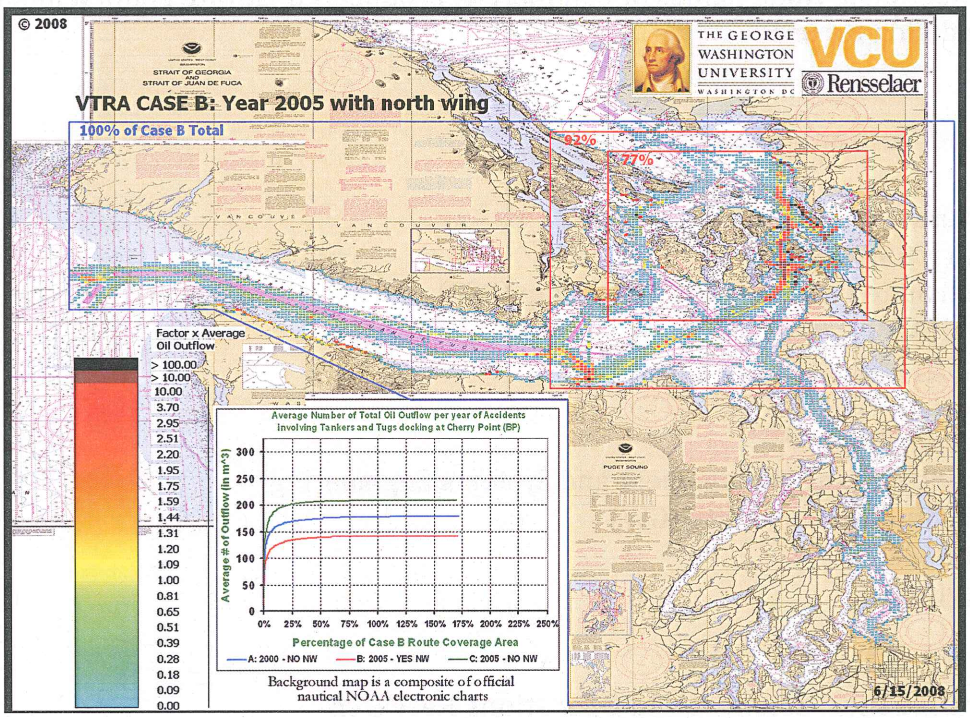
Vessel Traffic Risk Assessment (VTRA):

Preventing Oil Spills from Large Ships and Barges In Northern Puget Sound & Strait of Juan De Fuca

Quality Assurance Project Plan



February 2013

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Each study conducted by EPA, or external parties funded by EPA, must have an approved Quality Assurance Project Plan (QAPP). The plan describes the objectives of the study and the procedures to be followed to achieve those objectives. After completing this study, the final report will be available upon request from the PSP.

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1. Abstract

Several commercial projects have been proposed for northern Puget Sound and southern British Columbia over the next decade, potentially increasing the amount of oil being transported and adding many hundreds of deep draft ship transits through the area. The purpose of this VTRA is to quantify the *relative difference between present and future risks*, and establish a well-accepted technical basis for making *decisions on what risk management measures would be beneficial in managing the risk of potential spills currently and in the future*.

This effort will utilize and leverage the extensive technical work already completed by the George Washington (GW) University and Virginia Commonwealth University (VCU) under previously funded projects. Specifically, the Prince William Sound Risk Assessment (1996), The Washington State Ferry Risk Assessment (1998), The San Francisco Bay Exposure Assessment (2004), the 2005 Vessel Traffic Risk Assessment (VTRA) funded by BP and most recently the update of that model funded by the Makah Indian Tribal Council. The 2005 VTRA analysis tool was developed using 2005 data from the federal Vessel Traffic Operational Support System (VTOSS) data, amongst other data sources. GW/VCU's VTRA analysis tool evaluates exposure, accident frequency and oil losses from pre-defined classes of focus vessels. The analysis results from this tool are useful to help inform a risk management strategy to prevent these accidents. The GWU/VCU analysis VTRA approach has been well documented and peer-reviewed in the academic literature.

The 2010 year is the last full year of traffic data recorded for VTOSS. The updating of the 2005 VTRA model to 2010 VTOSS data is funded under a separate contract between the Makah Indian Tribal Council and GWU/ VCU. Updating under the Makah grant of the 2005 VTRA model to a 2010 base year will more closely approximate the present-day patterns in traffic compared to those exhibited in the modeled scenarios in future projects. Included under the Makah grant is a 2010 vessel traffic analysis for the 2005 VTRA focus vessel group of all oil tankers, Articulated Tug Barges (ATB) and Integrated Tug Barges (ITB), expanded from those just docking at the BP Cherry Point terminal.

To distinguish the study described herein from the previous 2005 VTRA study it will be labeled the 2010 VTRA. The starting point for the 2010 VTRA analysis is the updated 2005 VTRA model with 2010 VTOSS data as agreed upon in the scope of work between GWU and the PSP. The 2010 VTRA will commence with establishing a baseline risk level for a pre-defined (enlarged from VTRA 2005) group of focus vessels for the year 2010 to include in addition: bulk carriers, container vessels and oil barges. Future scenarios will be run adding anticipated vessel traffic increases as a result of select future anticipated developments. Risk mitigation scenarios will be developed to attempt to manage potential risk increases arising from potential growth in vessel traffic associated with these future scenarios. Project success can be gauged by the completion of the number of future scenarios analyzed, risk mitigation scenarios analyzed and by the completion of a final report synthesizing the analysis results.

