CHAPTER 3

VTRA 2010 FINAL REPORT

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

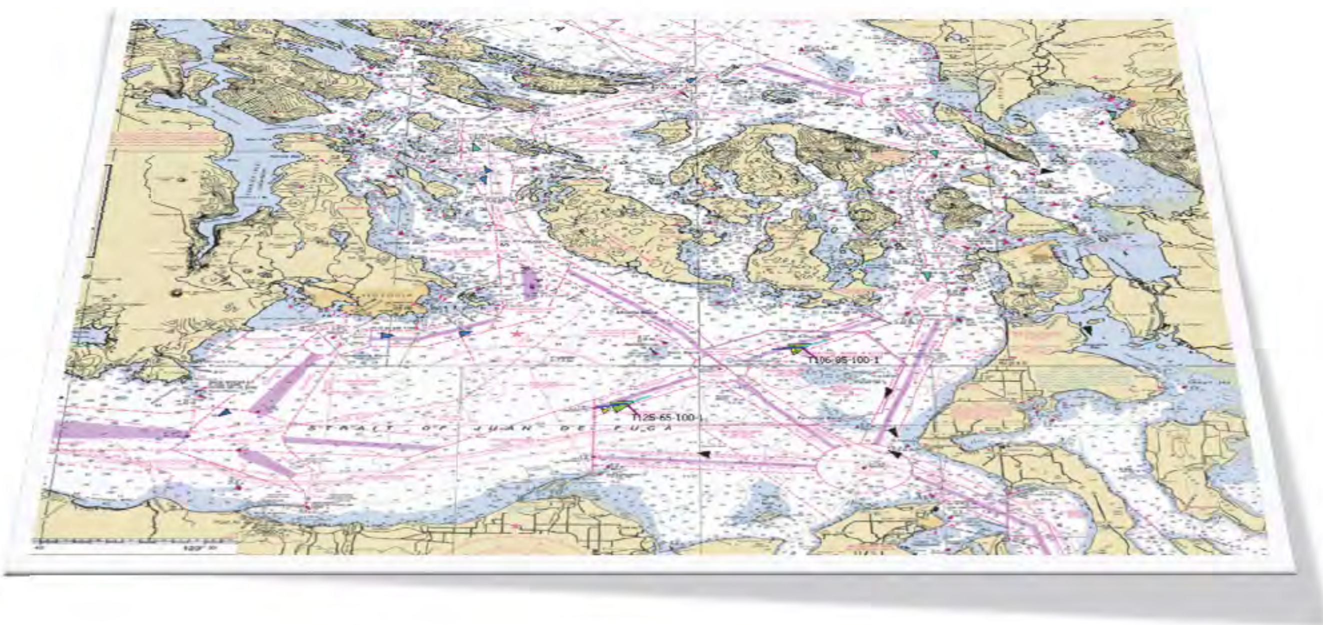

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Table Contents

3. UPDATING THE 2005 VTRA GW/VCU Model USING VTOSS 2010 DATA

By updating the 2005 VTRA model to a 2010 base year, it will more closely approximate the present-day patterns in traffic when using the GW/VCU VTRA analysis model to inform, for example, the State of Washington and the United States Coast Guard on what potential actions should be taken to mitigate increases in oil spill risk from large commercial vessel oil spills in the northern Puget Sound and the Strait of Juan de Fuca areas. The data source for modeling Vessel Traffic Service (VTS) responding traffic in the 2005 VTRA model was VTOSS 2005 data. Figure 19 displays the VTOSS coverage area including the Seattle, Tofino and Victoria VTS that service this area covering both US and Canadian waterways. An advantage of the VTOSS data is that it provides a single US - Canadian cross boundary data source for the three VTS providers. However, this too provides for one of the challenges when modeling vessel traffic as recording across these three VTS providers in the VTOSS data set is not consistent. For example, a vessel travelling through these three VTS areas on a single transit is assigned three separate trip ID's, one for each VTS.

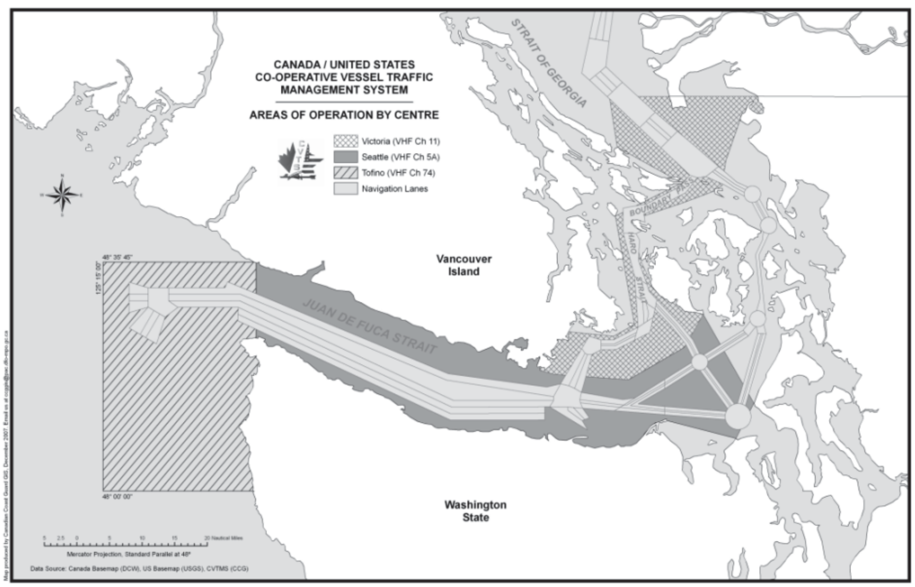

Figure 19.Coverage area of the Vessel Traffic Operational Support System (VTOSS).

To deal with this particular data issue, a modeling decision was made during the 2005 VTRA to resort to the construction of representative vessel routes by vessel type. In total 1756 representative vessel routes, depicted in Figure 20, were constructed to model all VTS responding traffic (both US and Canadian). Of that, a relative large number of 158 representative routes, depicted in Figure 12, were constructed to model the movement of oil tankers (≈ 2% of all traffic, see Figure 21).

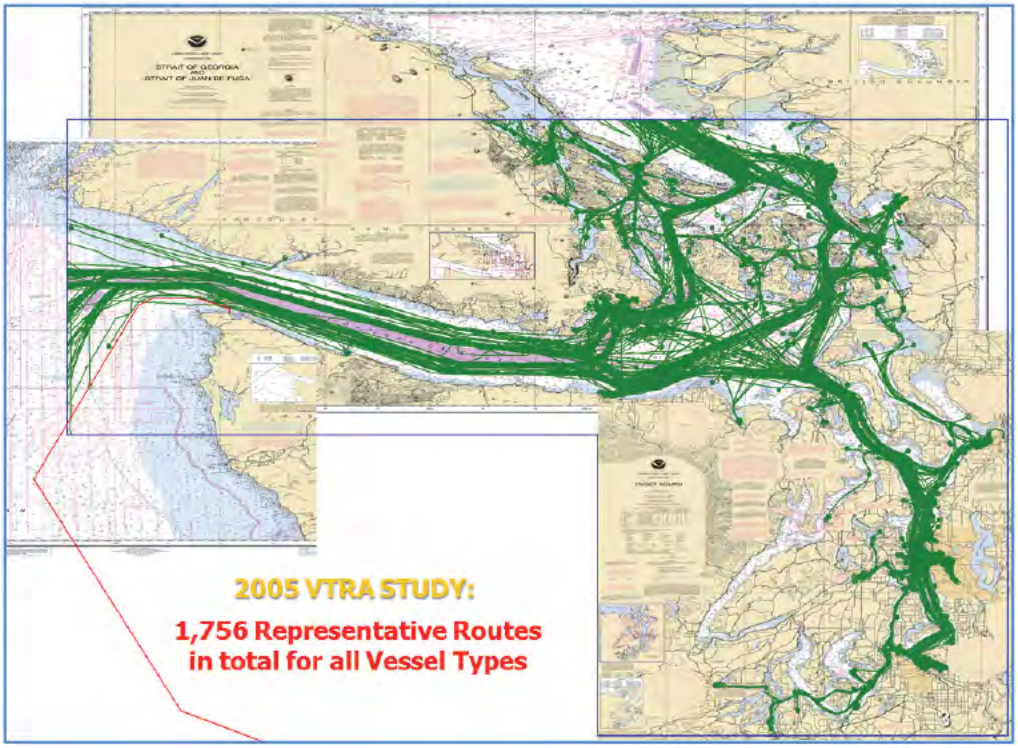

Figure 20. In total 1756 representative vessel route were constructed from 2005 VTOSS data during the 2005 VTRA to model the movement of VTS responding traffic in the GW/VCU MTS simulation model.

