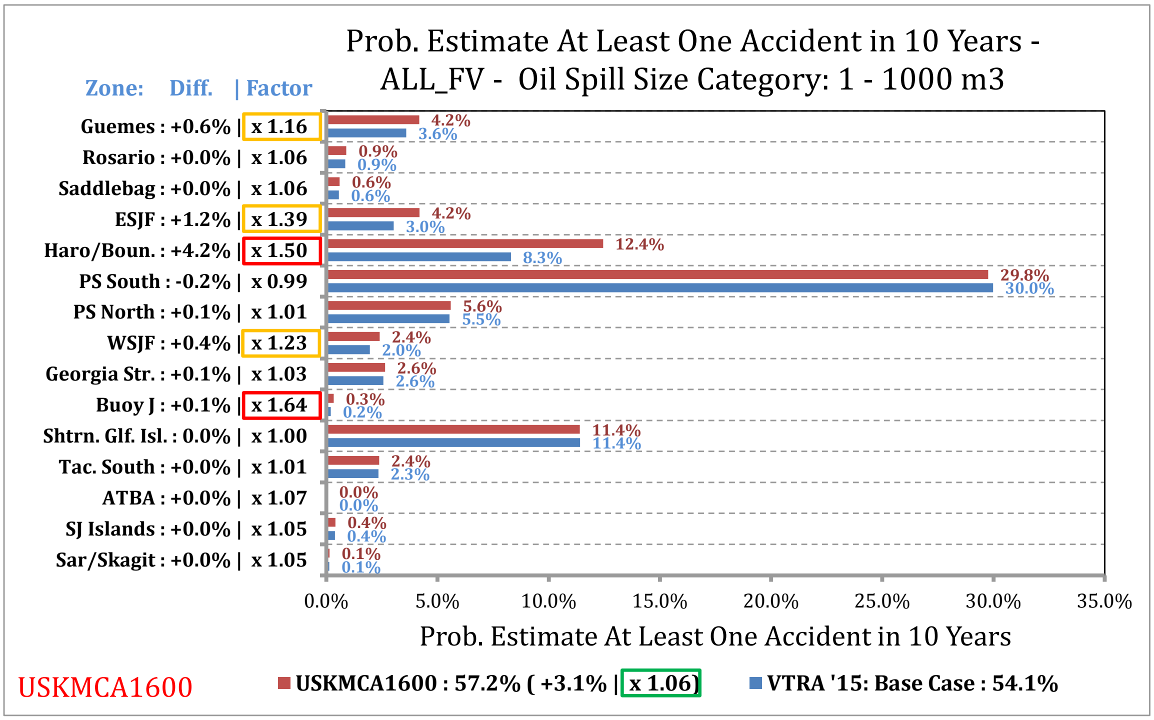

Figure E-15. Relative comparison of the probability of one or more accidents within a 10-year period in the Oil Spill Size category 1 m³ - 1000 m³ by waterway zone. Blue bars show these probabilities by waterway zone for the Base Case 2015 scenario, red bars show these probabilities for What-If Scenario USKMCA1600 in terms of base case percentages. Absolute differences by waterway zone and relative multipliers by waterway zone are provided in the y-axis labels.

Analysis Observation 10: The estimated probability of one or more accidents in the VTRA Study Area over a 10-year period within the loss category 1 m³ - 1000 m³ increased from an estimated 54.2% for the Base Case 2015 Scenario to an estimated 57.2% for the USKMCA1600 What-if Scenario (i.e. an increase by a relative factor 1.06). For the Buoy J and Haro-Strait/Boundary Pass waterway zones their estimated probability of one or more accidents in the VTRA Study Area over a 10-year period within the loss category 1 m³ - 1000 m³ increased by about a relative factor 1.64 and 1.50 (red highlight in Figure E-15), respectively, should all maritime terminal developments in the What-If Scenario USKMCA1600 come to fruition.

Having explained that, should all the maritime terminal development projects in the USKMCA1600 What-If Scenario come to fruition, the relative risk factors neither change uniformly by-waterway-zone nor by POTENTIAL Oil Loss category, Figure E-16 summarizes the by VTRA Study Area wide relative factors for the five different What-If Scenarios evaluated and by the four different POTENTIAL Oil Loss categories. Specifically, Figure E-16 provides the relative multipliers by VTRA Study Area from the Base Case 2015 Scenario results for the probability of at least one accident occurring over a 10-year period by POTENTIAL Oil Loss category. For example, the factor 2.71 (green highlight in Figure E-13) is observed in Figure E-16 in the first row and the second column.

Also, for example, the factor 1.06 (green highlight in Figure E-15) is observed in Figure E-16 in the third row and the second column. From Figure E-16 one observes across the five What-If Scenarios evaluated that the relative multipliers increase by oil spill size category within each What-If Scenario evaluated, except for the CA1020 What-If Scenario where the relative multipliers for the 1000 m^3 – 2500 m^3 and 2500 m^3 or more POTENTIAL Oil Loss categories are of about the same value.

VTRA Study Area	USKMCALN2250	USKMCA1600	KM348	CA1020	US232
2500 m3 or More	2.80	2.71	1.95	1.10	1.60
1000 m3 - 2500 m3	1.58	1.56	1.37	1.11	1.09
1 m3 - 1000 m3	1.10	1.06	1.00	1.05	1.00
0 gallons - 264 gallons	1.00	1.00	1.00	1.00	1.00

Figure E-16. Relative multiplier comparison of the estimated probability of one or more accidents occurring within a 10-year period by POTENTIAL Oil Loss category over the VTRA Study Area for the five What-If Scenarios evaluated.

Moreover, from Figure E-16 one observes that the relative factor increase in the estimated probability of at least one accident occurring in the VTRA Study Area over a 10-year period is highest in the 1 m^3 – 1000 m^3 POTENTIAL Oil Loss category for the USKMCALN2250, USKMCA1600 and CA1020 What-If Scenarios with relative multipliers of 1.10, 1.06 and 1.05, respectively[11]. On the other hand, the relative multiplier for this estimated probability for the 2500 m^3 or more POTENTIAL Oil Loss category is lowest for the CA1020 What-If Scenario (1.10) compared to the other What-If Scenarios US232, KM348, USKMCA1600 and USKMCALN2250 with relative multipliers 1.60, 1.95, 2.71 and 2.80 in the top row of Figure E-16, respectively. A similar observation can be made for the CA1020 What-If Scenario for the 1000 m^3 – 2500 m^3 POTENTIAL Oil Loss category. In absorbing the relative multiplier results above for the VTRA Study area across the evaluated What-If Scenarios and by POTENTIAL Oil Loss category, it is important to recall the earlier discussion regarding the difference in nature of the portfolio of focus vessels added to the Base Case 2015 Scenario between, on the one hand, the CA1020 What-If Scenario and, on the other hand, the US232 and KM348 What-If Scenarios. At the same time, one needs to recall that the USKMCA1600 What-If Scenario is defined as the combination of the US232, KM348 and CA1020 What-If Scenarios.

