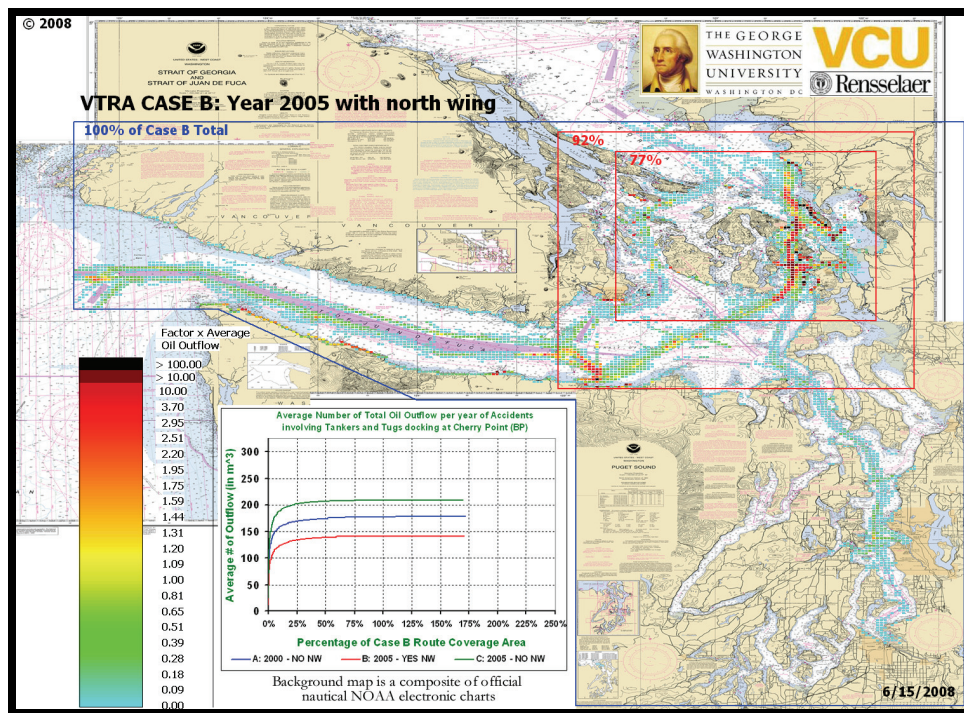


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## MAIN REPORT



### Assessment of Oil Spill Risk due to Potential Increased Vessel Traffic at Cherry Point, Washington

Submitted by VTRA TEAM:

Johan Rene van Dorp (GWU), John R. Harrald (GWU),  
Jason R. W. Merrick (VCU) and Martha Grabowski (RPI)

August 31, 2008

## TABLE OF CONTENTS

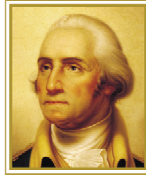
PREFACE.....	2
PROJECT TEAM MEMBERS .....	6
EXECUTIVE SUMMARY .....	7
1. Introduction.....	19
2. Scope of the Study .....	21
3. Description of the System .....	23
3.1. Traffic to BP Cherry Point .....	23
3.2. Deep Draft Traffic.....	27
3.3. Ferry Traffic.....	31
3.4. Small Vessel Traffic .....	33
3.5. Traffic Rules .....	35
3.6. Overall Traffic Density .....	36
3.7. Environmental Factors – Wind, Visibility, and Current .....	38
4. Model Integration and Data Sources .....	42
4.1. Interactions .....	42
4.2. Incidents .....	44
4.3. Accidents .....	45
4.4. Oil Outflow.....	47
4.5. Organizations that Provided Experts .....	50
4.6. Data Sources Used.....	50
5. Analysis Results .....	52
5.1. Explanation of Cases Analyzed .....	52
5.2. Risk Changes from Adding North Wing.....	55
5.3. Future Changes in Risk .....	61
5.4. Evaluation of scope risk interventions .....	68
6. Conclusions.....	76
References .....	83

**Sub-Appendix:** J.R.W. Merrick, J. R. van Dorp, T. Mazzuchi, J. Harrald, J. Spahn and M. Grabowski (2002). “The Prince William Sound Risk Assessment”. *Interfaces*, Vol. 32 (6): pp.25-40.

**Sub-Appendix:** J.R. van Dorp, J.R.W. Merrick, J.R. Harrald, T.A. Mazzuchi, and M. Grabowski (2001). “A Risk Management procedure for the Washington State Ferries”, *Journal of Risk Analysis*, Vol. 21 (1): pp. 127-142.

**Sub-Appendix:** P. Szwed, J. R. van Dorp, J.R.W.Merrick, T.A. Mazzuchi and A. Singh (2006). “A Bayesian Paired Comparison Approach for Relative Accident Probability Assessment with Covariate Information”, *European Journal of Operations Research*, Vol. 169 (1), pp. 157-177.