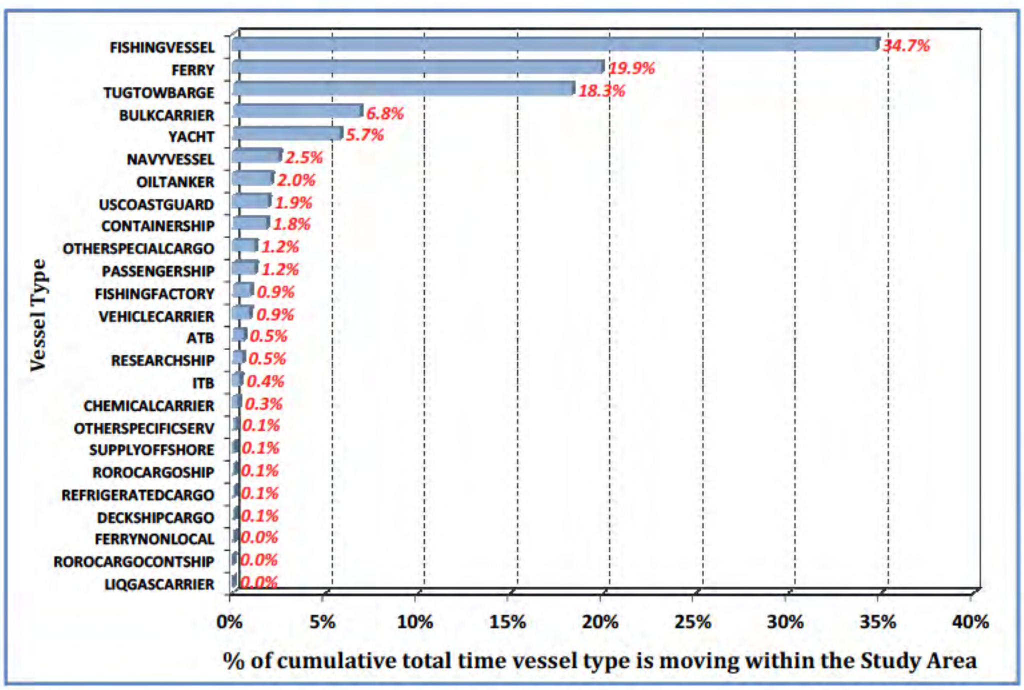

Figure 21. Tornado diagram displaying the cumulative percentage of time a vessel of a certain type is moving with the study area in the 2005 VTRA model over the course of one simulation year.

For example, only 22 representative routes were utilized to model container traffic (≈ 2% of all traffic, see Figure 21) and 47 to model bulk carrier traffic (≈ 7% of all traffic, see Figure 21). The specific routes for container vessels and bulk carriers in the 2005 VTRA are depicted in Figure 22. A relative large number of representative routes was selected in modeling oil tanker traffic during the 2005 VTRA since oil tankers were part of the FV group in that study, whereas container vessels and bulk carriers were considered Interacting Vessels (IV's), not FV's.

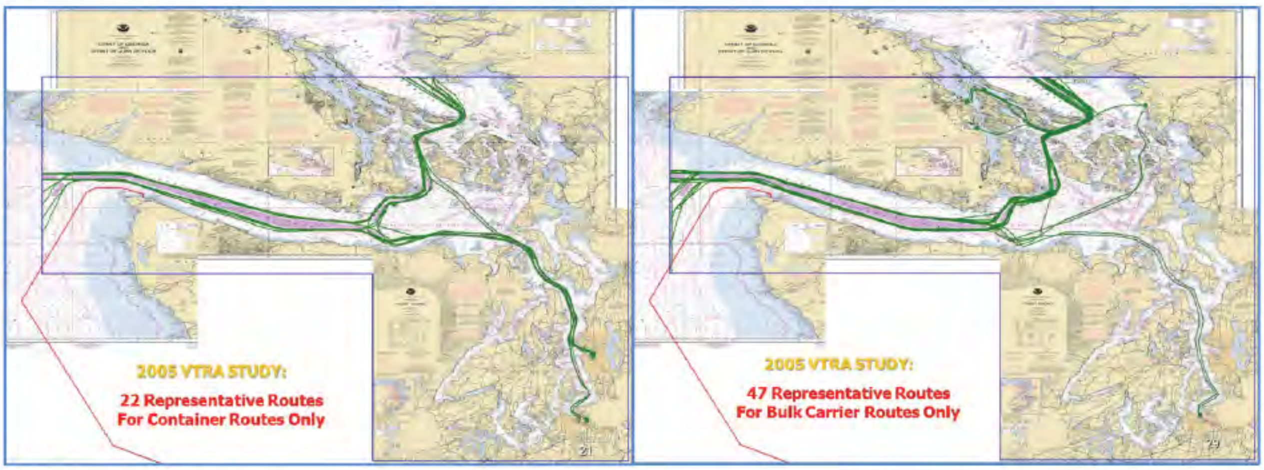

Figure 22. In total 22 (47) representative vessel route were constructed from 2005 VTOSS data during the 2005 VTRA to model the movement of container vessel (bulk carrier) traffic in the GW/VCU MTS simulation model.

To allow for inclusion of container vessel and bulk carriers in the focus vessel group for further analyses with the GW/VCU VTRA model, it would appear that a higher number of routes for these vessel types would be desirable. To that end, a modeling decision was made in updating the 2005 VTRA model to 2010 VTOSS data to attempt to retain a vessel's individual route throughout its transit rather than resorting to representative routes by vessel type. In that manner, FV group selection is not affected by a route modeling approach.

Algorithmic cleaning of VTOSS 2010 data

The VTOSS 2010 data consists of a set of waypoints of vessels along with identifying information about the vessel and the VTS center that collected the data point. Since 2005, VTOSS also added a trip identification number that indicates a set of waypoints for a particular vessel transiting through one VTS center's area. However, each VTS center assigns a different trip identification number to a vessel as it transits through the system leaving route segments and not complete routes. In addition, frequent alternative spellings of vessel names were observed. Once the vessel names were disambiguated, as many route segments as possible were connected algorithmically to make complete routes of vessels transiting the system. Figure 23 shows the result of algorithmically connecting route segments and depicts the remaining modeling challenges alluded to previously. Needless to say, remaining errors are apparent in Figure 23.

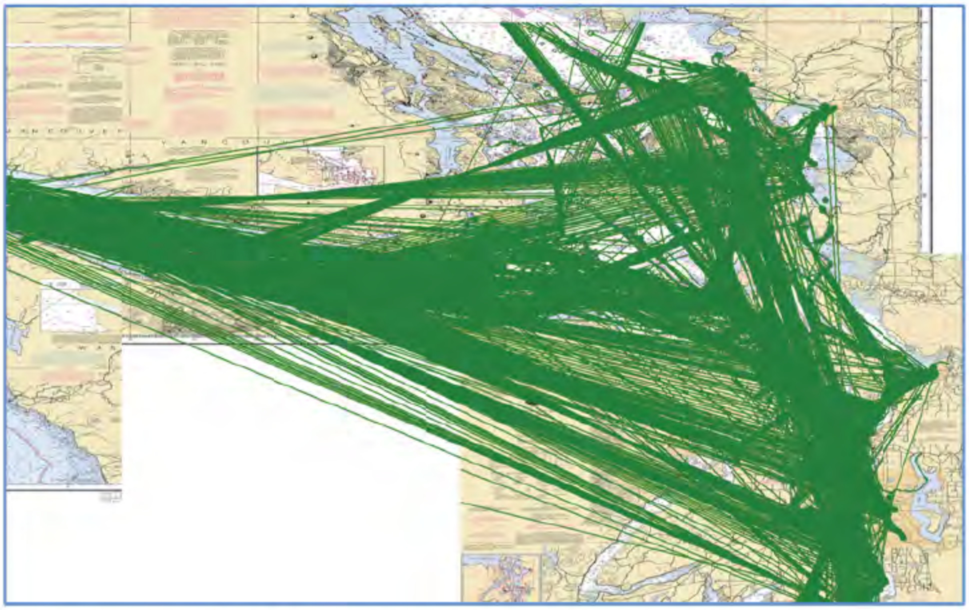

Figure 23. Route plots of the VTOSS 2010 data after algorithmically joining route segments.