2. Background

Washington State shares the Salish Sea with the province of British Columbia. A large number of ships and barges operate in these shared waters, placing the area at risk for major and catastrophic oil spills. While citizens in the region enjoy a relatively safe marine transportation system compared to most other port states in the world, the potential for catastrophic spills continues to be a huge concern for the region's environment, economy and quality of life, and the impact of a major spill would likely be devastating on the long-term restoration and protection of Puget Sound.

The purpose of the 2010 VTRA is to inform the State of Washington and the United States Coast Guard on what potential actions should be taken to mitigate any increase in oil spill risk from large commercial vessel oil spills in the northern Puget Sound and the Strait of Juan de Fuca areas. This study area is expected to experience significant changes in deep draft vessel traffic during the next decade. The 2010 VTRA is also intended to inform federal agencies, tribes, local governments, industry and non-profit groups in Washington State and British Columbia on potential risk management options and facilitate their input into achieving consensus risk management decisions regarding vessel operations in the study area

The development of the 2010 VTRA is expected to proceed in several phases following the collaborative analysis approach [1] involving coordination with a Puget Sound Advisory group/steering committee of stakeholders to be selected early on in the 2010 VTRA by the PSP.

"In collaborative analysis, the groups involved in a policy debate work together to assemble and direct a joint research team, which then studies the technical aspects of the policy issue in question. Representative from all the participating groups are given the ability to monitor and adjust the research throughout its evolution. Collaborative analysis aims to overcome suspicions of distorted communication giving each group in the debate the means to assure that other groups are not manipulating the analysis. The ultimate goal is to generate a single body of knowledge that will be accepted by all the groups in the debate as a valid basis for policy negotiations and agreements. – George J. Busenberg, 1999."

The 2005 VTRA was developed using 2005 data from the federal Vessel Traffic Operational Support System (VTOSS) data, amongst other data sources. Although the 2005 VTRA incorporates the movement patterns of nearly all classes of vessels that can interact in the system its analysis was limited to accidents involving Focus Vessels (FV) that dock at the BP Cherry Point refinery, specifically: Oil Tankers, Articulated Tug Barges (ATB) and Integrated Tug Barges (ITB) that dock at Cherry Point. These represent only a very small percentage (~1%) of all vessel traffic in the region. Accident types included in the 2005 VTRA were collisions, powered groundings, drift grounding and allisions. Vessels that can collide with FVs in the 2005 VTRA are termed Interacting Vessels (IVs). The 2010 year is the last full year of traffic data recorded for VTOSS.

The starting point for the 2010 VTRA analysis is the updated 2005 VTRA model with 2010 VTOSS data to establish a 2010 base case scenario to more closely approximate the present-day patterns in traffic compared to those exhibited in the modeled scenarios in future projects. This base case 2010 VTRA scenario update will allow an expansion of the analysis to include other focus vessels—like the non-BP tank vessels (another 2% of traffic overall), other classes of deep draft vessels (e.g., container ships, bulk cargo vessels, tugs towing oil barges, etc.) and allow for the 2010 VTRA to incorporate more current (or more accurate/realistic) estimates of anticipated traffic levels and routes than used in the 2005 VTRA.

3. Project Description

The development of the 2010 VTRA will proceed in several phases. The first phase will determine a short list (likely two or three) of future projects, to include the proposed Gateway terminal, for future scenario definition for the 2005 updated VTRA model. Based on the types of ships projected to call on those future projects, the 2010 VTRA will determine a set of focus vessels (FVs) in the analyses. At this point, GW/VCU and PSP Advisory group will determine jointly the estimated number of transits, likely routes, and other parameters from recently published project descriptions and stakeholder engagement efforts with the corresponding maritime industries and specific commercial projects. This data collected is the only data gathering effort under this grant. Collected data will serve as the input data for the definition of a number of future traffic scenarios to be jointly defined in cooperation with the PSP and engaged stakeholders This step, consequently, enlarges the class of focus vessels (FVs) from the 2005 VTRA to include potentially: Oil Tankers, ATB's, ITB's, Oil Barges, Bulk Carriers and Container vessels. This is a preliminary list as enlarging the class of FVs markedly increases the computational complexity —stretching potentially the limits of the updated 2005 VTRA analysis model.

The main factor in evaluating a need to modify the updated 2005 VTRA analysis model is determined by observed computation times and computer memory capacity limitation when expanding the 2005 VTRA analysis using 2010 VTOSS Traffic data for the larger focus vessel group. Simulation and subsequent analysis runs using the 2005 VTRA model took approximately 8 hours for the 2005 focus vessel group. Enlarging the focus vessel group will likely require a separation of the analysis per focus vessel due to file size limitations of VTRA model recorded accident scenarios, potentially increasing calculation times by a factor two or more. Should computational complexity explode beyond reasonable calculation limits, a reduction of the focus vessel group may be required, but such decisions shall be made in cooperation with the PSP advisory group.