Analysis Observation 11: The relative multipliers for the estimated probabilities of at least one accident occurring in the VTRA Study Area over a 10-year period by and large increase by oil spill size category within the five different What-If Scenarios evaluated. While the relative multiplier for the CA1020 What-If Scenario is amongst the highest for the 1 m^3 – 1000 m^3 POTENTIAL Oil Loss category, its relative multiplier is the lowest for the 2500 m^3 or more POTENTIAL Oil Loss category.

[11] Recall that in the USKMCALN2250 What-If Scenario the added LNG tankers are minimally modelled for traffic impact only in terms of consequences as cargo-focus vessels since the VTRA 2015 model does not contain a POTENTIAL consequence model for accidents with LNG tankers.

More detailed analysis results presentations for the evaluated What-If Scenarios in the VTRA 2015 study are posted at the following url:

https://www.seas.gwu.edu/~dorpjr/VTRA_2015/VTRA_2015_Presentations.html

Risk Mitigation Measure Scenario Results

A series of risk mitigation measures were proposed over the course of the VTRA 2015 study either with involvement of the VTRA 2015 Working Group or by GW/VCU to help inform a risk management process should some of the maritime terminal development projects represented in the five What-If Scenarios USKMCALN2250, USKMCA1600, KM348, CA1020 or US232 come to fruition. However, the system-wide and the by-waterway-zone specific relative effectiveness of these risk mitigations measures were only evaluated relative to the USKMCA1600 What-If scenario. In other words, caution is in order in not interpreting these relative RMM effectiveness evaluations as being applicable to other What-If Scenarios, or the Base Case 2015 Scenario analysis for that matter. The manner of implementation of these risk mitigations measure in the VTRA 2015 model was as follows (in no specific order):

DH100-RMM: 100% Double hull fuel protection of cargo focus vessels (increased from 40% in the Base Case 2015 Scenario).

HM50-RMM: Reduce human error and mechanical failure on tugs (excluding oil barges) by 50%.

SE-RMM: Remove from the VTRA 2015 Simulation Model its special events, i.e. the modeled regatta, whale watching, and commercial and tribal fishing openers. Combined fishing vessels and yachts/recreational vessels account for about $(39.5\% + 3.6\%) \approx 43.1\%$ of the non-focus vessel traffic (see Figure E-4) in the VTRA 2015 model or $(43.1 \times 75.8\%) \approx 32.7\%$, i.e. about a third, of the VTRA Model traffic in terms of vessel time exposure (VTE). See also, Figure E-4 and Figure E-6A.

OAE-RMM: Continuously escort laden oil barges and ATBs east of Port Angeles (untethered).

KME-RMM: Extend escorting of Kinder Morgan outbound laden tankers to Buoy J.

SRT-RMM: Station a rescue tug at Sidney, BC and model its coverage in the same manner as the coverage model that was developed for the Neah Bay rescue tug in the VTRA 2005.

125-RMM: Lift the 125 DWT limit on laden crude inbound tankers while reducing the number of crude inbound tanker transits to keep the volume of crude inbound tankers approximately the same.

17-RMM: Reduce the speed of container vessel to 17 knots throughout the VTRA 2015 Study Area, a speed restriction currently practiced by container ships south of Admiralty Inlet (i.e. the entrance to the Puget Sound) by container ships.

VBRT-RMM: Station a rescue tug at Victoria, BC, and Bedwell Harbor, BC, and model their coverage in the same manner as the coverage model that was developed for the Neah Bay rescue tug in the VTRA 2005.

The first three components DH100-RMM, HM50-RMM and SE-RMM are referred to in combination as the USCG-RMM Suite. DH100-RMM is currently being phased in by vessel owners to meet the requirements of the International Maritime Organization (IMO) Convention for the Prevention of Pollution from Ships, Annex I, Regulation 12A. The intent of the HM50-RMM is to conduct a maximum benefit type evaluation utilizing the VTRA 2015 model through the on-going implementation of 46CFR Subchapter M, which establishes safety regulations governing the inspections, standards, and safety management systems of towing vessels. The intent of including the SE-RMM is to conduct a maximum benefit type evaluation utilizing the VTRA 2015 model through increased carriage of AIS transponders by fishing and passenger vessels, changes to USCG VTS software that will allow VTS operators to display additional small vessel and recreational boat AIS data, and mandatory safety inspections for commercial fishing vessels. The effect of the SE-RMM implementation in the VTRA 2015 model evaluations is the removal of all POTENTIAL collisions in the VTRA analysis with special event vessels and the removal of the contributing effect that the presence of these special event vessels may have on other focus vessel accidents. By no means ought the implementation method of the HM50-RMM and the SE-RMM in the VTRA 2015 model, and their effectiveness evaluation, be interpreted as the manner in which the HM50-RMM and the SE-RMM are operationalized in practice.

To achieve risk reduction across the VTRA Study Area, we believe that the question "which risk mitigation measure should one implement?" is not the right question to ask, but rather it should be "which portfolio of risk mitigation measures should one implement?". Two of these trial portfolio scenario analyses were conducted utilizing the VTRA 2015 model. The first portfolio is referred to as the **5RMM** Scenario and combines the USCG RMM Suite (i.e. the DH100-RMM, HM50-RMM and the SE-RMM), with RMMs 2 through 5 (i.e. the OAE-RMM, KME-RMM, SRT-RMM and the 125-RMM). The second portfolio is referred to as the **3RMM** Scenario combining the DH100-RMM, 17-RMM and the VBRT-RMM. Four RMMs were evaluated individually: the OAE-RMM, SRT-RMM, KME-RMM and the 125-RMM. In summary, a total of six RMM Scenarios were evaluated during the VTRA 2015 Study of which two were portfolios of RMMs. The POTENTIAL effectiveness of these six RMM scenarios was evaluated in the VTRA 2015 model by implementing them on top of the USKMCA1600 What-If Scenario only. As such, these analyses solely reflect POTENTIAL effectiveness evaluation of these RMMs should all maritime development projects in the USKMCA1600 Scenario come to fruition and subsequently these RMMs have been adopted.