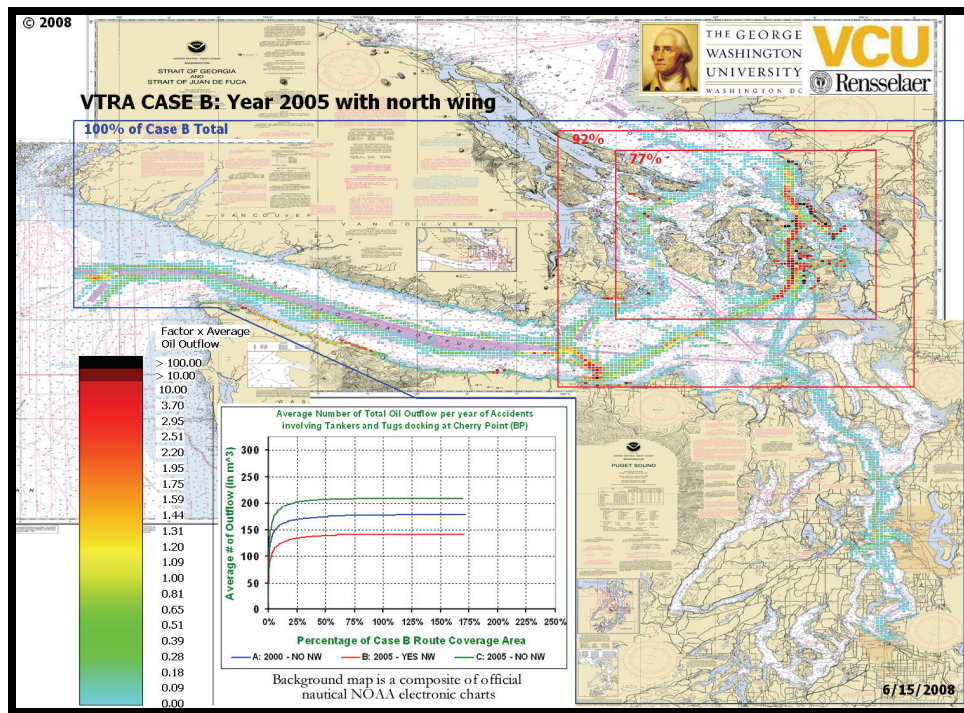
**Sub-Appendix:** J.R.W. Merrick, J.R. van Dorp, J.P. Blackford, G.L. Shaw, T.A. Mazzuchi and J.R. Harrald (2003). “A Traffic Density Analysis of Proposed Ferry Service Expansion in San Francisco Bay Using a Maritime Simulation Model”, *Reliability Engineering and System Safety*, Vol. 81 (2): pp. 119-132.



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## TECHNICAL APPENDIX A: DATABASE CONSTRUCTION AND ANALYSIS



### Assessment of Oil Spill Risk due to Potential Increased Vessel Traffic at Cherry Point, Washington

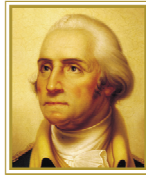
Submitted by VTRA TEAM:

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Jason R. W. Merrick (VCU) and Martha Grabowski (RPI)

## TABLE OF CONTENTS

<b>Section A-1. The Puget Sound VTRA Accident-Incident Database</b>	<b>A-3</b>
<b>Section A-2. VTRA Accident-Incident Database Development</b>	<b>A-4</b>
<b>Section A-3. Challenges with Accident, Incident and Human Factors Data</b>	<b>A-6</b>
Accident and Incident Data	A-6
Impact of Data Challenges on Puget Sound Accident-Incident Database	A-6
<b>Section A-4. Data Sources</b>	<b>A-8</b>
The Challenge of Integrating Multiple Data Sources	A-11
Differences between Key Data Sources: USCG and Washington DOE Data	A-13
Impact of Data Sources on Puget Sound VTRA Accident-Incident Database	A-20
<b>Section A-5. Database Analysis</b>	<b>A-22</b>
Maritime Events in Puget Sound, 1995-2005	A-23
Events by Year	A-25
Events by Vessel Type	A-29
Events by Location	A-32
Events by Season	A-33
Events by Time of Day	A-37
Events by Vessel Flag	A-38
Events by Owner	A-41
Events by Classification Society	A-41
Events by Weather Condition	A-43
Events by Direction (Inbound/Outbound)	A-43
Events by Accident and Incident Type	A-43
Events by Error Type	A-44
Human and Organizational Error Analysis	A-51
Error Analysis – BP Cherry Point Calling Fleet Accidents and Incidents	A-58
Summary of Significant Event Results, 1995-2005	A-62
Accidents in Puget Sound, 1995-2005	A-65
Incidents in Puget Sound, 1995-2005	A-69
<b>References</b>	<b>A-73</b>
<b>Appendix A-1 Puget Sound Tanker Events, Accidents and Incident Analysis</b>	<b>A-75</b>
<b>Appendix A-2 Puget Sound Tug-Barge Events, Accidents and Incident Analysis</b>	<b>A-98</b>
<b>Appendix A-3 Influence Diagrams for Puget Sound Tanker, ATB/ITB Calibration Accidents, Sample Incidents and Unusual Event</b>	<b>A-119</b>