Based on the stakeholder vetted future scenario inputs, the VTRA analyses are expected to show changes in the region's risk profile—both system-wide and in specific geographic sub-regions (e.g., Western Strait of Juan de Fuca, Rosario Strait, etc.). An example of a geographic risk profile developed during the 2005 VTRA is displayed in Figure 1. Those changes will be conveyed to the PSP advisory group, who will use those results to suggest the most meaningful potential intervention measures to be modeled. Because: (1) the Puget Sound Harbor Safety Committee and US Coast Guard have agreed to use the GW/VCU VTRA as a common "language" by which they discuss and manage system-wide maritime traffic risk, and (2) there is strong stakeholder participation and transparency in the process – the researchers and the principal agencies involved (PSP, Ecology, USCG) expect that the results of this study will be embraced widely and used to modify regional Best Management Practices/Standards of Care and make regulatory improvements to improve maritime safety.

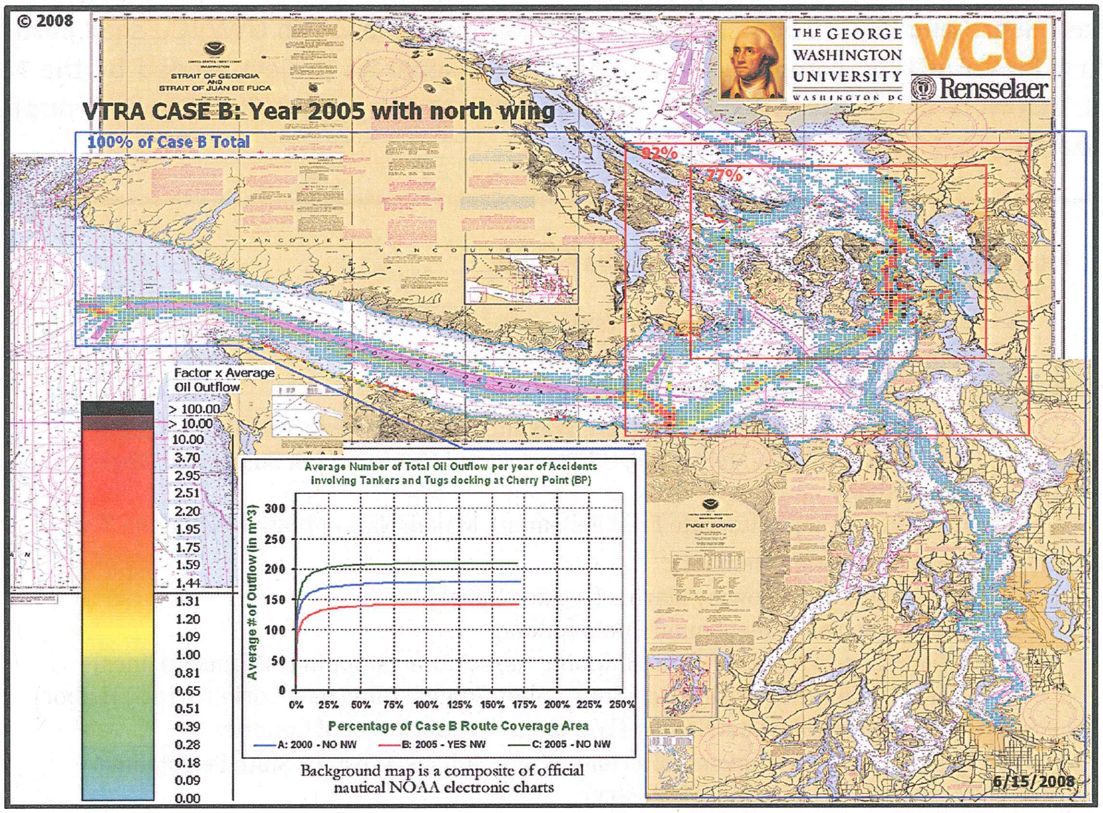

Figure 1. Example geographic profile of oil spill risk (*from 2005 VTRA*).

4. Organization and Schedule

The overall project to complete the 2010 VTRA and develop a Risk Management Strategy (RMS) is expected to proceed in five PHASES. The first PHASE involves a stakeholder process led by the Puget Sound Partnership and the Washington State Department of Ecology; supported by the US Coast Guard and Puget Sound Harbor Safety Committee in which GW/VCU shall participate. This first PHASE will be completed in parallel with a separate project funded by the MAKAH TRIBAL COUNCIL to update GW/VCU's VTRA analysis tool by GW/VCU. Figure 2 displays an organization chart of the PSP advisory group.

Puget Sound Partnership VTRA Advisory Group

Co-Chairs:

- Todd Hass, Puget Sound Partnership
- John Veentjer, Puget Sound Harbor Safety Committee

Federal, State and Tribal Leads [representing]:

- Chip Boothe (alternate John Neel), Washington State (Department of Ecology)
- Kiley Ross and R.E. McFarland, US Coast Guard [Sector Puget Sound and District 13, respectively
- Chad Bowechop (alternate Fred Felleman), Makah Nation [native American Tribes]

Core Steering Committee Members:

- Mark Homeyer, Crowley Marine [tug and barge]
- Del Mackenzie, Puget Sound Pilots [pilots]
- Mike Moore, Pacific Mechant Shipping Association [shipping/steamship lines]
- Vince O'Halloran, Washington State Labor Council (alternate Lori Provinci) [Labor]
- Mike Doherty, Clallam County [Washington Association of Counties
- Jess Shaw, Polar Tankers(alternate Frank Holems, Western State Petroleum Association) [petroleum industry]

Figure 2. Organizational Chart of PSP Advisory Group.