Similar to Figure E-16, Figure E-17 provides the relative multipliers by VTRA Study Area of the probability of one or more accidents occurring over a 10-year period by POTENTIAL Oil Loss category for the six evaluated RMM Scenarios (Columns 1 through 6) together with the relative multipliers for the USKMCA1600 What-If Scenario in the seventh column (see also the second column in Figure E-16).

VTRA Study Area	USKMCA1600 5RMM	USKMCA1600 3RMM	USKMCA1600 OAE-RMM	USKMCA1600 SRT-RMM	USKMCA1600 KME-RMM	USKMCA1600 125-RMM	USKMCA1600 NO RMM
2500 m3 or More	**2.28**	2.68	2.70	2.71	2.70	2.83	2.71
1000 m3 - 2500 m3	**1.04**	1.53	**1.38**	1.52	1.52	1.41	1.56
1 m3 - 1000 m3	**0.86**	**0.94**	1.03	1.06	1.06	1.05	1.06
0 m3 - 1 m3	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Figure E-17. Relative multiplier comparison of the probability of one or more accidents occurring within a 10 year period by Oil Spill Size Category over the VTRA Study Area for the six RMMs Scenarios evaluated and enacted upon the What-If Scenario USKMCA1600.

From Figure E-17 one observes that the relative multipliers evaluated for both RMM portfolios of these probabilities for the VTRA Study area are less than 1.0 in the 1 m^3 - 1000 m^3 POTENTIAL Oil Loss category (i.e. 0.86 for the 5RMM Scenario and 0.94 for the 3RMM Scenario indicated in a bold and underlined font in Figure E-17). This implies that a lesser POTENTIAL Oil Loss is observed in this particular POTENTIAL Oil Loss category than was evaluated for this POTENTIAL Oil Loss category in the Base Case 2015 Scenario. Recall, see Figure E-9, that the 1 m^3 - 1000 m^3 POTENTIAL Oil Loss category contributed the most (45%) to POTENTIAL Oil Loss in the Base Case 2015 Scenario analysis and second to most (73%), see Figure E-11, in the USKMCA1600 What-If Scenario.

Other notable reductions for the 5RMM Scenario are observed from Figure E-17 in both the 2500 m^3 and more POTENTIAL Oil Loss Category (going from a relative multiplier 2.71 in the USKMCA1600 What-If Scenario to a relative multiplier of 2.28 in the 5RMM Scenario enacted upon the USKMCA1600 What-If Scenario, i.e. a relative multiplier reduction of 2.27/2.71 ≈ 0.84) and the 1000 m^3 - 2500 m^3 POTENTIAL Oil Loss Category (going from a relative multiplier 1.56 in the USKMCA1600 What-If Scenario to a relative multiplier of 1.04 in the 5RMM Scenario enacted upon the USKMCA1600 What-If Scenario, i.e. a relative multiplier reduction of 1.04/1.56 ≈ 0.67). Both observations are indicated in Figure E-11 in a bold only font, as is the cell in the 1000 m^3 - 2500 m^3 POTENTIAL Oil Loss Category for the OAE-RMM Scenario which shares with these two cells a relative multiplier less than 0.90 from their USKMCA1600 What-If Scenario evaluated levels. Similar reductions, on the other hand, in the 2500 m^3 or more POTENTIAL Oil Loss Category and the 1000 m^3 - 2500 m^3 POTENTIAL Oil Loss Category are not observed from Figure E-11 for the 3RMM Scenario. That being said, it is important to note that the 5RMM Portfolio Scenario makes maximum benefit type assumptions with respect to its components HM50-RMM and SE-RMM, whereas the 3RMM Portfolio Scenario and the OAE-RMM Scenario do not contain these two components and therefore do not make these maximum benefit type assumptions for their effectiveness evaluation.

Analysis Observation 12: The relative multipliers for the probabilities of at least one accident occurring in the VTRA Study Area over a 10-year period in the 1 m^3 - 1000 m^3

POTENTIAL Oil Loss category are less than 1.0 for the 5RMM Portfolio Scenario (with a relative multiplier 0.86) and the 3RMM Portfolio Scenario (with a relative multiplier 0.94) enacted on the USKMCA1600 What-If Scenario, implying a lesser POTENTIAL Oil Loss evaluated for these two portfolio RMM Scenarios than evaluated for the Base Case 2015 Scenario in this particular POTENTIAL Oil Loss category. Other notable reductions are observed from Figure E-17 for the 5RMM Scenario in the 2500 m^3 or more POTENTIAL Oil Loss Category and for the 5RMM Scenario and OAE-RMM Scenario in the 1000 m^3 - 2500 m^3 POTENTIAL Oil Loss Category.

Figure E-18 provides the by-waterway-zone relative multipliers of the probability of at least one accident occurring over a 10-year period within the 1 m^3 - 1000 m^3 POTENTIAL Oil Loss category for the six evaluated RMM Scenarios (Columns 1 through 6) and the relative multipliers for the USKMCA1600 What-If Scenario in the seventh column (see also the seventh column in Figure E-17 for VTRA Study Area wide relative factors). As mentioned previously, VTRA study wide effects are not distributed uniformly across the VTRA Study Area (i.e. not with the same relative multipliers across the fifteen different waterway zones).

One must realize in evaluating the VTRA 2015 RMM analysis results in Figure E-18 that risk does not necessarily disappear when mitigated, but tends to migrate in these analysis results as demonstrated by some waterway zones experiencing increases in risk from the USKMCA1600 Scenario, whereas other waterway zones see risk reductions. This is in large part a result of a maritime transportation system being dynamic, where a small traffic perturbation can precipitate traffic behavior changes later in time and elsewhere in the VTRA 2015 Model. Such migrations are preferably avoided in a sound risk management strategy, but some risk migration may be inevitable. In addition, the VTRA 2015 maritime simulation model contains some random elements in terms of its traffic simulation for what are termed "special events" representing movements in the VTRA model of smaller vessels (less than 20 meters in length). These special events represented in the VTRA model are modeled whale watching activities, regattas, tribal fishing openers (US and Canadian), and commercial fishing openers[12]. As a result of these random elements, some small risk changes in the evaluated RMM Scenarios (and the What-If Scenarios) are a result of these random elements changing their behavior from scenario simulation run to scenario simulation run.