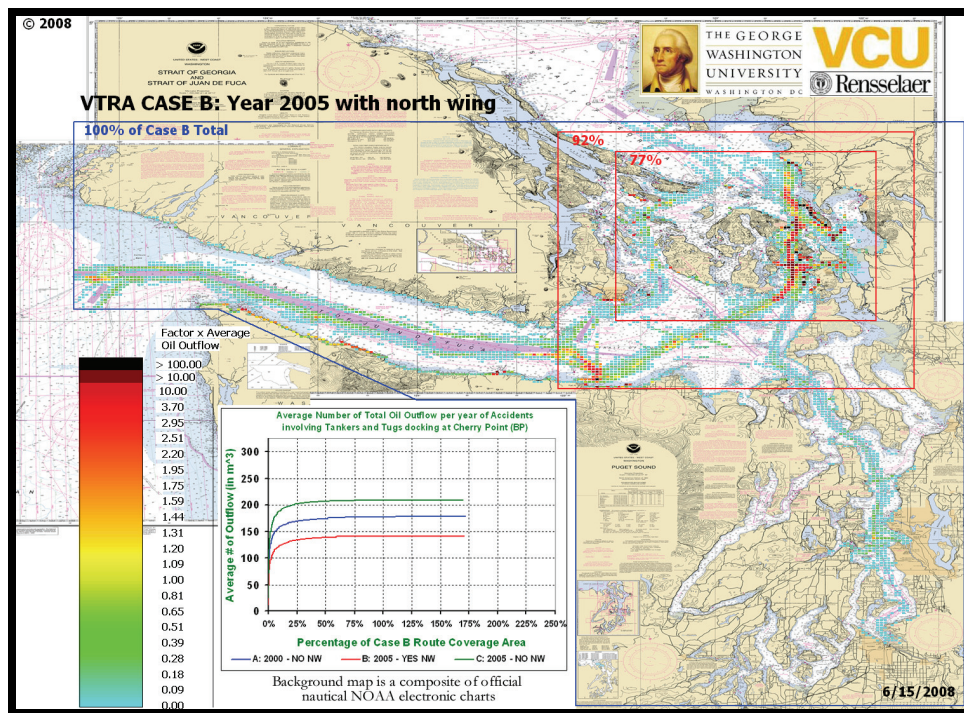




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## TECHNICAL APPENDIX B: SYSTEM DESCRIPTION



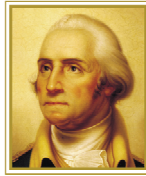
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## TABLE OF CONTENTS