The second PHASE under this grant will firstly establish a 2010 VTRA base case scenario for the enlarged focus vessel group. The Phase II analysis for the enlarged focus vessel group can only commence with the completion of the MAKAH contract with GWU/VCU (anticipated by the end of February '13).

It is expected that the second and third PHASE will be led by the PSP Advisory Group with strong technical support from GW/VCU using this updated VTRA analysis tool. Pending additional funding, the fourth PHASE GW/VCU will provide technical support to a regional expert panel for the formulation of an RMS and the fifth implementation PHASE will be largely independent of the university consortium's work. This GW/VCU grant is to provide funding for GW/VCU cost and expenses for phases I-III only. Figure 3 provides an approximate timeline for the completion of Phases I-III.

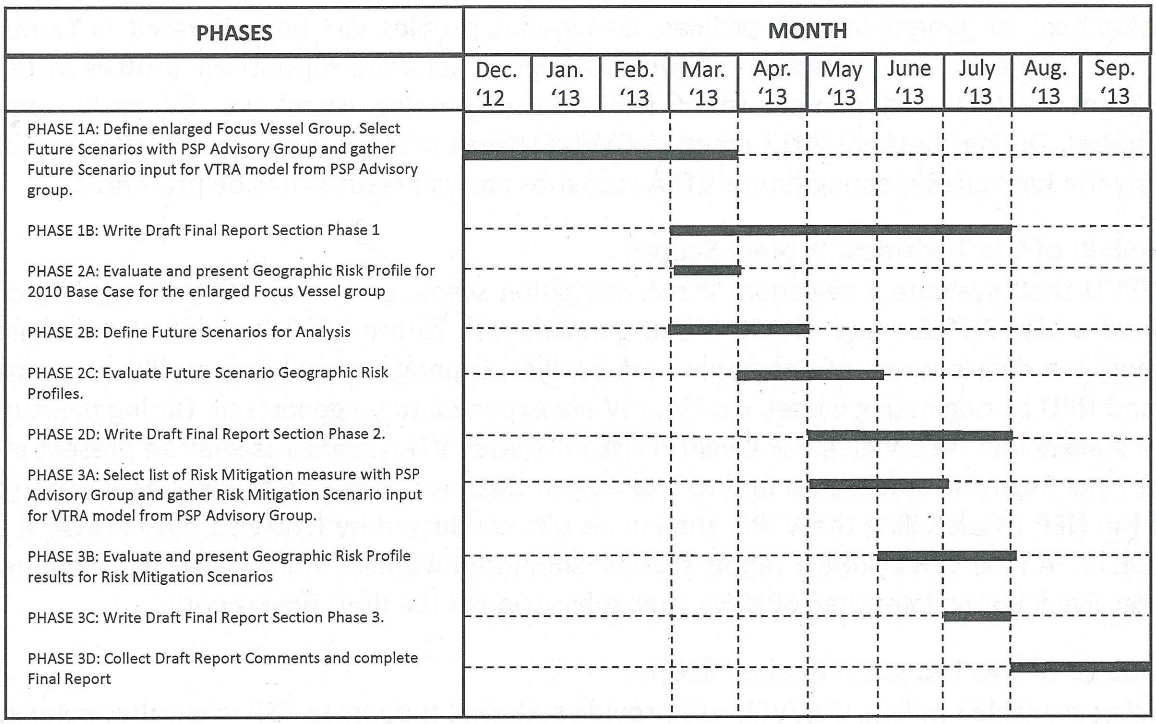

Figure 3. Approximate Timeline for PHASE I, II and III.

The PSP Advisory Group will meet/advise GWU/VCU in their development of the 2010 VTRA through meetings every two months to coincide with the meeting schedule of the PSHSC in 2013 (Every two months, first Wednesday in the month, first meeting in February 2013). During these meetings GW/VCU shall prepare progress presentations. GW/VCU will also be available via video conference for interim monthly with the PSP advisory group. Below a more detailed description of the different phases is provided.

PHASE I of the Technical Project Scope:

GWU/VCU met with a preliminary PSP Advisory group in October of 2012 and met with an established PSP advisory group in December 2012. During October 2012, December 2012 and February 2013 meetings, GW/VCU was available for consultation to facilitate the definition of future scenarios to be analyzed by GW/VCU during PHASE II and reported on analysis progress under the Makah contract with GWU/VCU. PSP will lead the effort to define the future scenarios during Phase I. To allow for their representation in the 2010 VTRA, questions need to be answered during PHASE I for future traffic scenarios involving number of vessels visiting other terminals in the area that are expected to increase vessel traffic and their anticipated vessel routes. This necessitates the close coordination with the PSP advisory group.

PHASE II of the Technical Project Scope:

GW/VCU will develop a 2010 baseline risk analysis scenario using the FV classes defined under PHASE 1. GW/VCU will implement the future traffic scenarios in their VTRA Analysis tool as defined under PHASE I and compare risk to the 2010 baseline risk scenario through the development of geographic risk profiles. Geographic profiles will be generated in terms of accident frequency and combined oil outflow volume. Separate oil outflow profiles in terms persistent oil (PO) and non-persistent (NPO) by originating vessel, i.e. FV or IV can be generated. During the April 2013 meeting GW/VCU shall present the baseline VTRA scenario. During the June 2013 meeting future VTRA scenarios analysis results shall be presented.