[12] Combined fishing vessels and yachts (or recreational vessels) account for about 43% of the non-focus vessel traffic modeled in the VTRA 2015 model which is equivalent to a about a third of the overall modeled traffic in the VTRA Model. See also, Figure E-4 and Figure E-6A.

1 m3 - 1000 m3	USKMCA1600	USKMCA1600	USKMCA1600	USKMCA1600	USKMCA1600	USKMCA1600	USKMCA1600
	5RMM	3RMM	OAE-RMM	SRT-RMM	KME-RMM	125-RMM	NO RMM
Haro/Boun.	0.92	1.29	1.50	1.46	1.50	1.51	1.50
Sthrn. Glf. Ils.	0.64	0.68	0.87	0.97	1.01	1.01	1.00
Buoy J	1.11	1.16	1.64	1.62	1.62	1.60	1.64
ESJF	1.22	1.27	1.36	1.38	1.38	1.36	1.39
WSJF	0.99	0.93	1.24	1.23	1.23	1.20	1.23
Guemes	0.66	1.13	0.79	1.21	1.21	**1.09**	1.16
Georgia Str.	0.82	0.99	1.06	1.09	1.09	0.99	1.03
Saddlebag	0.74	1.03	0.94	1.09	1.09	**0.99**	1.06
Sar/Skagit	0.93	0.84	1.13	1.07	1.07	1.15	1.05
SJ Islands	0.99	1.03	1.04	1.06	1.13	1.04	1.05
Rosario	0.56	1.14	0.82	1.12	1.12	1.12	1.06
ATBA	1.02	1.02	1.04	1.08	1.07	1.05	1.07
PS North	0.85	0.82	0.96	1.01	1.01	1.01	1.01
PS South	0.83	0.85	1.00	0.99	0.99	0.99	0.99
Tac. South	0.80	0.99	0.84	0.99	0.99	0.98	1.01

Figure E-18. Relative multiplier comparison by waterway zone of the probability of at least one accident occurring within a 10 year period for the 1 m^3 - 1000 m^3 POTENTIAL Oil Loss Category for the six RMM Scenarios evaluated and enacted upon the What-If Scenario USKMCA1600.

With the caveat above, however, one observes from Figure E-18 relative multipliers less than 1.0 for the probability of at least one accident occurring within a 10-year period for twelve out of the fifteen waterway zones (the exceptions being the Buoy J, East Strait of Juan de Fuca and ATBA waterway zones) for the 5RMM Scenario in the 1 m^3 - 1000 m^3 POTENTIAL Oil Loss category. Similarly, relative multipliers less than 1.0 are observed for these probabilities for seven out of the fifteen waterway zones for the 3RMM Scenario and six out of the fifteen waterway zones for the OAE-RMM Scenario. That being said, it is important to note that 5RMM Portfolio Scenario makes maximum benefit type assumptions with respect to its components HM50-RMM and SE-RMM, whereas the 3RMM Portfolio Scenario and the OAE-RMM Scenario do not contain these two components and therefore do not makes these maximum benefit type assumptions for their effectiveness evaluation.

Analysis Observation 13-A: For the 5RMM, 3RMM and OAE-RMM Scenarios, enacted on the USKMCA1600 What-If Scenario, relative multipliers with a value less than 1.0 are observed from Figure E-18 for the probabilities of at least one accident occurring within a 10-year period for the 1 m^3 - 1000 m^3 POTENTIAL Oil Loss category for respectively, twelve, seven and six out of the fifteen waterway zones in the VTRA Study Area (implying a lesser POTENTIAL Oil loss than evaluated for the Base Case 2015 Scenario in these waterway zones for this POTENTIAL Oil Loss category than the USKMCA1600 What-If Scenario).

Other notable by-waterway-zone risk reductions in Figure E-18, although not reduced to below Base Case 2015 Scenario levels, is the reduction for the 5RMM Scenario in the relative multiplier for the Buoy J waterway zone (going from a relative multiplier 1.64 evaluated for the USKMCA1600 What-If Scenario to a relative multiplier 1.11 in the 5RMM Scenario enacted upon the USKMCA1600 What-If Scenario, i.e. a relative multiplier reduction of $1.11/1.64 \approx 0.68$) and the reduction for the 3RMM Scenario in the relative multiplier for the Buoy J waterway zone (going from a relative multiplier 1.64 evaluated for the USKMCA1600 What-If Scenario to a relative multiplier 1.16 in the 3RMM Scenario enacted upon the USKMCA1600 What-If Scenario, i.e. a relative multiplier reduction of 1.11/1.64 ≈ 0.71).

Overall, across all six RMM Scenarios relative multipliers reductions are observed in terms of the probability of at least one accident over a 10-year period in the 1 m^3 - 1000 m^3 POTENTIAL Oil Loss Category from their USKMCA1600 What-If Scenario probabilities in 63 out of their 90 by-waterway-zone cells (i.e. 6 RMM Scenarios × 15 Waterway Zones) in Figure E-18, with 29 out of these 63 cells having a relative multiplier less than 0.95 for their USKMCA1600 What-If Scenario estimated probability levels (indicated in a bold font in Figure E-18), and with 25 out of these 29 having a relative multiplier less than 0.90 for their USKMCA1600 What-If Scenario estimated probabilities (indicated in a bold and underlined font in Figure E-18). That being said, 55 out of the 90 relative multipliers in Figure E-18 are larger than one, implying larger than Base Case 2015 Scenario analysis results for these probabilities in these waterway zones, should all the terminal projects in the USKMCA1600 Scenario come to fruition, despite the six RMM Scenarios evaluated in the VTRA 2015 Study.

Analysis Observation 13-B: Overall, across all six RMM Scenarios relative multipliers less than 0.95 are evaluated for the probability of at least one accident occurring over a 10-year period in the 1 m^3 - 1000 m^3 POTENTIAL Oil Loss Category <u>from their USKMCA1600 What-If Scenario estimated probability levels</u> in 29 out of 90 by-waterway-zone cells (i.e. 6 RMM Scenarios × 15 Waterway Zones) in Figure E-18. These 29 cells are indicated in a bold font (underlined or not) in Figure E-18. That being said, 55 out of the 90 relative multipliers in Figure E-18 are larger than one, implying larger than Base Case 2015 Scenario analysis results for these probabilities in these waterway zones, should all the terminal projects in the USKMCA1600 Scenario come to fruition, despite the six RMM Scenarios evaluated and enacted upon the USKMCA1600 Scenario.