Multiple VTOSS data phenomena cause the errors observed in Figure 23. Firstly, the time of collection of each waypoint is recorded in the VTOSS data and is used to sort the waypoints in order to form a route. The time is recorded using a 24 hour clock, but points occurring in the hour after midnight are frequently recorded as *12:xx* instead of *00:xx*. This causes the points recorded as *12:xx* to be a mixture of the vessel's location after midnight and after midday, causing the route to zigzag back and forth as shown in Figure 24. Another problem was caused by pieces of a route not being recorded by VTOSS, leaving non-contiguous pieces of a route connected by a straight line. In yet other cases, the same VTS center can assign a new identification number half way through a vessel's transit through their waters. Also simple errors were observed in identifying the location of the vessel as shown in Figure 25.

Additional algorithms were developed to remove a large proportion of the data inaccuracies depicted in Figure 23, Figure 24 and Figure 25. These algorithms were also designed to reduce the size of the VTOSS dataset by removing intermediate points when a vessel was in fact moving in a straight line. Once developed, these algorithms took <u>one month</u> to run on the approximately 50GBs of VTOSS 2010 data on a MacBrook Pro with a 2.7 Ghz Intel Core i7, 16 GB of 1600 Mhz DDR3 RAM, and 768GB SSD hard drive.

Figure 24. A route affected by the time problem after midnight in the VTOSS 2010 data.

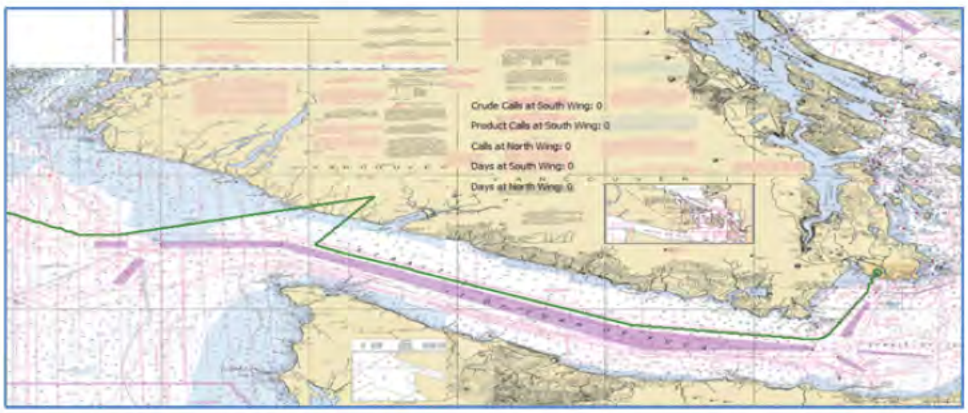

Figure 25. A route affected by problems identifying the correct location of the vessel.

Manual cleaning of VTOSS 2010 data

Unfortunately, as shown in Figure 26's left panel not all data inaccuracies can be resolved mathematically and removed algorithmically. Despite algorithmically cleaning the VTOSS 2010 data to construct contiguous routes for a single transit, some route segmentation remains. Algorithmic cleaning of oil tanker routes resulted in 2,345 route segments for oil tankers (see left panel of Figure 26). Observe from of Figure 26's left panel that following algorithmic cleaning only, oil tanker routes segments still display errors as a result of electronic transmission problems when recording a vessel transit in the VTOSS data. To further correct for those errors these 2345 route segments were manually cleaned resulting in 2328 route segments for oil tankers depicted in Figure 26's right panel using the VTOSS 2010 dataset. Recall that during the VTRA 2005 analysis a total of 1756 representative routes were constructed for all vessel types.

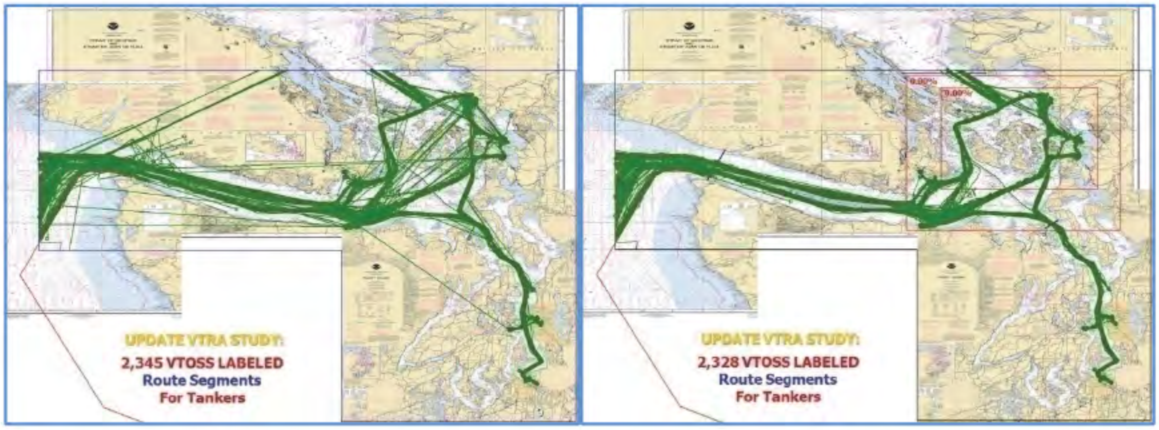

Figure 26. Left panel: 2,345 route segments after algorithmic cleaning of oil tanker routes. Right panel: 2328 route segments following manual cleaning of tankers routes following algorithmic cleaning.

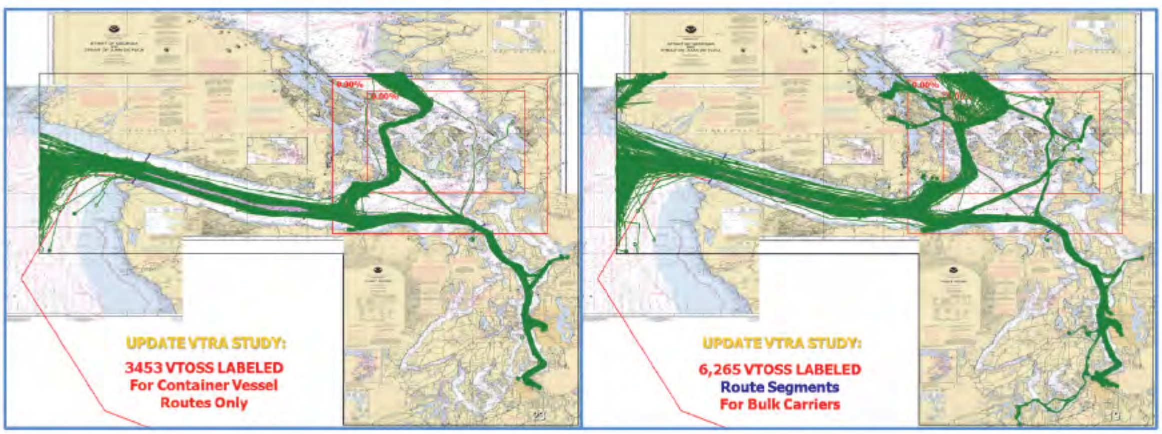

Figure 27. Left panel: 3,453 route segments after algorithmic and manual cleaning of container vessel routes. Right panel: 6265 route segments following algorithmic and manual cleaning of bulk carrier routes.

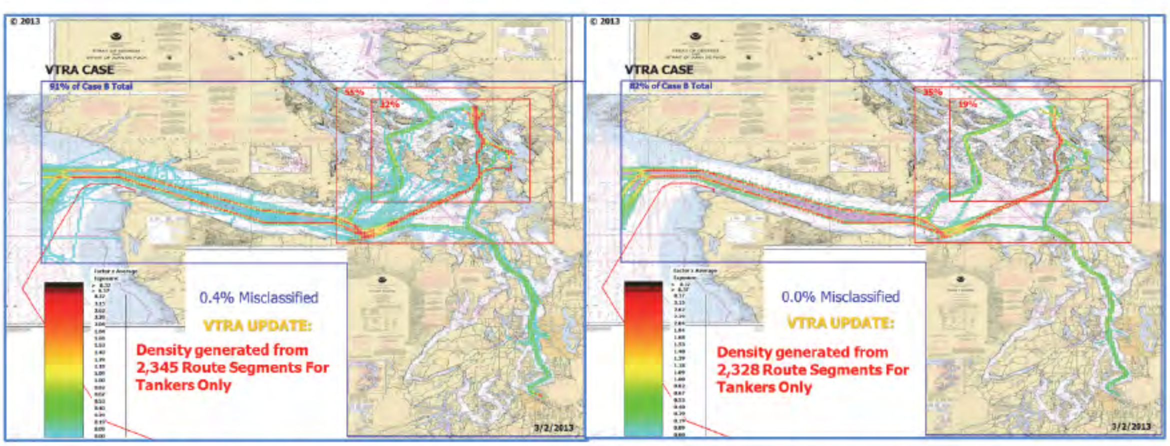

Figure 28.Left panel: Oil density tanker geographic profile generated using left panel routes in Figure 26. Right panel: Oil density tanker geographic profile generated using right panel routes in Figure 26.