PHASE III of the Technical Project Scope:

GW/VCU shall evaluate a selection of risk mitigation scenarios in their VTRA Analysis tool as defined under PHASE I and PHASE II and compare risk to the 2010 baseline VTRA scenario through the development of geographic risk profiles. Separate oil outflow profiles in terms of PO and NPO by originating vessel, i.e. FV or IV are expected to be generated. During the August 2013 stakeholder meeting(s), risk levels of risk mitigation VTRA scenarios shall be presented. A draft Final Report is anticipated mid to late August 2013 for review to the PSP Advisory Group and the NEP QC detailing the VTRA analysis results conducted by GW/VCU over PHASE II and PHASE III. A final VTRA project report shall be submitted within a month after final comments are received, but no later than 60 days after submission of the draft final report.

PHASE IV of the Technical Project Scope:

Pending available funding, GW/VCU will provide technical support to PSP when they convene a regional expert panel in developing a Risk Management Strategy (RMS) being informed by the PHASE III final report. This phase seeks to support and inform the existing regional model of continuous improvement in maritime safety—especially as articulated in the PSHSC's Harbor Safety Plan—endorsed by the US Coast Guard Captain of the Port.

5. Project Work Products

The primary written work product to be developed is a final report that details:

(1) A historical vessel trend analysis;
(2) A description of the development and assumptions of future projection scenarios GW/VCU were asked to conduct under PHASE II; and
(3) A description of the development and assumptions of risk mitigation scenarios GWU/VCU were asked to evaluate under PHASE III; and
(4) A detailed description of 2010 FV traffic baseline risk for an extended FV class; and
(5) A comparison of PHASE II future traffic scenario risk levels to the 2010 baseline risk; and
(6) The effect of PHASE III risk mitigation scenarios on PHASE II future traffic scenarios.

A draft outline of the final report is provided in Figure 4.

1. EXECUTIVE SUMMARY
2. PROJECT DESCRIPTION
3. SUMMARY OF METHODOLOGY
4. THE 2010 BASELINE ANALYSIS
    4.1. Selection of focus vessel class
    4.2. Baseline geographic profile results
5. FUTURE SCENARIO ANALYSIS
    5.1. Selection and definition of future scenarios
    5.2. Future scenario geographic focus results
6. RISK MITIGATION SCENARIOS
    6.1. Selection and definition or risk mitigation scenarios
    6.2. Risk mitigation geographic profile focus results
7. CONCLUSION AND RECOMMENDATIONS
8. REFERENCES
9. APPENDICES
    9.1. Baseline individual focus vessel geographic profile results
    9.2. Future scenario focus vessel geographic profile results
    9.3. Risk mitigation focus vessel geographic profile results.

Figure 4. Draft outline of 2010 VTRA Final Report for PHASE I, II and III.

Presentations shall utilize the generated geographic risk profiles to facilitate stakeholder understanding and will synthesize/summarize analytical results. Interim presentations, the draft final report and final report shall be posted on Professor van Dorp's faculty page as agreed upon between the PSP and GWU/VCU.

6. Summary of 2005 VTRA Model Methodology

Is it safer for a river gambling boat in New Orleans to be underway than to be dockside? Should wind restrictions for outbound tankers at Hinchinbrook Entrance in the Prince William Sound Alaska be lowered from 40 knots to 35 knots? Is investment in additional life craft on board Washington State Ferries in Seattle warranted or should the International Safety Management (ISM) code be implemented fleet wide? Can enhanced ferry service in San Francisco Bay and surrounding waters alleviate traffic congestion on roadways in a safe manner? Do potential traffic increases made possible through the addition of a pier terminal at a refinery located north of the San Juan Islands in Washington State increase or reduce oil transportation risk?

The risk management questions above were raised in a series of projects over a time frame spanning more than 10 years and were addressed using a single risk management analysis methodology developed over the course of these projects by a consortium of universities. This methodology centers around stakeholder involvement and dynamic maritime risk simulations of Maritime Transportation Systems (MTS) that also integrate incident/accident data collection, expert judgment elicitation and consequence models [2-3]. Our model represents the chain of events that could potentially lead to an oil spill (see Fig .5). It has been peer reviewed by the National Research Council [4], top experts in the field of expert elicitation design and analysis, and has been continuously improved over time since its initial development in 1996. The model has been previously been used in the Prince William Sound Risk Assessment ([5-8]), the Washington State Ferries Risk Assessment [9], and the Exposure Assessment of the San Francisco Bay ferries [10]. Our analysis approach of involving stakeholders has been referred to in [1] as the collaborative analysis approach:

"In collaborative analysis, the groups involved in a policy debate work together to assemble and direct a joint research team, which then studies the technical aspects of the policy issue in question. Representative from all the participating groups are given the ability to monitor and adjust the research throughout its evolution. Collaborative analysis aims to overcome suspicions of distorted communication giving each group in the debate the means to assure that other groups are not manipulating the analysis. The ultimate goal is to generate a single body of knowledge that will be accepted by all the groups in the debate as a valid basis for policy negotiations and agreements. – George J. Busenberg, 1999."

The model was most recently used during the 2005 VTRA [11-13] and has been updated to 2010 traffic for the Makah Tribal Council. Thus, all data and model assumptions are pre-existing before this contract and have been peer-reviewed [2-13]. The following is a brief description of this modeling approach.