Figure E-19 provides the by-waterway-zone relative multipliers of the probability of at least one accident occurring over a 10-year period within the 1000 m^3 - 2500 m^3 POTENTIAL Oil Loss category for the six evaluated RMM Scenarios (Columns 1 through 6) and the relative multipliers for the USKMCA1600 What-If Scenario in the seventh column (see also the seventh column in Figure E-17 for VTRA Study Area wide relative factors). One immediately observes from Figure E-19 relative multipliers from the Base Case 2015 Scenario for the Haro/Boundary Pass waterway zone of larger than 3.0, regardless of the six RMM Scenarios evaluated. Furthermore, one observes relative multipliers of about 1.5 to 2.5 for the waterway zones Buoy J and West Strait of Juan de Fuca and relative multipliers larger than 1.0 for the East Strait of Juan de Fuca waterway zone for this 1000 m^3 - 2500 m^3 POTENTIAL Oil Loss Category. Overall, 61 out of the 90 relative multipliers in Figure E-19 are larger than one, implying larger than Base Case 2015 Scenario analysis results for these probabilities in these waterway zones, should all the terminal projects in the USKMCA1600 Scenario come to fruition, despite the six RMM Scenarios evaluated in the VTRA 2015 Study.

1000 m3 - 2500 m3	USKMCA1600 5RMM	USKMCA1600 3RMM	USKMCA1600 OAE-RMM	USKMCA1600 SRT-RMM	USKMCA1600 KME-RMM	USKMCA1600 125-RMM	USKMCA1600 NO RMM
Haro/Boun.	3.26	3.81	4.09	3.98	4.06	4.00	4.05
Sthrn. Glf. Ils.	0.57	0.38	0.59	0.63	0.65	0.66	0.65
Buoy J	2.46	1.81	2.46	2.10	1.93	2.17	2.06
ESJF	1.14	1.25	1.24	1.31	1.31	1.28	1.31
WSJF	1.58	1.89	1.91	2.05	1.85	1.96	2.04
Guemes	0.78	1.45	1.05	1.17	1.17	1.24	1.21
Georgia Str.	0.81	1.25	1.09	1.41	1.41	1.29	1.41
Saddlebag	0.55	1.32	1.19	1.30	1.34	0.83	1.37
Sar/Skagit	0.59	0.97	1.14	1.20	1.17	1.21	1.17
SJ Islands	0.89	0.43	0.92	1.36	1.31	1.03	1.32
Rosario	0.48	1.09	0.62	1.02	1.07	0.90	1.08
ATBA	1.16	0.98	1.02	1.19	1.16	0.98	1.16
PS North	0.71	0.92	0.79	1.08	1.08	1.05	1.08
PS South	0.78	1.09	0.92	1.05	1.05	0.97	1.05
Tac. South	0.86	0.86	0.88	1.00	1.00	1.02	1.00

Figure E-19. Relative multiplier comparison by waterway zone of the probability of one or more accidents occurring within a 10 year period for the 1000 m³ - 2500 m³ POTENTIAL Oil Loss Category for the six RMM Scenarios evaluated and enacted upon the What-If Scenario USKMCA1600.

Analysis Observation 14-A: Most of the relative multipliers, 61 out of 90 (i.e. 6 RMM Scenarios × 15 Waterway Zones), in Figure E-19 for the probability of at least one accident over a 10-year period in the 1000 m³ - 2500 m³ POTENTIAL Oil Loss category are larger than 1.0 across the fifteen waterway zones in the VTRA Study Area, implying larger than Base Case 2015 Scenario analysis results for these probabilities. In fact, the analysis results in Figure E-19 demonstrate relative multipliers larger than 3.0 in this POTENTIAL Oil Loss category for the Haro-Strait/Boundary Pass waterway zone and multipliers ranging from 1.5 to 2.5 for the Buoy J and West Strait of Juan de Fuca waterway zones, despite the six RMM Scenarios evaluated and enacted upon the USKMCA1600 What-If Scenario.

This does not mean that the six RMM Scenarios evaluated in Figure E-19 do not show risk reduction in this 1000 m³ - 2500 m³ POTENTIAL Oil Loss Category from the USKMCA1600 Scenario. In fact, the 5RMM Scenario shows relative multipliers of these probabilities of less than 1.0 in ten of the fifteen waterway zones, implying a lesser probability in Figure E-19 for at least one accident occurring in a 10-year period in these waterway zones in the 1000 m³ - 2500 m³ POTENTIAL Oil Loss category than evaluated for the Base Case 2015 Scenario. Similarly, relative multipliers less than 1.0 are observed for these probabilities for six out of the fifteen waterway zones for the 3RMM Scenario and the OAE-RMM Scenario. That being said, it is important to note that 5RMM Portfolio Scenario makes maximum benefit type assumptions with respect to its components HM50-RMM and SE-RMM, whereas the 3RMM Portfolio Scenario and the OAE-RMM

Scenario do not contain these two components and therefore do not makes these maximum benefit type assumptions for their effectiveness evaluation.

Other by-waterway-zone risk reductions are observed in Figure E-19, although not reduced to below Base Case 2015 Scenario levels. For example, one observes a reduction for the KME-RMM Scenario in the relative multiplier for the West Strait of Juan de Fuca waterway zone going from a relative multiplier 2.06 evaluated for the USKMCA1600 What-If Scenario to a relative multiplier 1.85 in the KME-RMM Scenario enacted upon the USKMCA1600 What-If Scenario (i.e. a relative multiplier reduction of $1.85/2.06 \approx 0.91$), and a reduction for the KME-RMM Scenario in the relative multiplier for the Buoy J waterway zone going from a relative multiplier 2.06 evaluated for the USKMCA1600 What-If Scenario to a relative multiplier 1.93 in the KME-RMM Scenario enacted upon the USKMCA1600 What-If Scenario (i.e. a relative multiplier reduction of $1.93/2.06 \approx 0.94$).

