MODEL SUMMARY AND RESULTS MASTER

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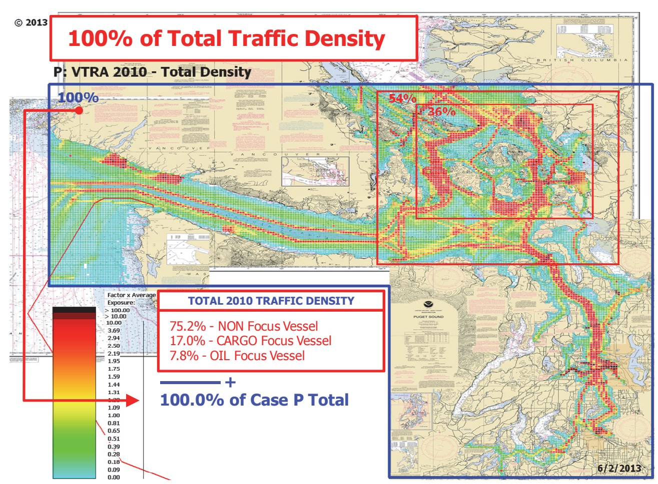
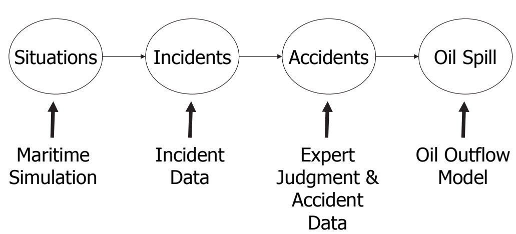
Washington State shares the Salish Sea with the province of British Columbia. A large number of ships and barges operate in these shared waters, placing the area at risk for major oil spills. While citizens in the region enjoy a relatively safe marine transportation system compared to most other port 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 and Salish Sea waters. Public concern for protecting the environment while pursuing maritime economic developments was the catalyst for this study funded by the EPA through the State of Washington and the Makah Tribe.

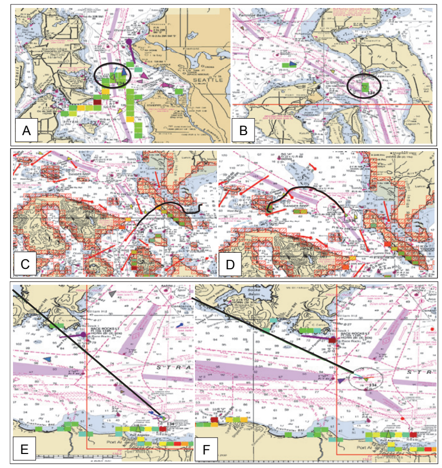


The purpose of the 2010 Vessel Traffic Risk Assessment (VTRA 2010) is foremost to evaluate potential changes in risk in light of these proposed maritime terminal expansions and to inform the State of Washington and the United States Coast Guard on what actions could be taken to mitigate increases in oil spill risk from large commercial vessel oil spills in the northern Puget Sound and the Strait of Juan de Fuca as a result. The VTRA study area includes: (1) portions of the Washington outer coast, (2) the Strait of Juan de Fuca and (3) the approaches to and passages through the San Juan Islands, Puget Sound and Haro-Strait/Boundary Pass (see blue border on the right). The VTRA 2010 is also intended to inform tribes, local governments, industry and non-profit groups in Washington State and British Columbia on potential risk management options and to facilitate their input towards achieving consensus risk management decisions regarding vessel operations in the study area.

Our VTRA model represents the chain of events that could potentially lead to an oil spill. The VTRA 2010 utilizes the extensive technical work already completed by the George Washington (GW) University and Virginia Commonwealth University (VCU) under prior projects. Specifically, the Prince William Sound Risk Assessment (1996), The Washington State Ferry Risk Assessment (1998), The San Francisco Bay Exposure Assessment (2004) and the 2005 Vessel Traffic Risk Assessment (VTRA) funded by BP. Our method has been developed over the course of over ten years of work in maritime risk assessment, has been peer reviewed by the National Research Council and top experts in the field of expert elicitation design and analysis, and has been improved thanks to a grant from the National Science Foundation.