Comparing Figure 26's right panel with Figure 11 one observes a larger dispersion of oil tanker routes in of Figure 26 than in Figure 11. The same observation can be made when comparing the algorithmically and manually cleaned routes for container vessels and bulk carriers in Figure 27 using VTOSS 2010 data, with the representative routes depicted in Figure 22 for these vessel types in the 2005 VTRA. In total, following algorithmic cleaning only of VTOSS 2010 data to construct route segments by vessel type, 79,500 route segments remained. Needless to say, it would simply be too time consuming to subject all these route segments to a manual cleaning process. Instead, it is suggested to manually clean routes, as demonstrated in Figure 26 for oil tankers and for those vessel types that are selected to be in a FV group. In anticipation of the inclusion of container vessels and bulk carriers in a FV group for scenario analyses their routes were manually cleaned as depicted in Figure 27.

Figure 28's left panel plots a route density for oil tankers generated using only the algorithmically cleaned routes displayed in Figure 26's left panel. Figure 28's right panel plots a route density for oil tankers using the both algorithmically and manually cleaned routes depicted in Figure 26's right panel. In Figure 28's left panel 99.6% of the tankers movements have a waterway zone (see Figure 28) assigned, whereas in its right panel 100% of tanker movements have a waterway zone assigned. In plotting this density, vessel movements that have no assigned waterway zone are not plotted. Figure 29 plots a graphic of the fifteen waterway zone definitions to be used in the updated GW/VCU MTS model.

The waterway zones ATBA (2), Islands Trust (10), San Juan Islands (11), Saragota Skagit (12) and Tacoma were added as separate zones in the updated VTRA model. The location ATBA (2) was assigned an equivalency of the WSJF (3) zone for the purposes of accident probability model, whereas the other added zones were assigned an equivalency with the Guemes Channel zone. The expansion of the number of waterway zones to accommodate an analysis for a larger class of focus vessels also required an expansion of the shoreline definition. The updated and expanded shoreline definition used in the VTRA 2010 model is depicted in Figure 30. Both the Department of Ecology and Puget Sound Pilots provided feedback on the shoreline definition in Figure 30, which plays an instrumental role in the analysis of POTENTIAL grounding frequencies.

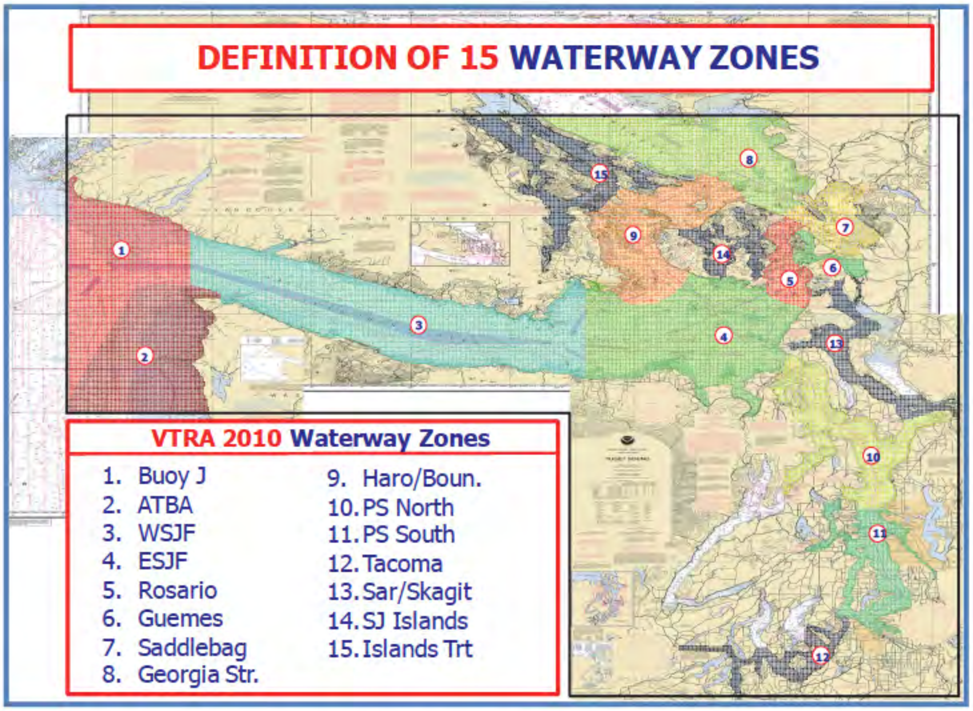

Figure 29. Waterway zone definitions used for the update of the GW/VCU MTS simulation from VTOSS 2005 to VTOSS 2010 data.

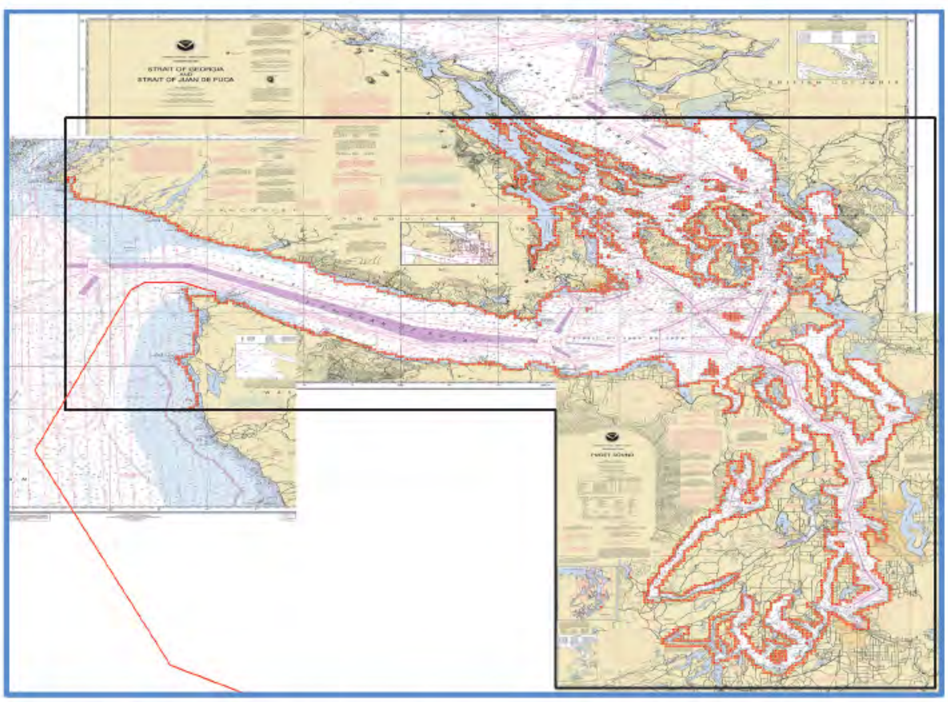

Figure 30. Expanded and revised shore line definition in VTRA 2010 model

Vessel master type definition

Table 3 shows a sample list of vessel names in the VTOSS 2010 data for which different vessel types are assigned. The number of route segments for each alternative vessel type is provided in the second columns. An examination of Table 3 reveals different vessel types that are commonly assigned to the same vessel name.

Some of the entries in Table 3 will indeed refer to different vessels that share the same name. In that case the different vessel types may be correctly assigned to the same vessel name. One suggestion to differentiate between vessels sharing the same name is to use Lloyd's identification numbers or other vessel identification numbers. Unfortunately, these identification numbers are not consistently entered across the three VTS centers Seattle, Tofino and Victoria providing the data for the VTOSS datasets. Thus, complete disambiguation of vessel names to vessel types is not possible.

Further examination of Table 3 also reveals vessel names that are assigned similar vessel types. Frequent groups of vessel types assigned to the same vessel names are:

1. Tanker and chemical carrier.
2. Ferry, non-local ferry, and passenger vessel.
3. Passenger vessel and yacht.
4. Container, bulk carrier, deck ship cargo, other special cargo, ro-ro cargo ship, ro-ro cargo container ship, vehicle carrier.
5. Research ship and other specific service vessel.