Overall, across all six RMM Scenarios relative multipliers reductions are observed in terms of the probability of at least one accident over a 10-year period in the 1000 m^3 - 2500 m^3 POTENTIAL Oil Loss Category from their USKMCA1600 What-If Scenario probabilities in 66 out of a total of their 90 by-waterway-zone cells in Figure E-19, with 45 out of these 66 having a relative multiplier less than 0.95 for their USKMCA1600 What-If Scenario estimated probabilities (indicated in a bold font in Figure E-19), and 35 out of these 66 having a relative multiplier less than 0.90 for their USKMCA1600 What-If Scenario estimated probabilities (indicated in a bold and underlined font in Figure E-19).

Analysis Observation 14-B: Overall, across all six RMM Scenarios relative multipliers less than 0.95 are evaluated for the probability of at least one accident occurring over a 10-year period in the 1000 m^3 - 2500 m^3 POTENTIAL Oil Loss Category <u>from their USKMCA1600 What-If Scenario estimated probability levels</u> in 45 out of 90 by-waterway-zone cells (i.e. 6 RMM Scenarios × 15 Waterway Zones) in Figure E-19. These 45 cells are indicated in a bold font (underlined or not) in Figure E-19.

Figure E-20 provides the by-waterway-zone relative multipliers of the probability of at least one accident occurring over a 10-year period within the 2500 m^3 or more POTENTIAL Oil Loss category for the six evaluated RMM Scenarios (Columns 1 through 6) and the relative multipliers for the USKMCA1600 What-If Scenario in the seventh column (see also the second column in Figure E-16). One immediately observes from Figure E-20 relative multipliers larger than 9.0 from the Base Case 2015 Scenario for the Haro/Boundary Pass waterway zone, regardless of the six RMM Scenarios evaluated. Furthermore, one observes relative multipliers of about 4.5 to 6 for the waterway zones Buoy J, East Strait of Juan de Fuca and relative multipliers of about 2 to 4 for the Guemes and Georgia Strait waterway zones for this 2500 m^3 or more POTENTIAL Oil Loss Category. Overall, 78 out of the 90 relative multipliers in Figure E-20 are larger than one, implying larger than Base Case 2015 Scenario analysis results for these probabilities in these waterway zones, should all the terminal projects in the USKMCA1600 Scenario come to fruition, despite the six RMM Scenarios evaluated in the VTRA 2015 Study.

2500 m3 or More	USKMCA1600 5RMM	USKMCA1600 3RMM	USKMCA1600 OAE-RMM	USKMCA1600 SRT-RMM	USKMCA1600 KME-RMM	USKMCA1600 125-RMM	USKMCA1600 NO RMM
Haro/Boun.	9.84	10.53	11.37	11.00	11.19	11.08	11.19
Sthrn. Glf. Ils.	5.49	1.88	6.39	5.82	6.04	6.76	6.04
Buoy J	4.89	5.24	5.35	5.23	4.88	6.03	5.25
ESJF	4.78	4.92	4.96	5.07	5.01	4.97	5.06
WSJF	2.89	2.89	2.83	3.14	3.05	3.23	3.10
Guemes	2.10	2.67	2.65	2.42	2.42	2.72	2.43
Georgia Str.	1.43	2.27	2.07	2.40	2.40	2.17	2.40
Saddlebag	1.29	1.76	1.63	1.73	1.71	2.26	1.71
Sar/Skagit	0.44	1.43	1.51	1.49	1.49	1.49	1.49
SJ Islands	1.22	1.56	2.08	1.23	1.23	1.41	1.23
Rosario	0.75	1.24	1.10	1.23	1.23	1.17	1.23
ATBA	1.00	1.21	1.26	1.16	1.17	1.21	1.17
PS North	0.89	0.92	0.98	1.04	1.04	1.01	1.04
PS South	0.79	1.02	1.02	1.03	1.04	0.91	1.04
Tac. South	0.88	1.07	0.82	0.96	0.96	0.76	0.96

Figure E-20. Relative multiplier comparison by waterway zone of the probability of one or more accidents occurring within a 10 year period for the 2500 m³ or more POTENTIAL Oil Loss Category for the six RMM Scenarios evaluated and enacted upon the What-If Scenario USKMCA1600.

Analysis Observation 15-A: Most of the relative multipliers, 78 out of 90 (i.e. 6 RMM Scenarios $\times$ 15 Waterway Zones), in Figure E-20 for the probability of at least one accident over a 10-year period in the 2500 m³ or more POTENTIAL Oil Loss category are larger than 1.0 across the fifteen waterway zones in the VTRA Study Area, implying larger than Base Case 2015 Scenario analysis results for these probabilities in the USKMCA1600 What-If Scenario. In fact, the analysis results in Figure E-20 demonstrate relative multipliers larger than 9.0 in this POTENTIAL Oil Loss category for the Haro-Strait/Boundary Pass waterway zone and multipliers ranging from 4.5 to 6.0 for the Buoy J, East Strait of Juan de Fuca and Southern Gulf Islands waterway zones, despite the six RMM Scenarios evaluated and enacted upon the USKMCA1600 What-If Scenario.

This does not mean that the six RMM Scenarios evaluated do not show risk reduction in this 2500 m³ or more POTENTIAL Oil Loss Category from the USKMCA1600 Scenario. In fact, in Figure E-20 in five of the fifteen waterway zones, the 5RMM Scenario shows relative multipliers with a value less than 1.0 of these probabilities, implying a lesser probability for one or more accidents occurring in a 10-year period in these waterway zones in the 2500 m³ or more POTENTIAL Oil Loss category than evaluated for the Base Case 2015 Scenario. Other notable by-waterway-zone risk reductions in Figure E-20, although not reduced to below Base Case 2015 Scenario levels, are the reduction for the 3RMM Scenario in the relative multiplier for the Southern Gulf Islands waterway zone (going from a relative multiplier 6.04 evaluated for the USKMCA1600 What-If Scenario to a relative multiplier 1.88 in the 3RMM Scenario enacted upon the USKMCA1600 What-If Scenario, i.e. a relative multiplier reduction of $1.88/6.04 \approx 0.31$) and the reduction for the

5RMM Scenario in the relative multiplier for the Georgia Strait waterway zone (going from a relative multiplier 2.40 evaluated for the USKMCA1600 What-If Scenario to a relative multiplier 1.43 in the 5RMM Scenario enacted upon the USKMCA1600 What-If Scenario, i.e. a relative multiplier reduction of $1.43/2.40 \approx 0.59$). That being said, it is important to note that 5RMM Portfolio Scenario makes maximum benefit type assumptions with respect to its components HM50-RMM and SE-RMM, whereas the 3RMM Portfolio Scenario does not contain these two components and therefore does not makes these maximum benefit type assumptions for their effectiveness evaluation.