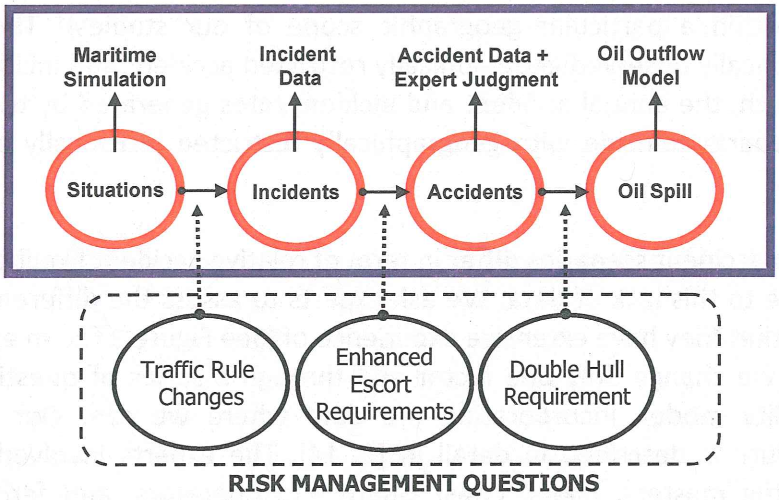

Figure 5. Causal chain of events interconnected by causal pathways. Risk management questions attempt to block these causal pathways.

Situations

Accidents can only occur when vessels are transiting through the system. Our maritime simulation model attempts to re-create the operation of vessels and the environment for one calendar year within the geographic scope of the study through maritime simulation/ replication. The traffic modeled re-plays the movement of VTS participating vessels (using VTOSS data) and simulates the movement of smaller fishing vessels, whale watchers, and organized regatta events. The environmental factors modeled include wind, fog, and current replayed hourly (using data sources publicly available from the National Climatic Data Center). Every minute over this calendar year, the simulation counts situations in which there is the potential for an accident to occur if things start to go wrong (see, e.g., [2]). The traffic conditions and environmental conditions are recorded in these situations and stored in a database representing an analysis scenario (for example the base case and various part or future traffic scenarios).

Incidents

Incidents are the events that immediately precede the accident. The types modeled include total propulsion losses, total steering losses, loss of navigational aids, and human errors. An exhaustive analysis of all possible sources of relevant accident, near miss, incident, and unusual event data is performed (see, e.g. [11, Appendices A and B]).

Accidents

The accident types included in this study are collisions between two vessels, groundings (both powered and drift), and allisions. The simulation counts the situations in which accidents could occur, while recording all the variables that could affect the chance that an accident will occur; these include the proximity of other vessels, the types of the vessels, the location of the situation and its wind, visibility and current. We know how often accidents do occur from our analysis of incident and accident data, but there is not enough data to say how each of these variables affects the chances of an accident; accidents are rare (typically, less than ten accidents were observed within a particular geographic scope of our studies)! The VTRA model is calibrated to historically observed geographically restricted accident and incident data (see [11, Appendix E]. As such, the annual accident and incident rates generated by the VTRA model for the base case scenario coincide with geographically restricted historically observed accident and incident rates.

To determine how accident scenarios differ in term of relative accident likelihood, we must turn to the experts due to this lack of data. We ask experts to assess the differences in risk of two similar situations that they have extensive experience of (See Figure 3 for an example question). In each question we change only one factor and through a series of questions we build our accident probability model, incorporating the data where we can. Our expert judgment elicitation procedure is described in detail in [2, 14]. The experts involved include typically tanker masters, tug masters, pilots, Coast Guard VTS operators, and ferry masters. A full description of the process, experts and series of questionnaires conducted during the 2005 VTRA is provided in [11, Appendix E]. No additional expert judgment elicitation is conducted during the 2010 VTRA and expert judgment elicitation results from the 2005 VTRA shall be used for the 2010 as agreed upon in the Scope of Work between GWU and the PSP.

Situation 1	TANKER DESCRIPTION	Situation 2
Strait of Juan de Fuca East	Location	-
Inbound	Direction	-
Laden	Cargo	-
1 Escort	Escorts	-
Untethered	Tethering	-
	INTERACTING VESSEL	
Shallow Draft Pass. Vessel	Vessel Type	-
Crossing the Bow	Traffic Scenario	-
Less than 1 mile	Traffic Proximity	-
	WATERWAY CONDITIONS	
More than 0.5 mile Visibility	Visibility	-
Along Vessel	Wind Direction	-
Less than 10 knots	Wind Speed	25 knots
Almost Slack	Current	-
Direction	Current Direction	-

Complete Propulsion Loss		
More? :____	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	____ : More?
Situation 1 is worse	<===================X===================>	Situation 2 is worse

Complete Steering Loss at a Moderate Angle		
More? :____	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	____ : More?
Situation 1 is worse	<===================X===================>	Situation 2 is worse

Complete Navigational Aid Loss		
More? :____	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	____ : More?
Situation 1 is worse	<===================X===================>	Situation 2 is worse

Human Error		
More? :____	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	____ : More?
Situation 1 is worse	<===================X===================>	Situation 2 is worse

Nearby Vessel Incident (but you do not know the specifics)		
More? :____	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	____ : More?
Situation 1 is worse	<===================X===================>	Situation 2 is worse

Figure 6. Example question during 2005 VTRA of a paired comparison questionnaire of situations for tanker collision accident attribute parameter assessment given all incidents.