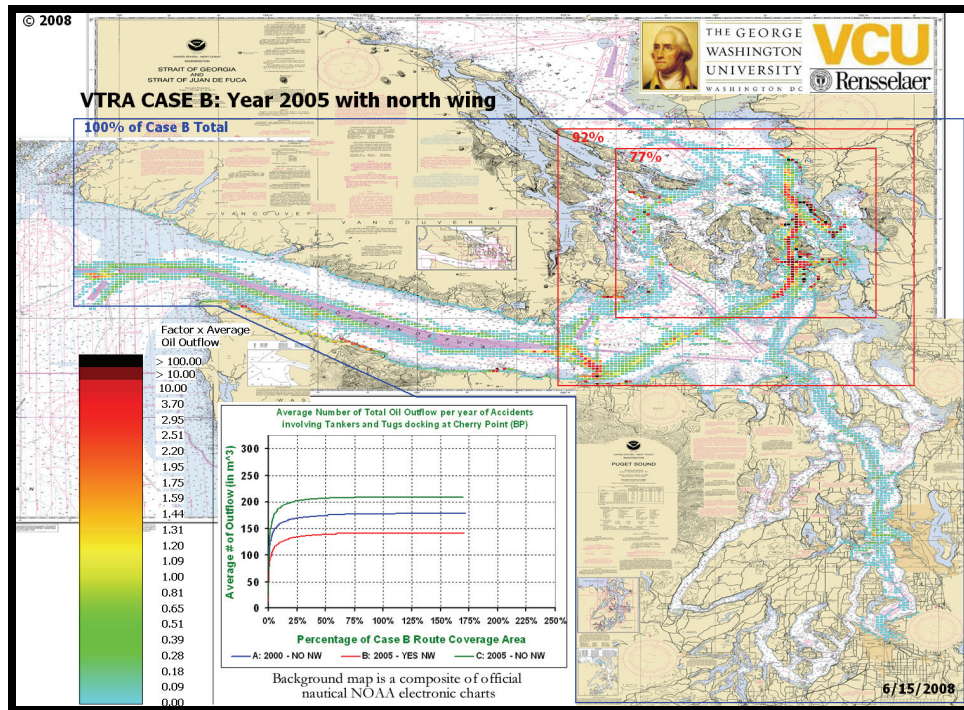
B-1.	Introduction .....	4
B-2.	Waters of the Vessel Traffic Risk Assessment.....	4
B-2.1.	Juan de Fuca-West:.....	4
B-2.2.	Juan de Fuca-East:.....	5
B-2.3.	Puget Sound .....	5
B-2.4.	Haro Strait-Boundary Pass.....	6
B-2.5.	Rosario Strait.....	6
B-2.6.	Cherry Point.....	6
B-2.7.	SaddleBag.....	7
B-2.8.	Guemes Channel .....	7
B-3.	Weather, Climate, Topography and Geology.....	8
B-3.1.	Wind .....	8
B-3.1.1.	Straits of Juan de Fuca and Georgia and the San Juan Islands .....	8
B-3.1.2.	Puget Sound.....	9
B-3.2.	Visibility .....	9
B-3.2.1.	Straits of Juan de Fuca and Georgia and the San Juan Islands .....	9
B-3.2.2.	Puget Sound.....	9
B-3.3.	Tides and Currents .....	9
B-3.3.1.	Straits of Juan de Fuca and Georgia and the San Juan Islands .....	9
B-3.3.2.	Puget Sound.....	10
B-4.	Maritime Vessel Traffic .....	11
B-4.1.	Cherry Point Oriented Traffic.....	11
B-4.2.	General Traffic.....	12
B-5.	Traffic Management Protocols and Technological Infrastructure.....	18
B-5.1.	Vessel Traffic Service - Puget Sound .....	18
B-5.1.1.	Vessel Movement Reporting System .....	19
B-5.1.2.	Traffic Separation Scheme.....	20
B-5.1.3.	Surveillance Systems.....	20
B-5.2.	Cooperative Vessel Traffic Service for the Juan de Fuca Region (CVTS).....	21
B-5.3.	Pilotage Requirements .....	21
B-5.4.	Escort Requirements.....	22



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## TECHNICAL APPENDIX C: SIMULATION CONSTRUCTION



### Assessment of Oil Spill Risk due to Potential Increased Vessel Traffic at Cherry Point, Washington

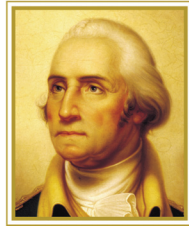
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## TABLE OF CONTENTS

C-1.	VTS Traffic Modeling.....	6
C-1.1.	The Vessel Traffic Operation Support System (VTOSS) repository .....	6
C-1.2.	Turning track data in to simulation routes .....	8
C-1.3.	Routes used in the simulation.....	12
C-1.4.	Vessel Dimensions.....	17
C-2.	Fishing Seasons Modeling.....	22
C-2.1.	US, Canadian, and tribal fishing data.....	22
C-2.1.1.	State Commercial Fisheries.....	22
C-2.1.2.	Tribal Commercial Fisheries.....	23
C-2.1.3.	Canadian Commercial Fisheries.....	26
C-2.2.	Creating fishing transits in the simulation .....	27
C-2.3.	Routes and fishing areas used in the simulation .....	30
C-3.	Regatta Modeling.....	30
C-3.1.	US regatta data.....	30
C-3.2.	Creating yacht transits in the simulation.....	31
C-3.3.	Regatta routes used in the simulation.....	31
C-4.	Whale Watcher Modeling.....	33
C-4.1.	The Sound Watch records of interaction with whales.....	33
C-4.2.	Creating whale watching transits in the simulation .....	34
C-4.3.	Routes used in the simulation.....	34
C-5.	Traffic Rules.....	35
C-5.1.	Regulations used.....	35
C-5.2.	Implementing traffic rules in the simulation.....	37
C-6.	Modeling weather and current within the VTRA Simulation.....	40
C-6.1.	Current Modeling.....	40
C-6.1.1.	Current data and list of current stations.....	41
C-6.1.2.	Overview of current model in the simulation .....	42
C-6.1.3.	Representative results of current in the simulation .....	43
C-6.2.	Wind Modeling.....	44
C-6.2.1.	NOAA weather station data.....	44
C-6.2.2.	Overview of wind modeling.....	44
C-6.2.3.	Representative results of wind in the simulation .....	47
C-6.3.	Visibility Modeling.....	48
C-6.3.1.	Overview of visibility modeling.....	49
C-6.3.2.	Calibrating the visibility model with expert judgments.....	56
C-6.3.3.	Summary results of visibility in the VTRA maritime simulation.....	61
References	.....	63