Overall, across all six RMM Scenarios relative multipliers reductions are observed in terms of the probability of at least one accident occurring within a 10-year period in the 2500 m^3 or more POTENTIAL Oil Loss Category from their USKMCA1600 What-If Scenario estimated probabilities in 51 of their 90 by-waterway-zone cells in Figure E-20, with 28 out of these 51 having a relative multiplier less than 0.95 for their USKMCA1600 What-If Scenario estimated probabilities (indicated in a bold font in Figure E-20), and with 16 out of these 28 having a relative multiplier less than 0.90 for their USKMCA1600 What-If Scenario estimate probabilities (indicated in a bold and underlined font in Figure E-20).

Analysis Observation 15-B: Overall, across all six RMM Scenarios relative multipliers less than 0.95 are evaluated for the probability of at least one accident occurring over a 10-year period in the 2500 m^3 or more POTENTIAL Oil Loss Category <u>from their USKMCA1600 What-If Scenario estimated probability levels</u> in 28 out of 90 by-waterway-zone cells (i.e. 6 RMM Scenarios × 15 Waterway Zones) in Figure E-20. These 28 cells are indicated in a bold font (underlined or not) in Figure E-20.

The combined effect of the RMM analysis observations described above for the 1 m^3 - 1000 m^3 POTENTIAL Oil Loss category, the 1000 m^3 - 2500 m^3 POTENTIAL Oil Loss category and the 2500 m^3 or more POTENTIAL Oil Loss category for the VTRA Study Area overall are depicted in Figure E-21.

VTRA Study Area	USKMCA1600 5RMM	USKMCA1600 3RMM	USKMCA1600 OAE-RMM	USKMCA1600 SRT-RMM	USKMCA1600 KME-RMM	USKMCA1600 125-RMM	USKMCA1600 NO RMM	2015 BASE CASE NO RMM
2500 m3 or More	83%	91%	92%	92%	91%	106%	91%	42%
1000 m3 - 2500 m3	**13%**	20%	**18%**	20%	20%	**18%**	20%	12%
1 m3 - 1000 m3	**<u>35%</u>**	**<u>37%</u>**	71%	71%	73%	72%	73%	45%
0 m3 - 1 m3	**<u>0.12%</u>**	0.61%	**<u>0.45%</u>**	0.62%	0.62%	0.56%	0.54%	0.46%
All Categories	131%	149%	181%	183%	184%	197%	185%	100%

Figure E-21. Percent POTENTIAL OIL Loss comparison measured in terms of Base Case 2015 percentage POTENTIAL Oil Loss for the Base Case 2015 Scenario, the USKMCA1600 What-If Scenario and the six RMMs Scenarios evaluated and enacted upon the What-If Scenario USKMCA1600

Figure E-21 provides the contribution in POTENTIAL Oil Loss, measured in terms of percentages of Base Case 2015 POTENTIAL Oil Loss, for the six RMM Scenarios evaluated, the USKMCA1600

What-If Scenario and the Base Case 2015 Scenario. Recall from Figure E-9, that the 2500 m^3 or more POTENTIAL Oil Loss category contributed second most (@42%) to POTENTIAL Oil Loss in the Base Case 2015 Scenario analysis and most (@91%), see Figure E-11, in the USKMCA1600 What-If Scenario analysis. These percentages are observed in the first row and the seventh and eighth columns of Figure E-21. Recall from Figure E-9, that the 1 m^3 - 1000 m^3 POTENTIAL Oil Loss category contributed most (@45%) to POTENTIAL Oil Loss in the Base Case 2015 Scenario analysis and second most (@73%), see Figure E-11, in the USKMCA1600 What-If Scenario analysis. These latter percentages are observed in the third row and the seventh and eight column of Figure E-21.

When comparing the percent POTENTIAL Oil Loss evaluation in the 7th column (i.e. the USKMCA1600 What-If Scenario analysis) and the 8th column (the Base Case 2015 Scenario analysis) with the percent contributions in Columns 1 through 6 for the six RMM Scenarios, one observes that increases in POTENTIAL Oil Loss are observed across all POTENTIAL Oil Loss categories from the Base Case 2015 Scenario, despite the six RMM Scenarios evaluated and enacted on top of the USKMCA1600 What-If Scenario, with the exception of the percent POTENTIAL Oil Loss evaluations for the 5RMM Scenario and the 3RMM Scenario in the 1 m^3 - 1000 m^3 POTENTIAL Oil Loss category and the percent POTENTIAL Oil Loss evaluations for the 5RMM Scenario and OAE-RMM Scenario in the 0 m^3 - 1 m^3 POTENTIAL Oil Loss category (indicated in a bold and underlined font in Figure E-21). That being said, it is important to note that the 5RMM Portfolio Scenario analysis makes maximum benefit type assumptions with respect to its components HM50-RMM and SE-RMM, whereas the 3RMM Portfolio Scenario and the OAE-RMM Scenario analyses do not contain these two components and therefore do not makes these maximum benefit type assumptions for their effectiveness evaluation.

Analysis Observation 16: Should all the terminal projects in the USKMCA1600 Scenario come to fruition and either the 5RMM Portfolio Scenario or the 3RMM Portfolio Scenario be enacted thereafter, the RMM Scenario POTENTIAL Oil Loss results show a reduction below the Base Case 2015 Scenario analysis results for the 1 m^3 - 1000 m^3 POTENTIAL Oil Loss Category in Figure E-21. The same applies to the POTENTIAL Oil Loss for the 5RMM Portfolio Scenario and the OAE-RMM Scenario in the 0 m^3 - 1 m^3 POTENTIAL Oil Loss Category. These four cells are indicated by a bold and underlined font in Figure E-21. Relative multiplier decreases of less than 0.90 are observed in the 1000 m^3 - 2500 m^3 POTENTIAL Oil Loss Category for the 5RMM Portfolio Scenario, and the OAE-RMM, 125-RMM Scenarios <u>from their USKMCA1600 What-If Scenario estimated levels</u> (these three cells being indicated in a bold only font in Figure E-21).