Oil Spill

An oil outflow model [3] for collision and grounding accidents explicitly links input variables such as hull design (single or double, see Figure 5), displacement and speed, striking vessel displacement and speed, and the interaction angle of both vessels to output variables (see Figure 6): longitudinal and transversal damage extents of the tanker. Overlaying these damage extents on the vessel's design (see Figure 5) yields an oil outflow volume totaling the capacity of the damaged tank compartments. A similar model was developed for grounding accidents during the VTRA 2005. A total of 80,000 simulation accident scenarios described in the National Research Council SR259 report [15] published in 2001 served as the joint data set of input and output variables used in this "linking" process. The oil outflow model was designed keeping computational efficiency in mind to allow for its integration with a maritime transportation system (MTS) simulation. A full description of the oil outflow model developed during the 2005 VTRA including its parameters and their estimation is provided in [11, Appendix D].

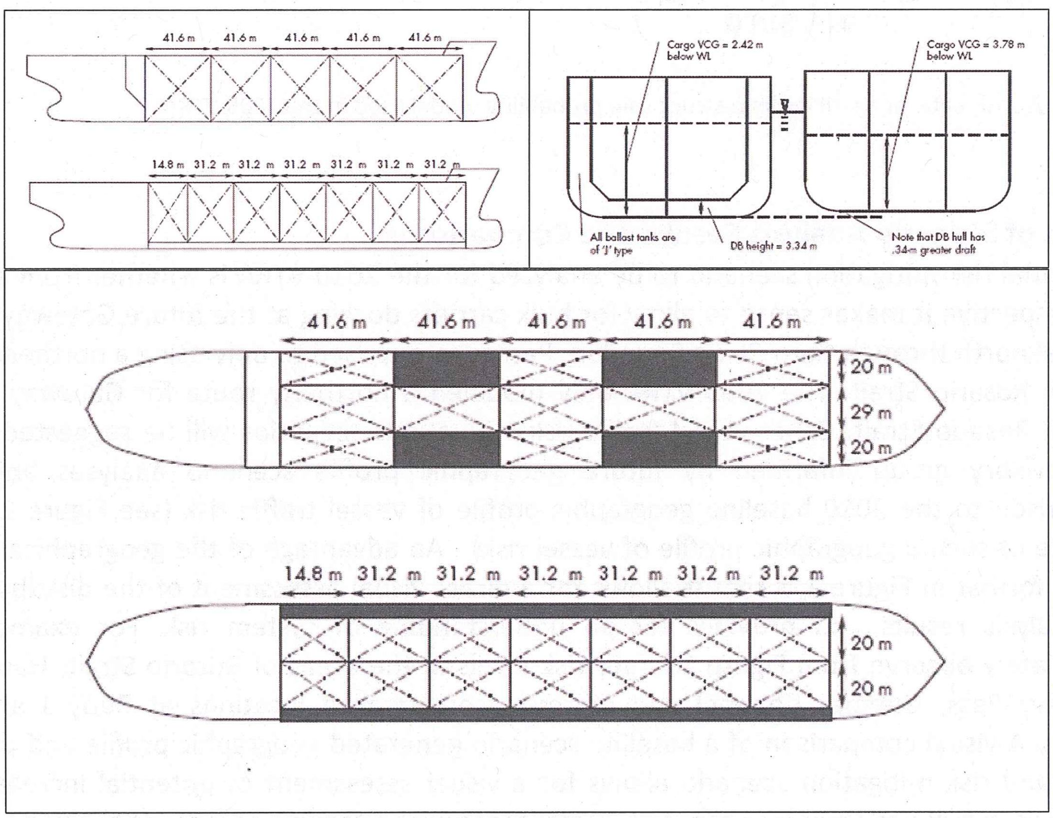

Figure 7. Single hull and double hull 150.000 DWT tanker designs used in 2005 VTRA taken from the National Research Council SR259 report [15].

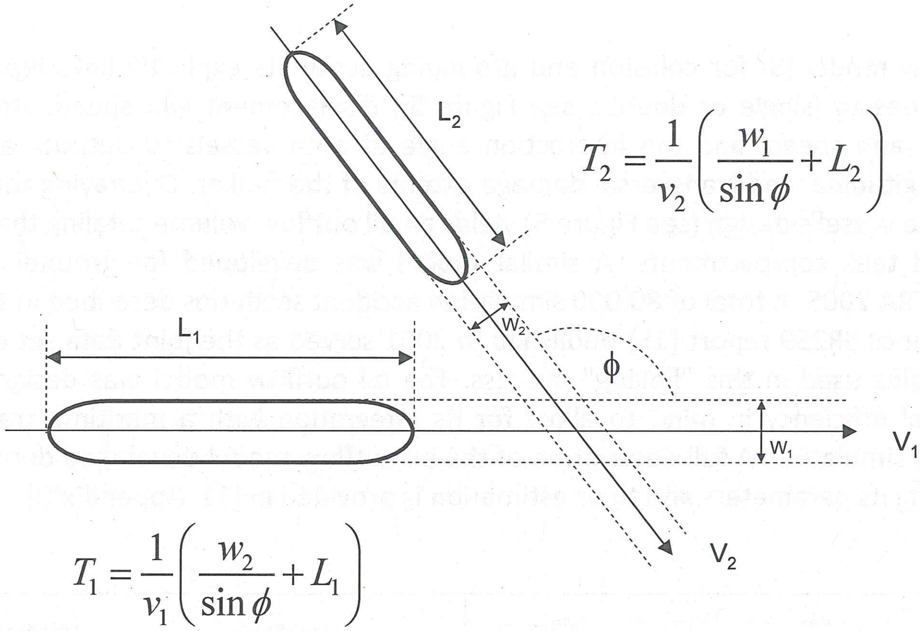

Figure 8. A schematic of a striking ship-struck ship probability model used in the 2005 VTRA.