Situations



Accidents can only occur when vessels are transiting through the system. Collisions can only occur when a vessel is in close proximity to another vessel. Grounding can only occur when a vessel is within close proximity (powered grounding) or drifting range (drift grounding) of shore or sufficiently shallow waters. Our maritime simulation model attempts to re-create the operation of vessels and the environment within the geographic scope of the study. The traffic modeled includes VTS participating vessels, smaller fishing vessels, whale watchers, and organized regatta events. The environmental factors modeled include wind, fog, and current. The simulation counts situations in which there is the potential for an accident to occur if things start to go wrong. The traffic conditions and environmental conditions are recorded in these situations. The map above shows the traffic density evaluated for all traffic in the VTRA maritime simulation model based on 2010 data.

Incidents & Accidents

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**	-
	VATERVAY CONDITIONS	
More than 0.5 mile Visibility	**Visibility**	-
Along Vessel	**Wind Direction**	-
Less than 10 knots	**Vind 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 vorse	<====================X====================>	**Situation 2 is vorse**

	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 vorse	<====================X====================>	**Situation 2 is vorse**

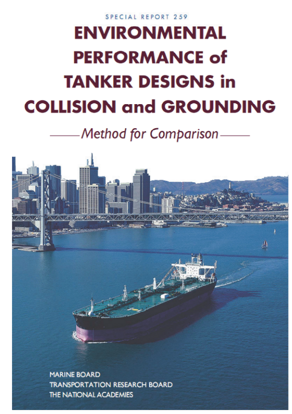
	Complete Navigational Aid Loss	
More? : ____	**9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9**	**____ : More?**
Situation 1 is vorse	<====================X====================>	**Situation 2 is vorse**

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

	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 vorse	<====================X====================>	**Situation 2 is vorse**

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. The accident types included in this study are collisions between two vessels, groundings (both powered and drift) and allisions. As the simulation counts the situations in which accidents could occur, it also records variables that could affect the chance that the accident will occur; these include the proximity of other vessels, the types of the vessels, the location of the situation, and environmental variables. Thankfully, incidents and accidents in this geographic area are rare and there is not enough data to say how each of these variables affects the chances of an accident. To determine this, we turned to maritime experts. We asked experts to assess the relative accident likelihood of two similar situations that they have extensive experience of. In each question we change only one factor and through a series of questions we build our accident probability model, incorporating historical data where we can. The type of incident that has occurred to lead to the possibility of an accident is also specified for each question. An example question is shown in the picture above; here an oil tanker with a untethered escort is meeting a ferry. The question asks how much an increased wind speed would affect an accident probability given the presence of the specified incident. The experts involved include tanker masters, tug masters, Puget Sound pilots, Coast Guard VTS operators, and ferry masters.

Potential Oil Spill



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

Modeling Assumptions

All models are abstractions of reality through a set of simplifying assumptions. For instance, we cannot include all factors in our expert judgment questionnaires, otherwise we would have to ask hundreds of questions and the experts would grow tired and not give useful, consistent information after a while. This also limits the level of granularity to which we can break down the factors. For instance, we must group similar types of vessels to reduce the number of categories (and questions) and we cannot model locations down to the seconds of the longitude and latitude coordinates. Essentially, as within any analysis model, we must make assumptions. However, we made every attempt to test our assumptions with experts and stakeholders through a collaborative analysis process. The updating of the 2005 VTRA model to the VTRA 2010 one followed this collaborative analysis approach involving coordination with Puget Sound stakeholders through the Puget Sound Harbor Safety Committee:

"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."*

What If Scenario Analysis

In the VTRA 2010 study, the Puget Sound Advisory group/steering committee chose to model only the traffic level impacts of planned expansion and construction projects that were in advanced stages of a permitting process. Each planned project forms a What-If scenario and What-If vessels are added to a maritime simulation of the 2010 Base Case year (Case P). Four What-If scenarios were modeled in the study:

(1) The Gateway bulk carrier terminal

(2) The Trans-Mountain pipeline expansion

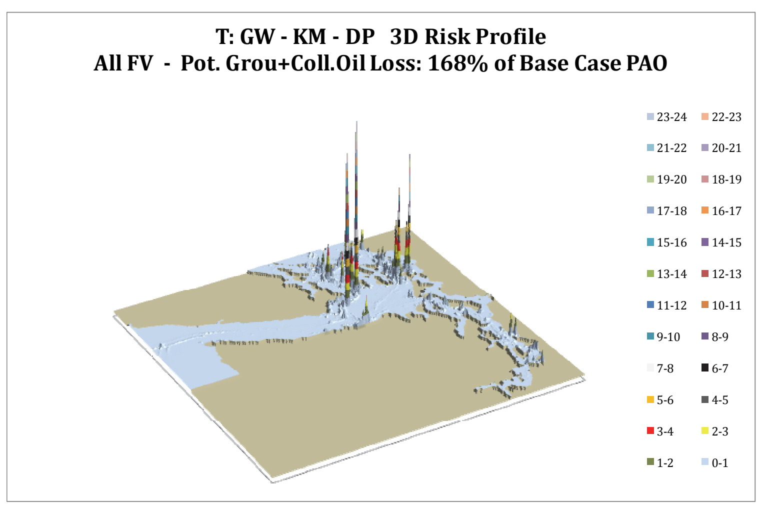
(3) The combination of proposed changes at Delta Port

(4) All three of above scenarios operating at the same time

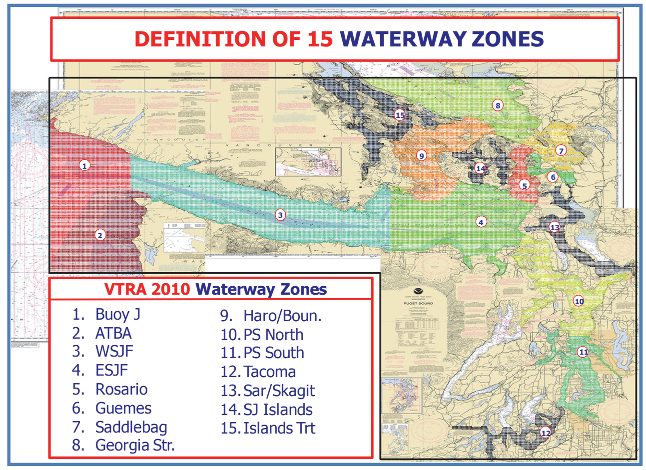
The steering committee determined that the following numbers of What-If vessels would be added to the 2010 Base Case simulation in each scenario:

(Q) The Gateway bulk carrier terminal: 487 bulk carriers (318 Panama class and 169 Cape Max class)
(R) The Trans-Mountain pipeline expansion: 348 crude oil tankers (each 100,000 DWT)
(S) The combination of proposed changes at Delta Port : 348 bulk carriers and 67 container vessels
(T) All three of above scenarios operating at the same time