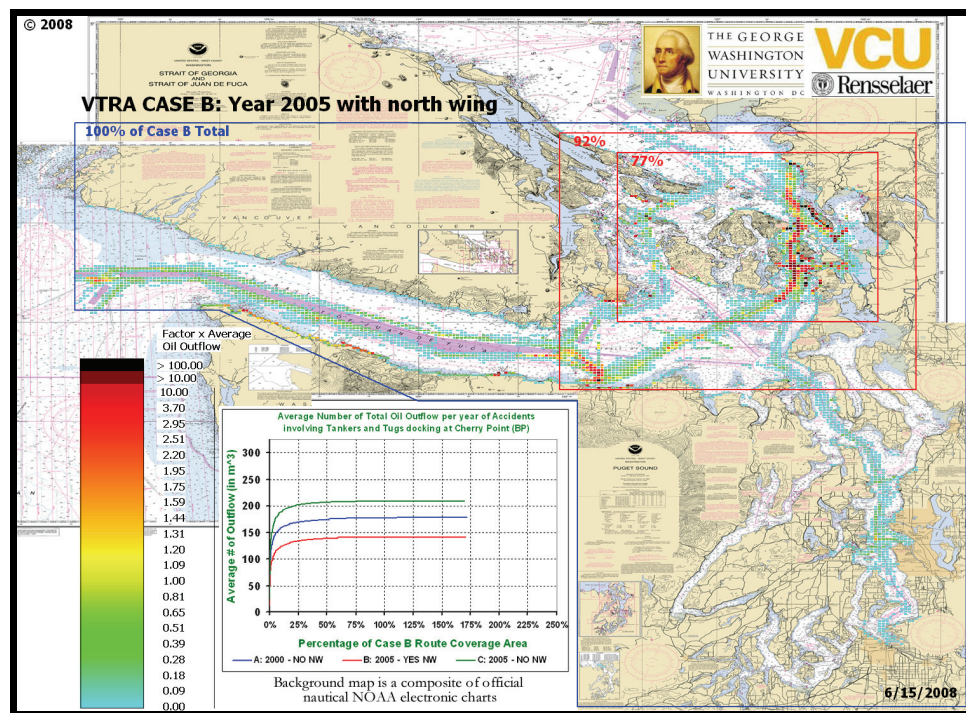




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## TECHNICAL APPENDIX D: EXPERT JUDGMENT ELICITATION



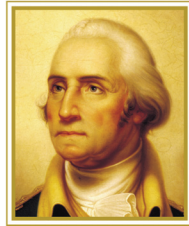
### Assessment of Oil Spill Risk due to Potential Increased Vessel Traffic at Cherry Point, Washington

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Jason R. W. Merrick (VCU) and Martha Grabowski (RPI)

## TABLE OF CONTENTS

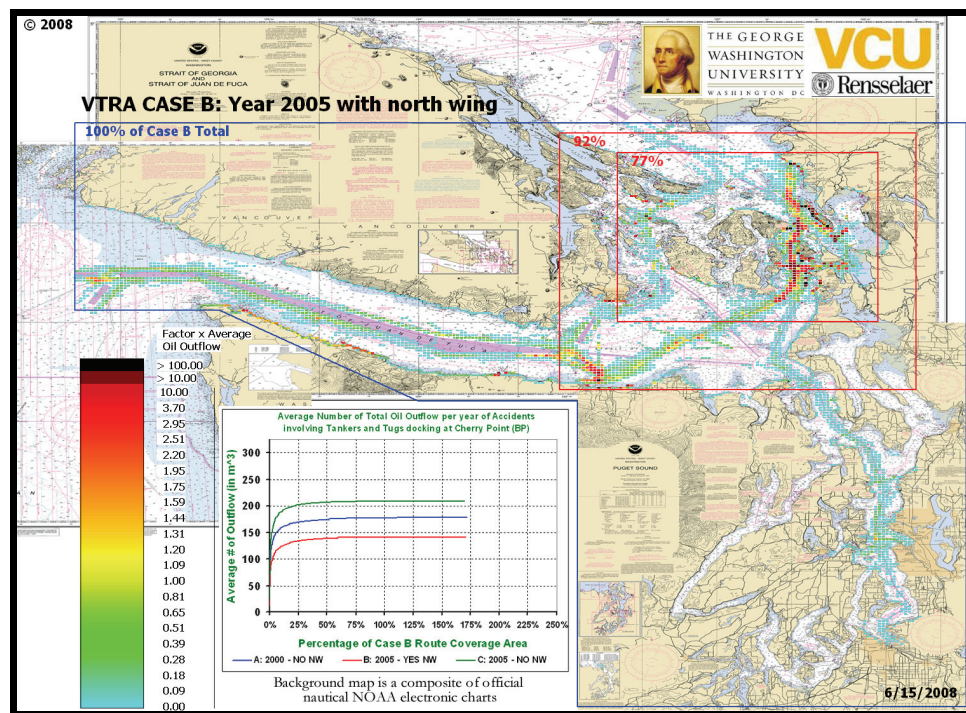
<b>Table of Figures</b> .....	D-3
<b>Table of Tables</b> .....	D-6
<b>D-1. Organizations that provided experts</b> .....	D-7
D-1.1. Questionnaires Developed.....	D-9
<b>D-2. Overview of expert judgment techniques</b> .....	D-10
D-2.1. Attribute scale development.....	D-11
D-2.2. Attribute Parameter Assessment.....	D-22
<b>D-3. Representative results of the expert judgment</b> .....	D-39
<b>D-4. Turning expert judgment into annual accident frequencies</b> .....	D-42
D-4.1. Simulation Counting.....	D-43
D-4.2. Incident Calibration.....	D-49
D-4.3. Accident Calibration.....	D-50
<b>References</b> .....	D-61