These similar classifications may also have been used differently across the three different VTS centers included in VTOSS 2010 dataset. To allow for this similar misclassification of vessel types, the vessel master type definition in Table 4 is introduced for the 26 vessel types in the VTOSS data sets. Observe from Table 4 that the vessel types in the first entry in the list above are counted as tankers, the second and third entries as passenger vessels, the fourth entry as cargo vessels, and the fifth entry as service vessels. This allows for meaningful comparisons between the VTOSS 2005 dataset and VTOSS 2010 dataset that are not affected by these similar vessel type misclassifications.

Misclassification of vessel types described above was also observed in the VTOSS 2005 data. However, about twice the number of route segments was involved as compared to the VTOSS 2010 dataset. Moreover in the VTOSS 2005 set misclassification across the vessel master type definitions in Table 4 were observed as well. For example, Table 5 shows a sample in the VTOSS 2005 dataset of cargo vessels that were sometimes classified as passenger vessels. Observe that in Table 5 that 50 transits (or route segments) were classified as passenger vessels when they should have been classified as cargo vessels. Moreover, in the VTOSS 2005 dataset route segments of vessels classified as passenger vessels were observed that did not have route segments classified as cargo vessels, but turned out to be cargo vessels when researched further. This problem was not apparent in the VTOSS 2010 data.

Table 3. A sample list of vessel names that are designated as different vessel types in VTOSS 2010

Vessel Name	# Route Segments	Vessel Type	Vessel Name	# Route Segments	Vessel Type
ABAKAN	3	BULK CARRIER	ALEXANDRIA BRIDGE	1	BULK CARRIER
ABAKAN	2	OTHER SPECIAL CARGO	ALEXANDRIA BRIDGE	2	CONTAINER SHIP
ADMIRAL PETE	22	FERRY (NONLOCAL)	ALIOTH LEADER	1	OTHER SPECIAL CARGO
ADMIRAL PETE	3	PASSENGER SHIP	ALIOTH LEADER	2	VEHICLE CARRIER
ADRIA ACE	1	OTHER SPECIAL CARGO	ALJALAA	3	CHEMICAL CARRIER
ADRIA ACE	2	VEHICLE CARRIER	ALJALAA	1	OIL TANKER
ADVENTURE	3	FISHING VESSEL	ALPINE PENELOPE	4	CHEMICAL CARRIER
ADVENTURE	1	YACHT	ALPINE PENELOPE	15	OIL TANKER
AEGEAN LEADER	4	OTHER SPECIAL CARGO	ALUMINATOR	14	FISHING VESSEL
AEGEAN LEADER	4	VEHICLE CARRIER	ALUMINATOR	2	TUG TOW BARGE
AFFINITY	5	CHEMICAL CARRIER	AMBA BHAVANEE	3	CHEMICAL CARRIER
AFFINITY	2	OIL TANKER	AMBA BHAVANEE	3	OIL TANKER
AKEMI	3	FISH(ING) FACTORY	AMERICAN BEAUTY	3	FISH(ING) FACTORY
AKEMI	1	FISHING VESSEL	AMERICAN BEAUTY	1	FISHING VESSEL
ALASKAN LEGEND	43	OIL TANKER	AMERICAN HIGHWAY	1	OTHER SPECIAL CARGO
ALASKAN LEGEND	1	YACHT	AMERICAN HIGHWAY	1	VEHICLE CARRIER
ALEUTIAN BEAUTY	2	FISH(ING) FACTORY	AMERICAN NO. 1	4	FISH(ING) FACTORY
ALEUTIAN BEAUTY	1	FISHING VESSEL	AMERICAN NO. 1	1	FISHING VESSEL
ALEUTIAN LADY	1	FISH(ING) FACTORY	AMETHYST ACE	3	OTHER SPECIAL CARGO
ALEUTIAN LADY	1	FISHING VESSEL	AMETHYST ACE	1	VEHICLE CARRIER
ALEX GORDON	5	SUPPLY (OFFSHORE)	AMY USEN	1	FISH(ING) FACTORY
ALEX GORDON	4	TUG TOW BARGE	AMY USEN	6	FISHING VESSEL
ALEXANDRIA BRIDGE	1	BULK CARRIER	ANDES	1	CHEMICAL CARRIER
ALEXANDRIA BRIDGE	2	CONTAINER SHIP	ANDES	1	OIL TANKER

Table 4. Master vessel type definition for the 26 VTOSS vessel type classification used in the GW/VCU MTS simulation model.

#	VESSEL TYPE	MASTER TYPE	#	VESSEL TYPE	Master Type
1	BULKCARRIER	Cargo	14	PASSENGERSHIP	Passenger
2	CHEMICALCARRIER	Tanker	15	REFRIGERATEDCARGO	Cargo
3	CONTAINERSHIP	Cargo	16	RESEARCHSHIP	Service
4	DECKSHIPCARGO	Cargo	17	ROROCARGOSHIP	Cargo
5	FERRY	Passenger	18	ROROCARGOCONTSHIP	Cargo
6	FERRYNONLOCAL	Passenger	19	SUPPLYOFFSHORE	Service
7	FISHINGFACTORY	Fishing	20	TUGTOWBARGE	Tugtow
8	FISHINGVESSEL	Fishing	21	UNKNOWN	Service
9	LIQGASCARRIER	Tanker	22	USCOASTGUARD	Service
10	NAVYVESSEL	Cargo	23	VEHICLECARRIER	Cargo
11	OILTANKER	Tanker	24	YACHT	Passenger
12	OTHERSPECIALCARGO	Cargo	25	ATB	Tanker
13	OTHERSPECIFICSERV	Service	26	ITB	Tanker

Table 5.Cargo vessels that were classified as passenger vessels in the VTOSS 2005 dataset

Vessel Name	Cargo Transits	Passenger Transits	Vessel Name	Cargo Transits	Passenger Transits
BRIGHT STATE	15	3	MIDNIGHT SUN	8	3
BRIGHT STREAM	16	7	MORNING MELODY	3	2
CAPE HORN	7	5	NORTH STAR	4	4
DONG FANG GAO SU	2	2	REINA ROSA	3	3
GREAT LAND	3	4	SKAUBRYN	17	6
IGARKA	3	3	SKAUGRAN	18	2
IVORY ARROW	4	2	UNITED SPIRIT	5	4
Total	**50**	**26**	**Total**	**58**	**24**

Comparing representative routes approach to the route segment approach

The fifth column in Table 6 provides by vessel master type the percentage of time that a waterway zone is assigned to a vessel movement for the GW/VCU MTS simulation model using VTOSS 2005 data. Similarly, the fifth column in Table 7 provides by vessel master type the percentage of time that a waterway zone is assigned to a vessel movement for the updated GW/VCU MTS simulation model using VTOSS 2010 data. Recall Table 4 provides the vessel master type definition used in the generation of Table 6 and Table 7 for the 26 vessel types in the VTOSS data sets. These percentages (in Table 6 and Table 7) are evaluated by dividing the number of minutes per year a vessel is moving within the MTS simulation with a waterway zone assigned by the total number of minutes a vessel is moving (see the third and fourth columns in Table 6 and Table 7).

Table 6. Route and density data for 6 vessel master types generated using the GW/VCU MTS simulation model with 2005 VTOSS data and location definitions in Figure 29.

Vessel Master Type	# Represent. Routes	# Minutes per Year	# Minutes per year No Location	% Time Location Assigned	% of Traffic	Average # Vessels
Cargo	106	5344799	6821	99.9%	13.7%	10.2
Tanker	164	1313096	444	100.0%	3.4%	2.5
TugTow	1185	7272609	17925	99.8%	18.7%	13.8
Service	5	1039769	942	99.9%	2.7%	2.0
Passenger	164	9701338	54771	99.4%	25.0%	18.5
Fishing	132	14201790	64223	99.5%	36.5%	27.0
Total	1756	38873401	145126	99.6%	100.0%	74.0

Table 7. Route and density data for 6 vessel master types generated using the updated GW/VCU MTS simulation model with 2010 VTOSS data and location definitions in Figure 29.