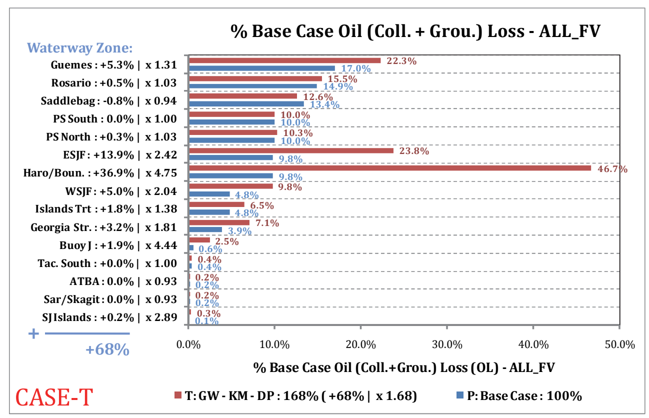
Moreover, the steering committee recommended that bunkering operations supporting these potential expansion projects be represented as well in the VTRA 2010. The figure to the right below demonstrates the VTRA 2010 3D output format of potential oil losses and their geographical distribution when all three what if scenarios are assumed operational at the same time. The title of the graph illustrates that potential oil losses increase by about a factor 1.68 times the potential oil losses of the Base Case 2010 year. This too demonstrates that throughout the VTRA 2010 we value less the absolute values of the results in our analysis comparisons but that we concentrate more on relative comparisons across accident types, across oil outflow categories, across what-



if scenarios and across waterway zones. In total 15 waterway zones were defined across the geographic scope.



For each what if scenario and each waterway zone (see graph on right) we evaluate the total annual focus vessel time of exposure (VTE) for a group of focus vessels (bulk carrier, container ships, other cargo, tankers, chemical carriers, articulated tug barges and oil barges) and compare it to their vessel time of exposure observed in the base case 2010 year. Similarly, we evaluate the total oil time exposure (i.e. the total amount of time a cubic meter of oil is moving through the area) for what-if scenarios, taking into account focus vessel fuel and oil cargo, and compare it to the oil time exposure (OTE) observed for the 2010 base case year. The vessel time of exposure tends to be a driver in the analysis of potential accident frequency, whereas the oil time of exposure tends to be a driver in the analysis of potential oil losses. The graph to the right demonstrates the by waterway zone comparison of the potential oil losses for the combined what-if scenario (Case T). From this figure one observes that while system wide potential oil losses increase by about a factor of 1.68, larger factors are observed for the waterway zones: East Strait of Juan de Fuca, Haro Strait/Boundary pass, West Strait of Juan de Fuca, Georgia Strait, Buoy J and finally the San Juan Islands. Most notably, for Haro Stait Boundary pass and Buoy J waterway zone factors larger than 4 are evaluated.



The by waterway zone analysis demonstrates the challenge of risk management. That is, for it to be location specific, taking into consideration the type and location of traffic and how risks changes as a result of potential traffic increases. Often risk does not necessarily disappear when mitigated locally, but has tendency to migrate. Such risk migrations are of course preferably avoided, but may be inevitable. Needless to say, in the best of all possible worlds risk mitigation at one location ought not result in an increase in risk elsewhere that is larger. This begs the question then, when faced with potential traffic increases how can one manage risk increases that cannot be fully mitigated? One approach could be to evenly distribute potential risk increases across the affected area, i.e. to allow for risk increases in locations that currently have low risk levels compared to those that are already higher. On the other hand, one could aim for an equitable distribution of future risk allowing for each location to have a similar relative percentage increase in risk. In our opinion, these risk management questions can only be answered utilizing the collaborative analysis approach (– *George J. Busenberg, 1999)*.

Risk Mitigation Measure (RMM) Scenario Analysis

Following the What-if scenario analysis, a series of risk mitigation measures were proposed to help inform a risk management process. The effect of these risk mitigations measure were postulated on VTRA 2010 model's input parameters and the system wide relative effectiveness of these measures were evaluated utilizing the VTRA 2010 model. Detailed analysis result presentations by waterway zone for what-if and risk mitigation scenarios are posted at the following url:

http://www.seas.gwu.edu/~dorpjr/tab4/publications_VTRA_Update.html

Their results are too detailed to be fully described here and we strongly encourage interested parties to visit the above url and study these results to help inform stakeholders prior to engaging in such a risk management process.

