Towards the Development of a Comprehensive Vessel Traffic Risk Management Tool

Presentation by: J. Rene van Dorp

GWU Personnel: Dr. J. Rene van Dorp, Dr. Jack Harrald, Dr. Greg Shaw, Adil Caner Sener, Christian Salmon

VCU Personnel: Dr. Jason R. W. Merrick, Christina Werner

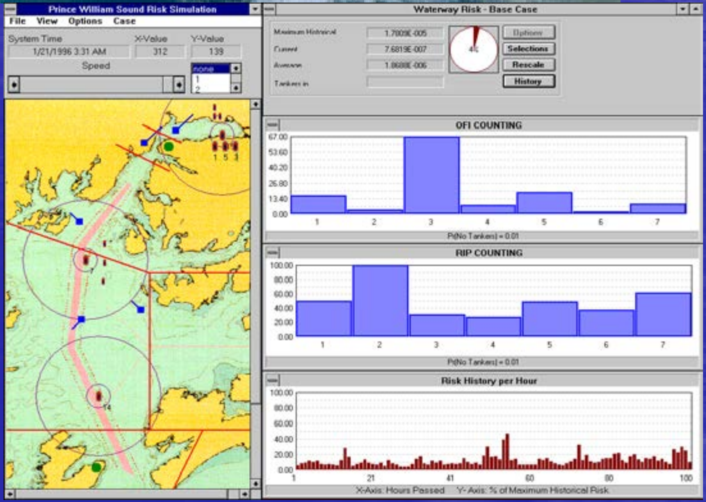
RPI Personnel: Dr. Martha Grabowski, Zhi Zhou, Michael Steward, Brittany Steward, Huawei Song, Zhuyu You

TU Delft Personnel: Giel van de Wiel

Puget Sound Harbor Safer Committee Presentation April 2012

Previous Work

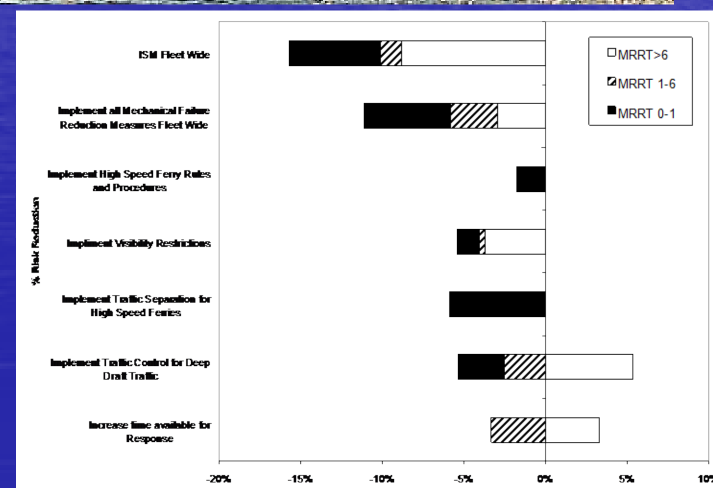
- Prince William Sound Risk Assessment
  - Site of the Exxon Valdez Disaster
  - Objective—reduce oil spill risk
  - Model used system simulation, data analysis and expert judgment
  - Capable of modeling systemic effects of proposed interventions
  - Multi-million dollar investments made to reduce risk of further oil spills



Merrick, J. R. W., J. R. van Dorp, T. Mazzuchi, J. Harrald, J. Spahn, M. Grabowski. 2002. The Prince William Sound Risk Assessment. *Interfaces* **32**(6) 25-40.

Previous Work

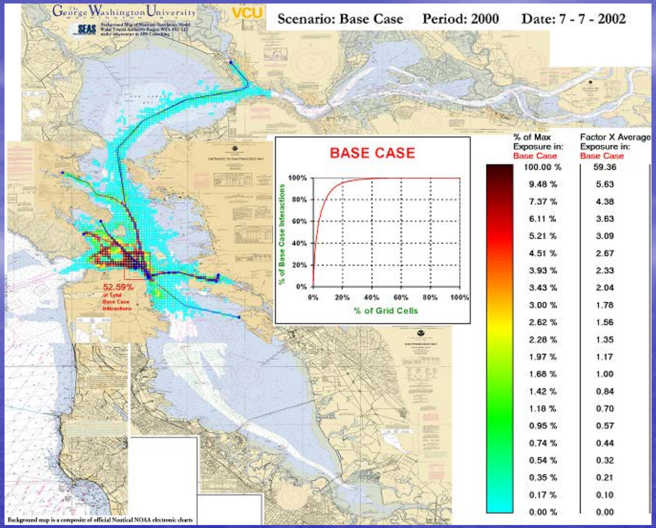
- **Washington State Ferries Risk Assessment**
  - Largest ferry system in the United States
  - Objective—Subchapter W determination, reduce risk alternatives to lifeboats
  - Simulation/expert judgment model improved based on NRC review of PWS study
  - Legislature approved funding of Safety Management System, training and emergency preparedness exercises