Vessel Master Type	# Represent. Routes	# Minutes per Year	# Minutes per year No Location	% Time Location Assigned	% of Traffic	Average # Vessels
Cargo	14640	7468850	51583	99.3%	18.5%	14.2
Tanker	3340	1287457	2838	99.8%	3.2%	2.4
TugTow	40704	7927747	171967	97.8%	19.7%	15.1
Service	2458	614972	6730	98.9%	1.5%	1.2
Passenger	14521	9090031	40756	99.6%	22.6%	17.3
Fishing	3837	13920520	68899	99.5%	34.5%	26.5
Total	79500	40309577	342773	99.1%	100.0%	76.7

The second column in Table 6 and Table 7 provides the number of route segments and representative routes used in the GW/VCI MTS simulation model using VTOSS 2005 and VTOSS 2010 data respectively. Although a slightly higher accuracy is observed in the fifth column in Table 6 (2005) compared to the fifth column in Table 7 (2010), a definite improvement in vessel route dispersion is observed by going from Figure 22 (2005) to Figure 27 (2010) for container vessels and bulk carriers. Thus by retaining a vessel's individual route using the VTOSS 2010 data, vessel movements in the updated GW/VCU MTS simulation are more representative than the former GW/VCU MTS model using the 2005 VTOSS dataset. The percentage of total moving traffic by vessel master type, depicted in the sixth columns in Table 6 and Table 7, are evaluated by dividing the number of minutes in the third columns by the total sum of the third column. The average number of moving vessels by master type at any arbitrary point in time is evaluated by dividing the minutes in the third column in Table 6 and Table 7 by the total number of minutes in a calendar year. Thus in Table 6 (2005) the GW/VCU MTS model evaluated an average of 74.0 moving vessels in the system at any arbitrary point in time, whereas in Table 7 (2010) an average of 76.7 vessels was evaluated.

To illustrate the fluctuation in the number of vessels moving in the study area over a calendar year, however, Figure 31 plots the time series (every 15 minutes) of the number of vessels excluding ferries, yachts and fishing vessels for the GW/VCU MTS simulation model using VTOSS 2005 and VTOSS 2010 data. Figure 32 on the other hand plots this time series comparison for ferries, yachts and fishing vessels. Both Figure 31 and Figure 32 serve as a reminder that "the world is not average" and that vessel risk, of which number of vessels moving in the system is a driver, is not a constant but a dynamic quantity that changes over time. The larger goal of vessel risk management is to reduce the overall average risk level while managing the variation of the time series of risk by avoiding "high" risk spikes.

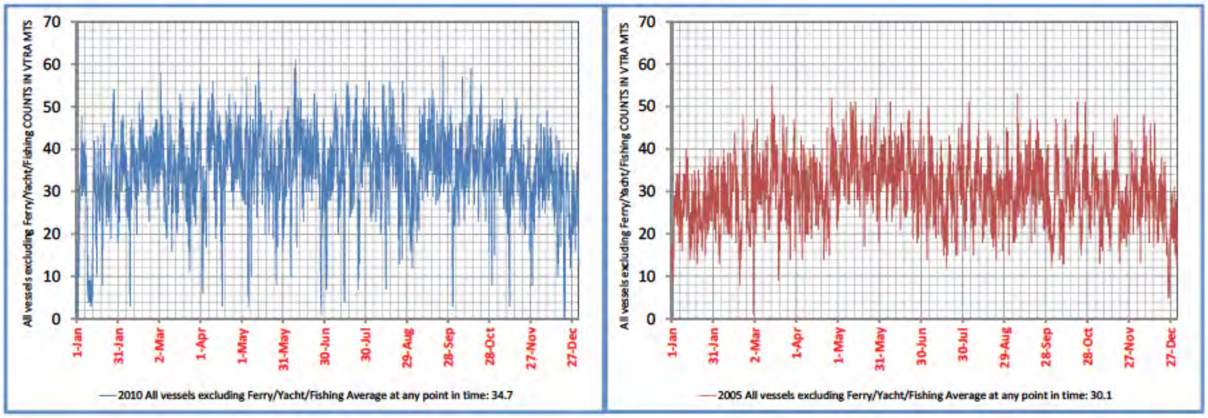

Figure 31.Left panel: Time series of counts of all vessels excluding ferries, yachts and fishing vessels in the system for the GW/VCU MTS simulation model using the VTOSS 2010 dataset; Right panel: Same using the VTOSS 2005 dataset.

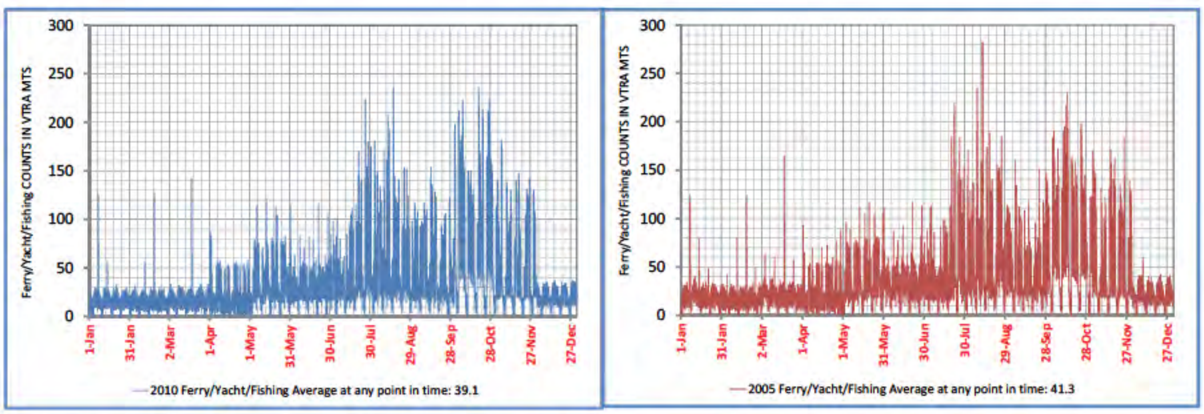

Figure 32. Left panel: Time series of counts of all ferries, yachts and fishing vessels in the system for the GW/VCU MTS simulation model using the VTOSS 2010 dataset; Right panel: Same using the VTOSS 2005 dataset.

Moving from Sampled Speeds to Calculated Speeds

As discussed in Section 2, the VTRA 2005 simulation sampled speeds from the distribution of all vessel speeds of a given type of vessel in the 2005 VTOSS database. So a given container vessel may actually transit at the speed of another container vessel in the database. The vessel also transited along a representative route for all vessels of that type traveling between its departure and destination points. In the VTRA 2010 simulation, the vessel travels along its own route and we have the start time and the end time for that transit in the 2010 VTOSS database. Figure 33 shows one such route for the Westwood Rainier cargo vessel. In the VTRA 2010 simulation, we calculate the length of the route, so we can calculate the average speed of the vessel on that transit. The Westwood Rainier started its transit at 8:58 pm on January 1st, 2010 and ended its transit the next morning at 8:09 am. The transit took 11 hours and 11 minutes and was calculated (after the route cleaning discussed above) to be 157.26 nautical miles. This means the vessel averaged 14.06 knots over the transit. The Westwood Rainier has a maximum speed of 16.1 knots and an average speed of 14.1 knots (according to www.marinetraffic.com), so this calculation appears quite accurate.

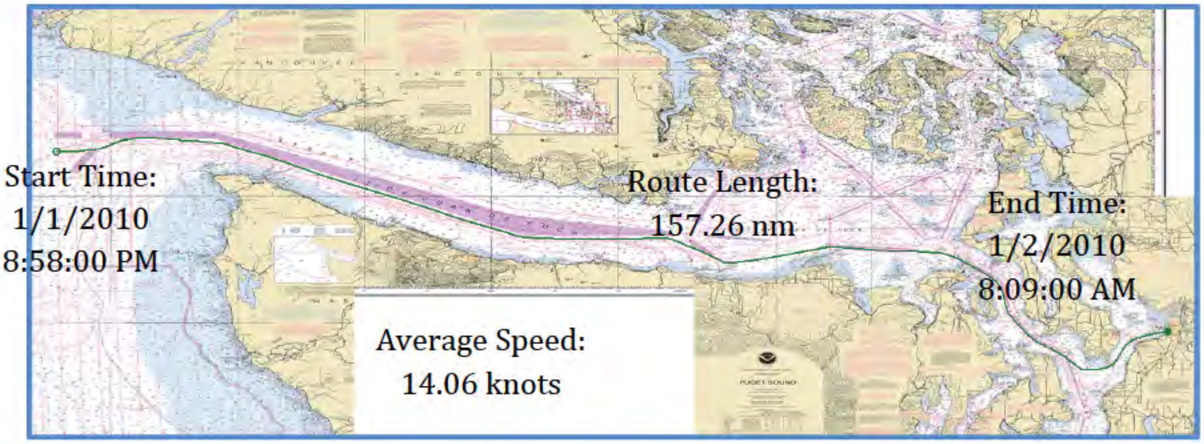

Figure 33. A route followed by the Westwood Rainier cargo vessel and its calculated average speed.