Closing Statement and Reference

For sure risk management questions above are equally important in other ongoing studies considering the potential risk of traffic increases as a result of proposed terminal expansion projects. We hope that other studies can benefit from the VTRA 2010 analysis in this regard. Below we provide master tables of scenario analysis conducted and their relative effect on the 2010 base case year. Summarizing, we advocate a collaborative systems approach towards answering risk management questions, not one that is just locally targeted missing potential side effects or points of view. Ultimately, we believe that the strength of the VTRA 2010 analysis lies in this systems view, but equally important in the evaluation of relative potential risk increases and decreases of what-if and risk mitigation scenarios within in a single framework utilizing a consistent set of assumptions across all of them. No doubt, the risk communication process amongst stakeholders that took place through the collaborative analysis approach in conducting these analyses and made possible by the Puget Sound Harbor Safety Committee is equally important, if not more.

George J. Busenberg (1999). "Collaborative and adversarial analysis in environmental policy", Policy Sciences, Vol. 32, pp. 1-11.

	WHAT IF SCENARIO ANALYSIS
P - Base Case	Modeled Base Case 2010 year informed by VTOSS 2010 data amongst other sources.
Q - GW - 487	Gateway expansion scenario with 487 additional bulk carriers and bunkering support
R - KM - 348	Transmountain pipeline expansion with additional 348 tankers and bunkering support
S - DP - 415	Delta Port Expansion with additional 348 bulk carriers and 67 container vessels
T - GW - KM - DP	Combined expnasion scenario of above three expansion scenarios
	CASE P - RISK MITIGATION MEASURE (RMM) ANALYSIS
P - BC & DH100	Base Case year with 100% double hull fuel tank protection for Cargo Focus Vessels
P - BC & HE00	Base Case Year with 50% human error reduction on Oil Barges
P - BC & HE50	Base Case Year with 100% human error reduction on Oil Barges
P - BC & CONT17KNTS	Base Case Year with max speed of 17 knots for container ships
	CASE Q - RISK MITIGATION MEASURE (RMM) ANALYSIS
Q - GW 487 & NB	Gateway expansion scenario and no bunkering support
Q - GW 487 & NB & OH	Gateway expansion scenario and no bunkering support and traversing only Haro routes
	CASE T - RISK MITIGATION MEASURE (RMM) ANALYSIS
T - GW - KM - DP & OW ATB	Case T with ATB's adhering to one way Rosario traffic regime
T - GW - KM - DP & EC	Case T with Cape Class bulk carrier given benefit of+ 1 escort on Haro and Rosario routes
T - GW - KM - DP & EH	Case T with all Focus Vessels given benefit of +1 escort vessel on Haro routes
T - GW - KM - DP & ER	Case T with Cape bulkers, laden Tankers, ATB's given benefit of +1 esc. on Rosario routes
T - GW - KM - DP & 6RMM	Case T with benefit OW ATB, EH, ER, P-HE50, Q-NB and P-CONT17 KNTS
	CASE P BENCHMARK (BM) & SENSITIVITY ANALYSIS
P - BC & LOW TAN + CFV	Base Case with Tankers and Cargo Focus Vessels set at a low historical year
P - BC & LOW TAN	Base Case with Tankers set at a low historical year
P - BC & HIGH TAN	Base Case with Tankers set at a high historical year
P - BC & HIGH TAN + CFV	Base Case with Tankers and Cargo Focus Vessels set at a high historical year
	CASE T BENCHMARK (BM) & SENSITIVITY ANALYSIS
T - LOW TAN + CFV	Case T with Tankers and Cargo Focus Vessels set at a low historical year
T - LOW TAN	Case T with Tankers set at a low historical year
T - GW - KM - DP & VAR	Case T with additional variability in timing of What-If Focus Vessel arrivals
T - HIGH TAN	Case T with Tankers set at a high historical year
T - HIGH TAN + CFV	Case T with Tankers and Cargo Focus Vessels set at a high historical year