A worthwhile observation from Figure E-21 is that the 5RMM Scenario is the only RMM Scenario that achieves a nearly 8% reduction in the 2500 m^3 or more POTENTIAL Oil Loss in category from the USKMCA1600 What-If Scenario (going from 91% to 83%), while containing within it the 125-

RMM component that has shown to increase close to 15% in POTENTIAL Oil Loss in this 2500 m^3 or more POTENTIAL Oil Loss category (when this 125-RMM Scenario was evaluated individually as an RMM-Scenario enacted upon the USKMCA1600 Scenario). On the other hand, the 125-RMM Scenario analysis does show a relative multiplier decrease of close to 18%/20% ≈ 0.90 (in evaluated POTENTIAL Oil loss in the 1000 m^3 - 2500 m^3 category), as does the OAE-RMM Scenario analyses. Moreover, the 5RMM Scenario also shows a relative multiplier decrease of close to 13%/20% ≈ 0.65 (in evaluated POTENTIAL Oil loss in the 1000 m^3 - 2500 m^3 category). All three observations above are indicated in a bold only font in Figure E-21). In other words, no conclusion can be drawn as to the specific increased percentage of effectiveness of a 4RMM type scenario analysis in terms of VTRA Study area wide POTENTIAL Oil Loss with the 125-RMM removed from 5RMM Scenario without conducting such a 4RMM Scenario portfolio RMM analysis (which has not been conducted under this VTRA 2015 study).

The last row in Figure E-21 provides the POTENTIAL Oil Loss measured in terms of overall Base Case 2015 Scenario evaluated POTENTIAL Oil Loss (note the 100% POTENTIAL Oil loss in the eighth column and fifth row in Figure E-21). One observes from this last row that should all the maritime development projects in the USKMCA1600 Scenario come to fruition, neither of the six RMM Scenarios that were evaluated using the VTRA 2015 model reduce POTENTIAL Oil Loss to below Base Case 2015 Scenario levels. Hence, should all the maritime development projects in the USKMCA1600 Scenario come to fruition it would be prudent to consider additional risk mitigation measures beyond the ones evaluated via the six RMM Scenarios enacted upon the USKMCA1600 What-If Scenario in this VTRA 2015 Study.

Analysis Observation 17: Overall, the six RMM Scenarios evaluated show VTRA Study area wide POTENTIAL Oil Loss increases ranging from 131% to 185% following their POTENTIAL enactment on the USKMCA1600 What-If Scenario. Hence, were the USKMCA1600 scenario come to effect, it would be prudent to consider implementation of risk mitigation measures beyond the six RMM Scenarios evaluated in the VTRA 2015 study to counter those POTENTIAL risk increases.

That being said, comparing the individual evaluated VTRA area study wide POTENTIAL Oil Losses for the KME-RMM, SRT-RMM and OAE-RMM Scenarios evaluated at 184%, 183% and 181%, respectively (see the last row of Figure E-21) with, on the one hand, the overall POTENTIAL Oil Loss evaluated for the USKMCA1600 What-If Scenario (@185%) and, on the other hand, the overall POTENTIAL Oil Loss evaluated for the 5RMM Scenario (@131%), there is no doubt that the combined effect of DH100-RMM, HM50-RMM and SE-RMM contributes the most to the evaluated risk reduction in evaluated VTRA Study Area wide POTENTIAL Oil Loss for the 5RMM Portfolio analysis. The largest part of that risk reduction is achieved in the 1 m^3 - 1000 m^3 POTENTIAL Oil Loss category (decreasing from 73% to 35%), where the 3RMM Portfolio evaluates a similar risk reduction in POTENTIAL Oil Loss (going from 73% to 37%)[13] in that particular POTENTIAL Oil Loss category. However, as mentioned previously, the 5RMM Scenario analysis does make maximum benefit type assumptions for its effectiveness analysis via its components HM50-RMM and SE-RMM, which are not components of the 3RRM Portfolio Scenario.

Closing Comments

By providing What-If Scenario and RMM Scenario analyses by waterway zone and by POTENTIAL Oil Loss category similar to the ones provided in this Executive Summary, an information source is provided to help answer difficult and location specific risk management questions in the event some or all of the maritime terminal projects considered in the VTRA 2015 study come to fruition.

In light of the analysis observations in this VTRA 2015 study, while considering a longer-term view of risk management in the VTRA Study Area, we close with the observation that there still is a serious need for an electronic data source that is cross-border (US and Canadian waters) where the vessel type is consistently defined and verified beyond cargo focus vessel or tank focus vessel classifications. VTOSS was and AIS is such cross-boundary data source that could serve this purpose. However, without AIS refining the classification of vessel type to the level that was customary in the VTOSS data, it will become increasingly difficult to further update the VTRA 2015 model solely using AIS data. While it may be possible to link vessel identifiers recorded in AIS data to databases to further refine AIS vessel type classification, the recording of four to five different vessel types in AIS compared to the 26 different vessel types in the decommissioned VTOSS data is a step in the opposite direction from a risk modeling perspective. That being said, there is no doubt that with more and more vessels participating in AIS, dynamic risk modeling, similar to the VTRA 2015 model, can become more representative of actual experienced risk levels.

Moreover, with the same eye towards risk management analysis it would be equally beneficial if AIS datasets capture cargo or at a minimum cargo levels (laden, un-laden, 50% laden, etc.) and a cargo type. In particular, we would like to specifically call out the need for the electronic recording at a much greater consistency of the barge type and cargo content of tug-tows. Not only would studies like these benefit from the availability of such a data source, but the immediacy of having such information available could also benefit first responders responding to a spill scenario both from a response and a safety to the first responder perspective.

Summarizing, we advocate an integrated systems approach towards answering risk management questions (i.e. combining the POTENTIAL impact of multiple maritime projects coming to fruition while combining the POTENTIAL effectiveness of a portfolio of RMMs) as opposed to the individual evaluation of these components, to not miss POTENTIAL synergistic effect that could be

[13] It is important to note here too that the 125-RMM does show a risk reduction in the 1 m^3 - 1000 m^3 POTENTIAL Oil Loss Category when evaluated individually and not a risk increase as was observed in the 2500 m^3 or more POTENTIAL Oil Loss category

missed by avoiding such combinations. Ultimately, we believe that the strength of the VTRA 2015 analysis lies in this systems view, but equally important is the evaluation of relative POTENTIAL risk changes of What-If Scenarios and RMM scenarios within a single common framework. No doubt, the risk communication process amongst stakeholders that took place following the collaborative analysis approach in conducting these analyses during the VTRA 2005, VTRA 2010 and this VTRA 2015 study is at least as important.