One must consider, however, that the vessel would have slowed around the pilot station and as it approached dock, so it would not have moved at this average speed throughout the transit. It also had moderately strong currents in the direction it traveled throughout the entire transit, so it would have made more than 14.1 knots for other parts of the transit. Thus, we must start the simulated transit at a higher speed and then reduce the speed based on the location of the vessel and the traffic rules (one-way zones, pilot station, approaching dock, etc.). For each transit, we calculated a speed accuracy factor by taking the simulated length of the transit using the average speed as the starting point and divided by the length of the transit in the 2010 VTOSS database. We calculated speed calibration multipliers for each vessel type to ensure that the speed accuracy factor was as close to 1 as possible.

Figure 34 shows the overall distribution of the speed accuracy factor for all vessels once the speed calibration multipliers were used for the initial speed of the vessel. The mean is 1.0003 with a 95% confidence interval of [0.9995,1.0012]. It is not possible to achieve a value of 1 as each change to the speed calibration factors can change the dynamics of the system, but the calculations are accurate on average to four decimal places. This does not mean that every transit is accurate to four decimal places. However, only 10% had a speed accuracy factor below 0.9 and only 10% had a speed accuracy factor over 1.1. Speeds that were clearly inaccurate based on the VTOSS data were sampled from the original speed distributions. Thus, we could accurately model the actual speed for a given transit and only sample general vessel type speeds for a few transits.

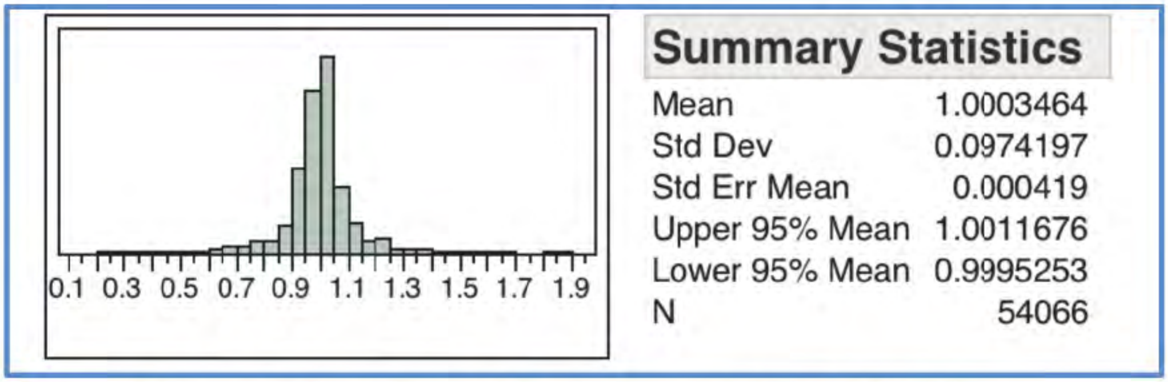

Figure 34.The distribution of the speed accuracy factor for all transits..

Extending VTRA 2005 incident and accident probability models

During the VTRA 2005 accident probability models given the occurrence of an incident (mechanical or human error) were developed separately for tankers and ATB's. Mechanical incidents considered were; propulsion, steering and navigational aid failures. To accommodate the expansion of the focus vessel class to include also bulk carriers, container vessels, chemical carriers and oil barges, the tanker accident probability models were utilized for the container vessels, bulk carriers and chemical carriers, whereas the ATB models were utilized for oil barges.

In the VTRA 2005 annualized historical mechanical incident data was collected for the tankers and ATB's that visit the cherry point terminal and were carefully vetted incident by incident. A factor 3 was applied to account for human error incidents, which was based on the observation that out of 4 accidents three had a human error as their immediate cause. The VTRA 2005 simulation model incident rates were calibrated to the annualized statistics and converted to an incident rate per unit time on the water, taking advantage of the VTRA 2005's model capability of distinguishing short routes from long ones while taking into account vessel speeds as well.

While incident data was collected for freighters as a vessel class during the VTRA 2005, it was not broken down by container, bulk carrier or any of the other 5 cargo vessel types and was not as carefully vetted as the incident data for tankers and ATB's. Hence, to accommodate the expansion to a larger focus vessel class we assumed that the incident rates by unit time on the water for tankers also apply to the container, bulk carrier and other cargo vessel class while taking into account the amount of travel time of each vessel class in the VTRA 2010 model. Figure 35A displays the incident rates by moving hour and demonstrates that bulk carriers, container ships, other cargo vessels and chemical carriers are assigned the incident rates for tankers, whereas the oil barge class are assigned the incident rates for ATB's.

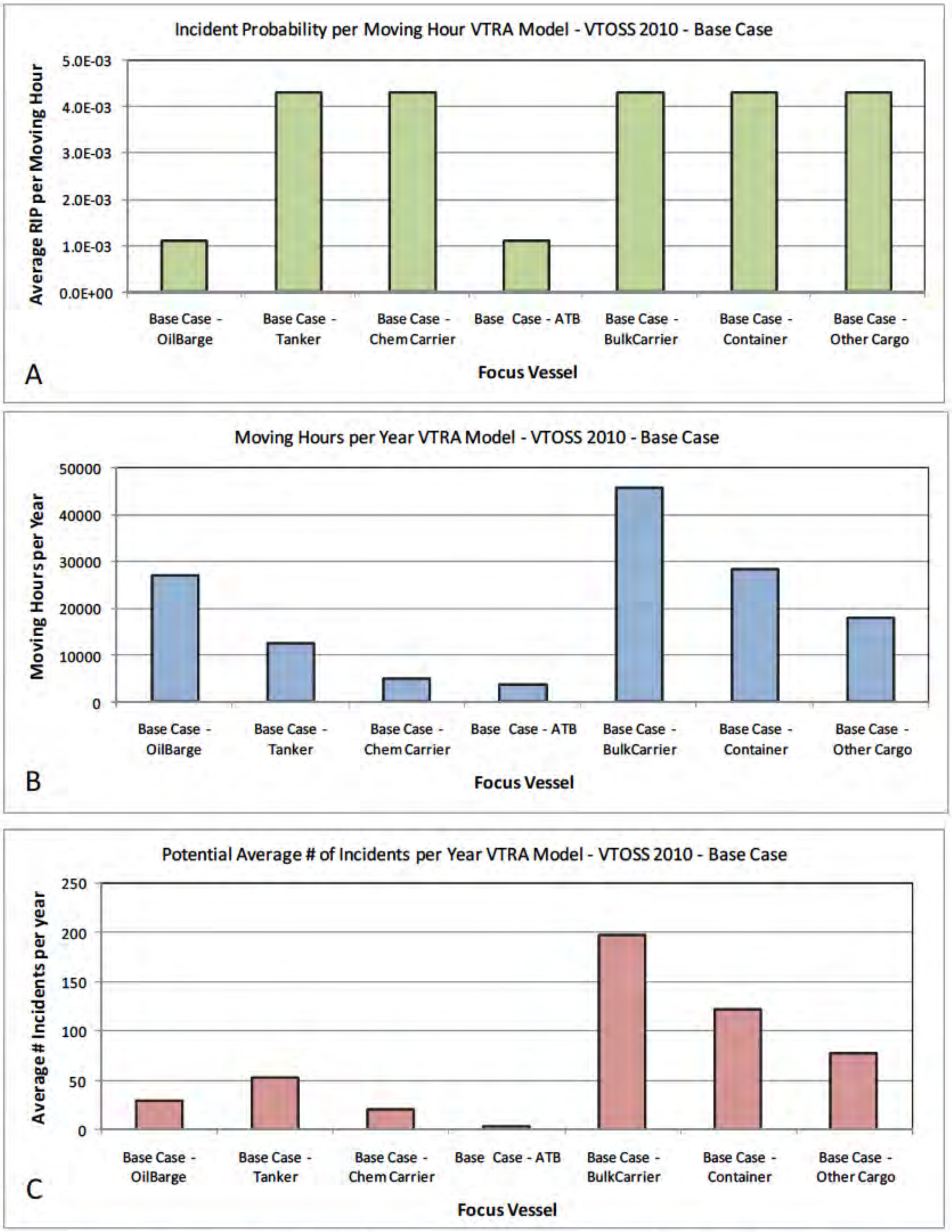

Figure 35. A: Incident rate per moving hour by focus vessel; B: Moving hours in VTRA 2010 model by focus vessel; C: Potential number incidents per year by focus vessel

Figure 35 further visualizes the effect of these assumptions on the annualized incident rates by vessel category. Combining the incident rates per moving hour (Figure 35A) with the amount of moving hours per year (Figure 35B) in the VTRA 2010 model, results in the potential average number of incidents per year as depicted in Figure 35C. Observe from Figure 35C that the bulk carrier class has the largest potential number of incidents per year in the VTRA 2010 model which is primarily driven by the fact that the largest portion of the focus vessel traffic in the VTRA study area are in fact bulk carriers.