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## TECHNICAL APPENDIX E: OIL OUTFLOW MODEL



### Assessment of Oil Spill Risk due to Potential Increased Vessel Traffic at Cherry Point, Washington

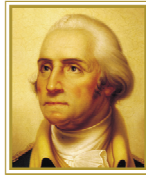
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## TABLE OF CONTENTS

<b>Table of Figures</b> .....	E-3
<b>Table of Tables</b> .....	E-5
<b>E-1. The NRC oil outflow report</b> .....	E-6
<b>E-3. Developing an oil outflow model</b> .....	E-7
E-2.1 Description of scenario data obtained from ..... the NRC Oil outflow Report	E-15
E-2.2 Striking and struck ship model.....	E-17
E-2.3 Bunker fuel and diesel fuel regression models.....	E-19
<b>E-3. Representative results from the oil outflow model</b> .....	E-27
<b>References</b> .....	E-37
<b>Sub Appendix:</b> .....	E-38
G.F. van de Wiel (2008). "A Probabilistic Model for Oil Spill Volume in Tanker Collisions and Groundings", Master's Thesis: Applied Mathematics, Delft University of Technology, The Netherlands.	

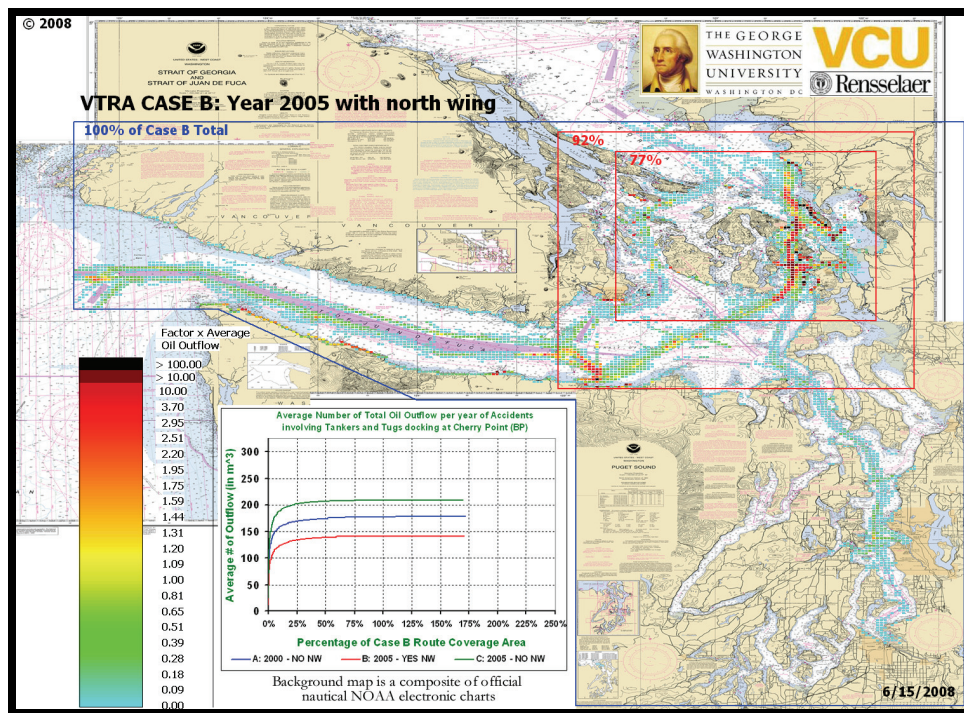




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## TECHNICAL APPENDIX F: FUTURE SCENARIOS