Format of Scenario Analysis Results and Comparisons

A potential risk mitigation scenario to be analyzed for the 2010 VTRA is whether from a vessel risk perspective it makes sense to allow for bulk carriers docking at the future Gateway facility to travel north through Haro-Strait Boundary Passes as opposed to only using a northerly route through Rosario Strait. The 2005 VTRA only modeled a northerly route for Gateway vessels through Rosario Strait. Other vessel traffic risk mitigations scenarios will be suggested by the PSP advisory group informed by future geographic profile scenario analyses and their comparison to the 2010 baseline geographic profile of vessel traffic risk (see Figure 1 for an example of such a geographic profile of vessel risk). An advantage of the geographical profile display format in Figure 1 is that it allows for a direct visual assessment of the distribution of the analysis results and provides for an understanding of system risk. For example, we immediately observe from Figure 1 larger risk levels in the areas of Rosario Strait, Haro-Strait Boundary Pass, Guemes Channel and at route convergence locations at Buoy J and Port Angeles. A visual comparison of a baseline scenario generated geographic profile and that of a future and risk mitigation scenario allows for a visual assessment of potential increases and decreases in risk and their location. The percentages in the top left corners of the rectangles in Figure 1 allows for a more quantitative evaluation of system risk and its changes from a baseline scenario to future and risk mitigation scenario analysis results.

Sensitivity and Uncertainty of Analysis Results

More data is being made available electronically over time allowing for an even more accurate representation of the movement of vessel traffic and modeling of the accident scenarios within an MTS simulation. As a result, the movement of traffic within the MTS simulation more resembles a replication of how vessels actually moved rather than simulating them. An example being that every vessel in the MTS simulation arrives and departs as per the VTOSS 2010 data while retaining its route segments and vessel characteristics, such as e.g. its own vessel name. No doubt, this added level of detail reduces model uncertainty to a great extent. The evaluation of model uncertainty is not accounted for in traditional sensitivity/uncertainty analysis approaches.

With the increased availability of this electronic data, however, the time to prepare it in an electronic format that can serve as input to an MTS simulation increases as well. Despite these advances, one should always bear in mind that any model is an abstraction of reality in which simplifying assumptions are often necessitated to maintain computational efficiency. The increase of computational complexity to reduce model uncertainty within the 2005 VTRA methodology, does unfortunately not allow for application of traditional sensitivity/uncertainty analysis of output analysis results. We are pushing computational boundaries of existing computation platforms that the 2005 VTRA model runs on. As a result, we find that solely relative comparisons across accident types, across oil outflow categories and across risk intervention scenarios are particularly enlightening and informative and we concentrate less on the absolute values of the results in our analysis comparisons.

That being said, uncertainty of output analysis results for the 2005 VTRA methodology has been studied and funded by the National Science Foundation for smaller analysis context instances (See, [16,17]). In these studies it was concluded that ranking of scenarios/alternatives are robust within our analysis methodology with respect to changes in vessel traffic.

References

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Appendix: Glossary and List of Acronyms

- Allision – The collision of a vessel with its intended docking berth.
- ATB – Articulated Tug Barge
- Ecology – The Washington Department of Ecology's Spill Prevention, Preparedness and Response Program which is the primary state organization with authority and accountability for managing oil and hazardous material spill risk state-wide. Ecology is assisting PSP in conducting the VTRA with its expertise and experience.
- EPA – Environmental Protection Agency.
- FV – Focus Vessel.
- GWU – George Washington University is the prime subgrant awardee.
- VCU – Virginia Commonwealth University is a sub-awardee to GWU.
- GW/VCU – The technical team composed of GWU and VCU.
- ITB – Integrated Tug Barge.
- IV – Interacting Vessel.
- MTS – Maritime Transportation System.
- NEP QC – National Estuary Program Quality Coordinator
- NGO – Non-Governmental Organization.
- NPO – Non-Persistent Oil
- PO – Persistent Oil.
- PSP – The Puget Sound Partnership is the Washington state agency responsible for developing a Puget Sound Action Agenda, convening a Cross Partnership Oil Spill Work Group and for coordinating work to restore and protect Puget Sound.
- PSHSC – The Puget Sound Harbor Safety Committee.
- PSP Advisory Group – A steering committee of stakeholders advising the Puget Sound Partnership and GWU/VCU over the course of this study.
- QAPP – Quality Assurance Project Plan
- Study Area – The Washington waters of Puget Sound east of Cape Flattery, north of Admiralty Inlet and west of Deception Pass, and their approaches.
- USCG – US Coast Guard Sector Seattle, District 13.
- VTOSS – Vessel Traffic Operational Support System
- VTRA – Vessel Traffic Risk Assessment
- VTS – Vessel Traffic Service is the real-time marine traffic monitoring system used by the USCG, similar to air traffic control for aircraft.