Oil carrying assumptions for focus vessels

Of the tank focus vessels, tankers and chemical carriers are identified in the vessel type record in VTOSS. ATBs and ITBs are not specifically identified, but there are a limited number of them, so they can be identified by name. However, oil barges are only listed as a tug tow barge in VTOSS. The records for tugs sometimes indicate the barge type as bulk cargo, derrick, light, log barge, petroleum, or wood chip. However, a blank record can either mean there is no barge or that the data was not recorded by the VTOSS. To identify oil barges, we collected the list of all tug names that were listed as towing a petroleum barge at some point in 2010. These names were then provided to the Puget Sound Pilots who indicated whether they were exclusively used for petroleum based on their extensive knowledge of vessels in the study area. They were also asked to identify other tugs that were exclusively used for petroleum. In this manner, we could use the non-blank VTOSS records to identify the tug's barge and use the Puget Sound Pilot's information to identify oil barges with blank records. While during the VTRA 2005 some tankers will still of the single hull type, in the VTRA 2010 analysis all tankers, ATB's and oil barges are of the double hull design. Moreover fuel tanks of 40% of cargo focus vessels are assumed double hull protected, whereas the remainder of the cargo focus vessel fuel tanks are single hull protected.

The culmination of the oil barge movement modeling effort is depicted in Figure 36 and Figure 37. Please observe from Figure 36 that oil barge movement modeling in the VTRA 2010 model accounts for about 54.5% of the movements of all tank focus vessels. The predominant movement of oil barges is a north south movement between the Cherry point, Ferndale and Anacortes refineries and the southern Puget Sound. However, quite a significant number of oil barges travel north and south to Canada. A lesser density is observed entering/leaving the Strait of Juan de Fuca.

Unfortunately, no information is collected within the VTOSS 2010 data set regarding the volume of cargo oil or type of cargo oil on board a particular tank vessel. While vessel traffic density movement tends to be a driver of accident frequency analysis, the oil that vessel carry tends to be a driver for oil outflow analysis. To represent oil movement within the VTRA 2010 model we have had to therefore rely on set of overarching assumptions regarding the amount and type of oil that moved through the study area by vessels. These assumptions were made based on interactions

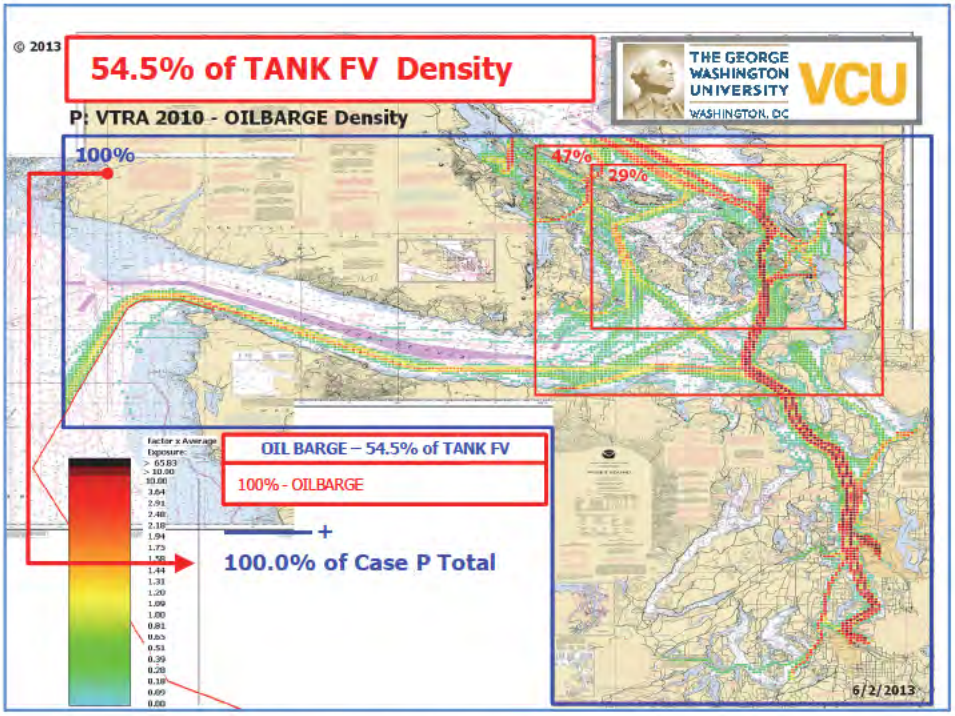

Figure 36.2D Traffic density of tugs towing/pushing oil barges in the VTRA 2010 model.

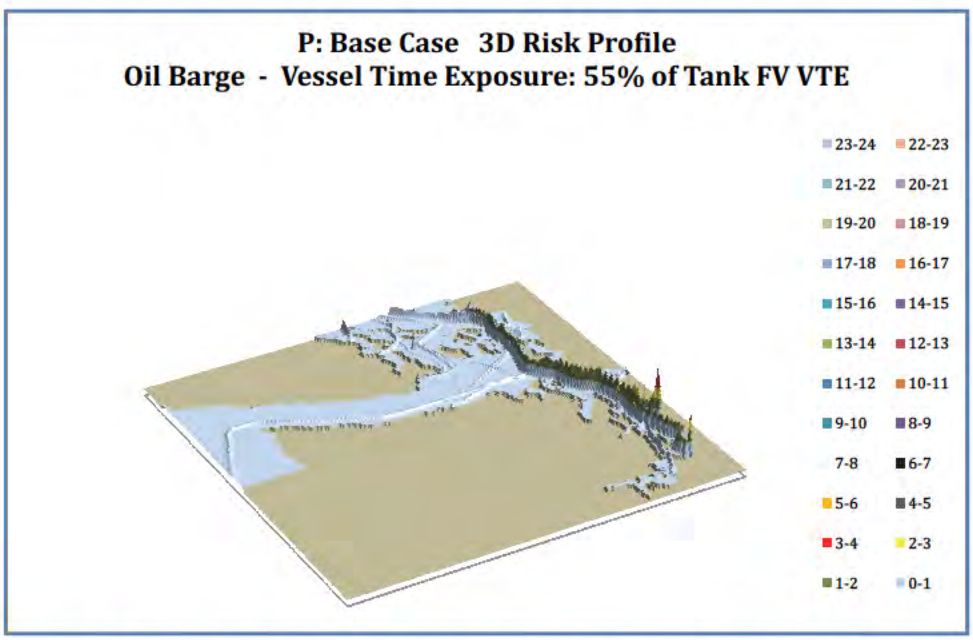

Figure 37. 3D Traffic density of tugs towing/pushing oil barges in the VTRA 2010 model.

with the VTRA 2010 Steering Committee and other stakeholders over the course of the study and are listed below.

List of oil carrying assumptions in VTRA 2010 model:

1. Tankers are classified as crude or product carriers by name
2. Chemical carriers transport product
3. Oil barges are assumed to transport product
4. Focus vessels fuel tanks are 50% full
5. US bound crude tankers are assumed fully laden as they arrive in study area and drop of equal amounts at their stops and leave empty
6. Canadian bound crude tankers are assumed empty as they arrive and fully laden as they depart
7. Product tankers and ATB's are assumed fully laden as they depart study area, empty as they arrive
8. Chemical carriers are assumed fully laden as they arrive in the study area, empty when they leave the study area
9. When ATB's go back and forth between two destinations within the study area they are assumed 50% full
10. Oil barges are assumed fully laden as they travel through study area
11. Tank focus vessels not covered by assumptions 1-10 are assumed fully laden

Combined with a validated picture of vessel traffic and data recorded in the VTOSS 2010 dataset regarding vessel size in terms of dead-weight tonnage, we hope the set of assumptions above adds realism to the movement of oil throughout the VTRA study area. Such realism is important when comparing a Base Case scenario to another What-If traffic scenario in terms of oil spill transportation risk. The effect of these assumptions are summarized in separate geographic density profiles of product, crude and fuel movements which serve as a starting point of the VTRA 2010 potential oil loss analyses (see, Figure 51 - Figure 54).