### Assessment of Oil Spill Risk due to Potential Increased Vessel Traffic at Cherry Point, Washington

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Jason R. W. Merrick (VCU) and Martha Grabowski (RPI)



**TABLE OF CONTENTS**

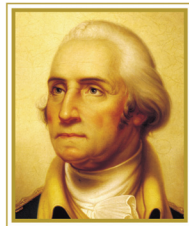
F-1. Historical data on traffic levels ..... 5

F-2. BP’s projection of Cherry Point Traffic..... 6

F-3. Overview of the development of future scenarios ..... 8

F-4. Time Series Forecasting of Traffic Levels ..... 13

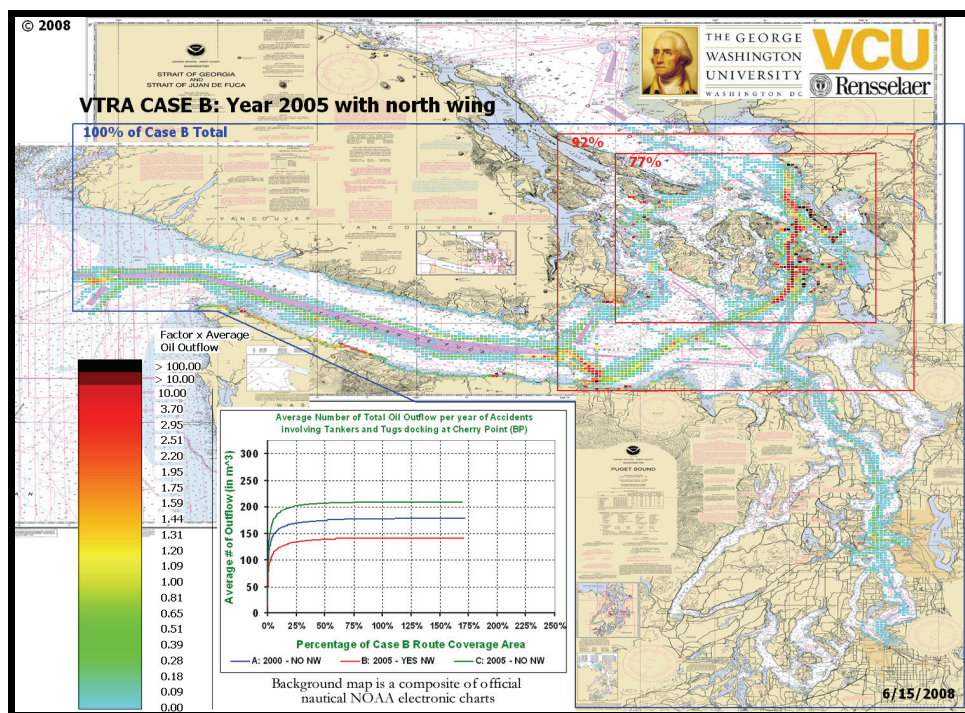
F-5. Traffic Levels Projected for 2025 ..... 18



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## TECHNICAL APPENDIX G: GEOGRAPHIC EXPOSURE, ACCIDENT AND OIL OUTFLOW PROFILES



### Assessment of Oil Spill Risk due to Potential Increased Vessel Traffic at Cherry Point, Washington

Submitted by VTRA TEAM:

Johan Rene van Dorp (GWU), John R. Harrald (GWU),  
Jason R.. W. Merrick (VCU) and Martha Grabowski (RPI)

## TABLE OF CONTENTS

<b>G-1. Roadmap of Appendix G</b> .....	G-5
<b>G-2. System Context Presentation</b> .....	G-8
<b>G-3. Summary Aggregate Results Presentations</b> .....	G-20
<b>G-4. Calibration VTRA CASE B Presentations</b>	
G-4.1. VTRA CASE B: Traffic Density.....	G-45
G-4.2. VTRA CASE B: Aggregate Results.....	G-47
G-4.3. VTRA CASE B: Collision.....	G-55
G-4.4. VTRA CASE B: Powered Grounding.....	G-63
G-4.5. VTRA CASE B: Drift Grounding.....	G-69
G-4.6. VTRA CASE B: Allisions.....	G-75
G-4.7. VTRA CASE B: Accident Probability Presentation.....	G-81
<b>G-5. VTRA Case Comparison: A-B-C Presentations</b>	
G-5.1. A-B-C: Exposure Presentation.....	G-86
G-5.2. A-B-C: Accident Frequency Presentation.....	G-90
G-5.3. A-B-C: Aggregate Oil Outflow Presentation.....	G-94
G-5.4. A-B-C: BP Persistent Oil Outflow Presentation.....	G-98
G-5.5. A-B-C: BP Non-Persistent Oil Outflow Presentation.....	G-102
G-5.6. A-B-C: Interacting Vessel Persistent Oil Outflow Presentation.....	G-106
G-5.7. A-B-C: Interacting Vessel Non-Persistent Oil Outflow Presentation.....	G-110
<b>G-6. VTRA Case Comparison: B-D-E Presentations</b>	
G-6.1. B-D-E: Exposure Presentation.....	G-114
G-6.2. B-D-E: Accident Frequency Presentation.....	G-118
G-6.3. B-D-E: Aggregate Oil Outflow Presentation.....	G-122
G-6.4. B-D-E: BP Persistent Oil Outflow Presentation.....	G-126
G-6.5. B-D-E: BP Non- Persistent Oil Outflow Presentation.....	G-130
G-6.6. B-D-E: Interacting Vessel Persistent Oil Outflow Presentation.....	G-134
G-6.7. B-D-E: Interacting Vessel Non-Persistent Oil Outflow Presentation.....	G-138