	WHAT IF SCENARIO ANALYSIS			
	Vessel Time Exposure (VTE)	Oil Time Exposure (OTE)	Pot. Accident Frequency (PAF)	Pot. Oil Loss (POL)
P - Base Case	100%	100%	100%	100%
Q - GW - 487	+13% | 113%	+5% | 105%	+12% | 112%	+12% | 112%
R - KM - 348	+7% | 107%	+51% | 151%	+5% | 105%	+36% | 136%
S - DP - 415	+5% | 105%	+3% | 103%	+6% | 106%	+4% | 104%
T - GW - KM - DP	+25% | 125%	+59% | 159%	+18% | 118%	+68% | 168%

	CASE P - RISK MITIGATION MEASURE (RMM) ANALYSIS			
	Vessel Time Exposure (VTE)	Oil Time Exposure (OTE)	Pot. Accident Frequency (PAF)	Pot. Oil Loss (POL)
P - BC & DH100	0% | 100%	0% | 100%	0% | 100%	-8% | 92%
P - BC & HE00	0% | 100%	0% | 100%	-16% | 84%	-4% | 96%
P - BC & HE50	0% | 100%	0% | 100%	-8% | 92%	-2% | 98%
P - BC & CONT17KNTS	+4% | 104%	+3% | 103%	-4% | 96%	-6% | 94%

	CASE Q - RISK MITIGATION MEASURE (RMM) ANALYSIS			
	Vessel Time Exposure (VTE)	Oil Time Exposure (OTE)	Pot. Accident Frequency (PAF)	Pot. Oil Loss (POL)
Q - GW 487 & NB	-5% | 108%	-1% | 104%	-1% | 111%	-10% | 103%
Q - GW 487 & NB & OH	-4% | 109%	-2% | 104%	-2% | 110%	-7% | 105%

	CASE T - RISK MITIGATION MEASURE (RMM) ANALYSIS			
	Vessel Time Exposure (VTE)	Oil Time Exposure (OTE)	Pot. Accident Frequency (PAF)	Pot. Oil Loss (POL)
T - GW - KM - DP & 6RMM	+4% | 128%	+4% | 163%	-29% | 89%	-44% | 123%
T - GW - KM - DP & OW ATB	+1% | 126%	+2% | 161%	0% | 118%	0% | 168%
T - GW - KM - DP & EC	0% | 125%	+0% | 159%	-2% | 116%	-4% | 164%
T - GW - KM - DP & EH	0% | 125%	+0% | 159%	-7% | 111%	-24% | 143%
T - GW - KM - DP & ER	0% | 125%	+0% | 159%	-8% | 111%	-12% | 156%

	CASE P BENCHMARK (BM) & SENSITIVITY ANALYSIS			
	Vessel Time Exposure (VTE)	Oil Time Exposure (OTE)	Pot. Accident Frequency (PAF)	Pot. Oil Loss (POL)
P - BC & LOW TAN + CFV	-3% | 97%	-14% | 86%	-5% | 95%	-20% | 80%
P - BC & LOW TAN	-2% | 98%	-13% | 87%	-4% | 96%	-22% | 78%
P - BC & HIGH TAN	+2% | 102%	+14% | 114%	+3% | 103%	+9% | 109%
P - BC & HIGH TAN + CFV	+7% | 107%	+15% | 115%	+4% | 104%	+8% | 108%

	CASE T BENCHMARK (BM) & SENSITIVITY ANALYSIS			
	Vessel Time Exposure (VTE)	Oil Time Exposure (OTE)	Pot. Accident Frequency (PAF)	Pot. Oil Loss (POL)
T - LOW TAN + CFV	-3% | 121%	-15% | 144%	-2% | 116%	-27% | 141%
T - LOW TAN	-2% | 123%	-13% | 146%	-3% | 116%	-23% | 145%
T - GW - KM - DP & VAR	-1% | 124%	-7% | 152%	-3% | 116%	-11% | 157%
T - HIGH TAN	+3% | 128%	+15% | 174%	+6% | 125%	+8% | 175%
T - HIGH TAN + CFV	+6% | 131%	+16% | 174%	+8% | 127%	+17% | 184%