## TABLE OF CONTENTS (Continued)

### **G-7. VTRA Case Comparison: B-F-G Presentations**

G-7.1. B-F-G: Exposure Presentation.....	G-142
G-7.2. B-F-G: Accident Frequency Presentation.....	G-146
G-7.3. B-F-G: Aggregate Oil Outflow Presentation.....	G-150
G-7.4. B-F-G: BP Persistent Oil Outflow Presentation.....	G-154
G-7.5. B-F-G: BP Non- Persistent Oil Outflow Presentation.....	G-160
G-7.6. B-F-G: Interacting Vessel Persistent Oil Outflow Presentation.....	G-162
G-7.7. B-F-G: Interacting Vessel Non-Persistent Oil Outflow Presentation.....	G-166

### **G-8. VTRA Case Comparison: B-H-I Presentations**

G-8.1. B-H-I: Exposure Presentation.....	G-170
G-8.2. B-H-I: Accident Frequency Presentation.....	G-174
G-8.3. B-H-I: Aggregate Oil Outflow Presentation.....	G-178
G-8.4. B-H-I: BP Persistent Oil Outflow Presentation.....	G-182
G-8.5. B-H-I: BP Non- Persistent Oil Outflow Presentation.....	G-186
G-8.6. B-H-I: Interacting Vessel Persistent Oil Outflow Presentation.....	G-190
G-8.7. B-H-I: Interacting Vessel Non-Persistent Oil Outflow Presentation.....	G-194

### **G-9. VTRA Case Comparison: B-J-H-K Presentations**

G-9.1. B-J-H-K: Exposure Presentation.....	G-198
G-9.2. B-J-H-K: Accident Frequency Presentation.....	G-203
G-9.3. B-J-H-K: Aggregate Oil Outflow Presentation.....	G-208
G-9.4. B-J-H-K: BP Persistent Oil Outflow Presentation.....	G-213
G-9.5. B-J-H-K: BP Non- Persistent Oil Outflow Presentation.....	G-217
G-9.6. B-J-H-K: Interacting Vessel Persistent Oil Outflow Presentation.....	G-223
G-9.7. B-J-H-K: Interacting Vessel Non-Pers. Oil Outflow Presentation.....	G-228

---

**TABLE OF CONTENTS (Continued)****G-10. VTRA Case Comparison: B-L-H-M Presentations**

G-10.1. B-L-H-M: Exposure Presentation.....	G-233
G-10.2. B-L-H-M: Accident Frequency Presentation.....	G-237
G-10.3. B-L-H-M: Aggregate Oil Outflow Presentation.....	G-243
G-10.4. B-L-H-M: BP Persistent Oil Outflow Presentation.....	G-248
G-10.5. B-L-H-M: BP Non- Persistent Oil Outflow Presentation.....	G-253
G-10.6. B-L-H-M: Interacting Vessel Persistent Oil Outflow Presentation.....	G-258
G-10.7. B-L-H-M: Interacting Vessel Non-Pers. Oil Outflow Presentation.....	G-263

**G-11. VTRA Case Comparison: B-N-H-O Presentations**

G-11.1. B-N-H-O: Exposure Presentation.....	G-268
G-11.2. B-N-H-O: Accident Frequency Presentation.....	G-273
G-11.3. B-N-H-O: Aggregate Oil Outflow Presentation.....	G-278
G-11.4. B-N-H-O: BP Persistent Oil Outflow Presentation.....	G-283
G-11.5. B-N-H-O: BP Non- Persistent Oil Outflow Presentation.....	G-288
G-11.6. B-N-H-O: Interacting Vessel Persistent Oil Outflow Presentation.....	G-293
G-11.7. B-N-H-O: Interacting Vessel Non-Pers. Oil Outflow Presentation.....	G-298