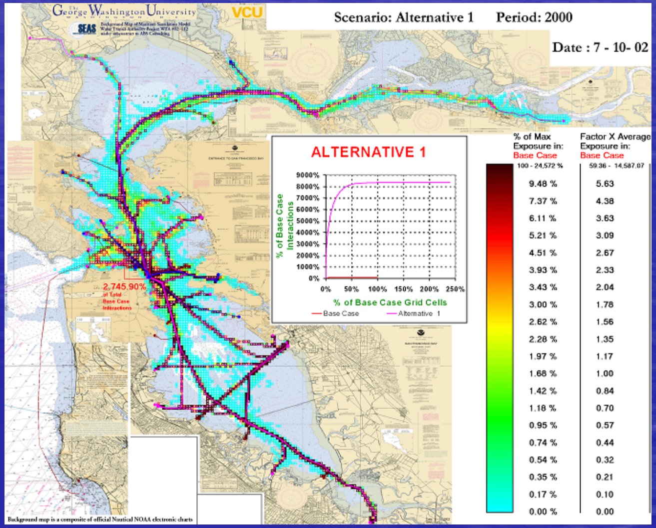


van Dorp, J. R., J. R. W. Merrick, J. Harrald, T. Mazzuchi, M. Grabowski. 2001. A Risk Management Procedure for the Washington State Ferries. *Risk Analysis* **21**(1) 127-142.

Previous Work

- San Francisco Bay Exposure Assessment
  - California legislature examining the effects of major expansion of ferry services
  - Objective—fulfill environmental impact requirement
  - Simulation model tested the impact of proposed expansion on vessel interactions
  - Legislature considering implementing proposed expansions

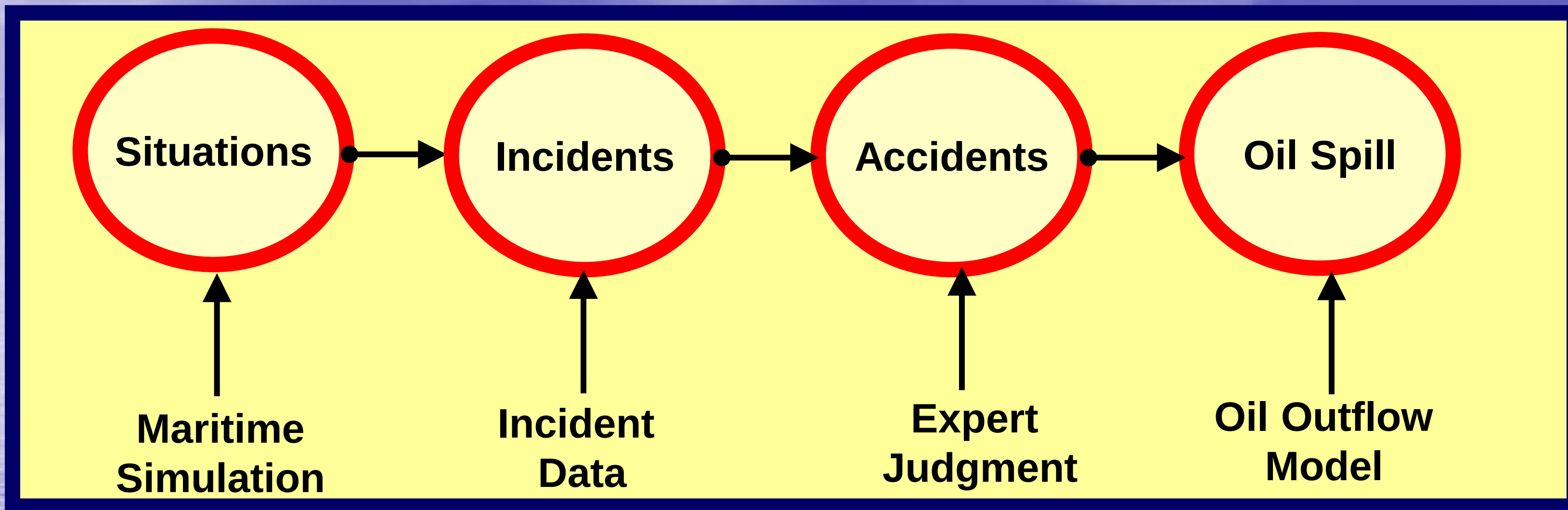




Merrick, J. R. W., J. R. van Dorp, J. P. Blackford, G. L. Shaw, J. Harrald, T.A. Mazzuchi. 2003. Traffic Density Analysis of Proposed Ferry Service Expansion in San Francisco Bay Using a Maritime Simulation Model. *Reliability Engineering and System Safety* **81**(2) 119-132.

CONTEXT OF VTRA STUDY

An Oil Spill is a series of cascading events referred to as a Causal Chain



$$R = \{< s_i, l_i, x_i >\}_c$$

Scenario i

Likelihood i

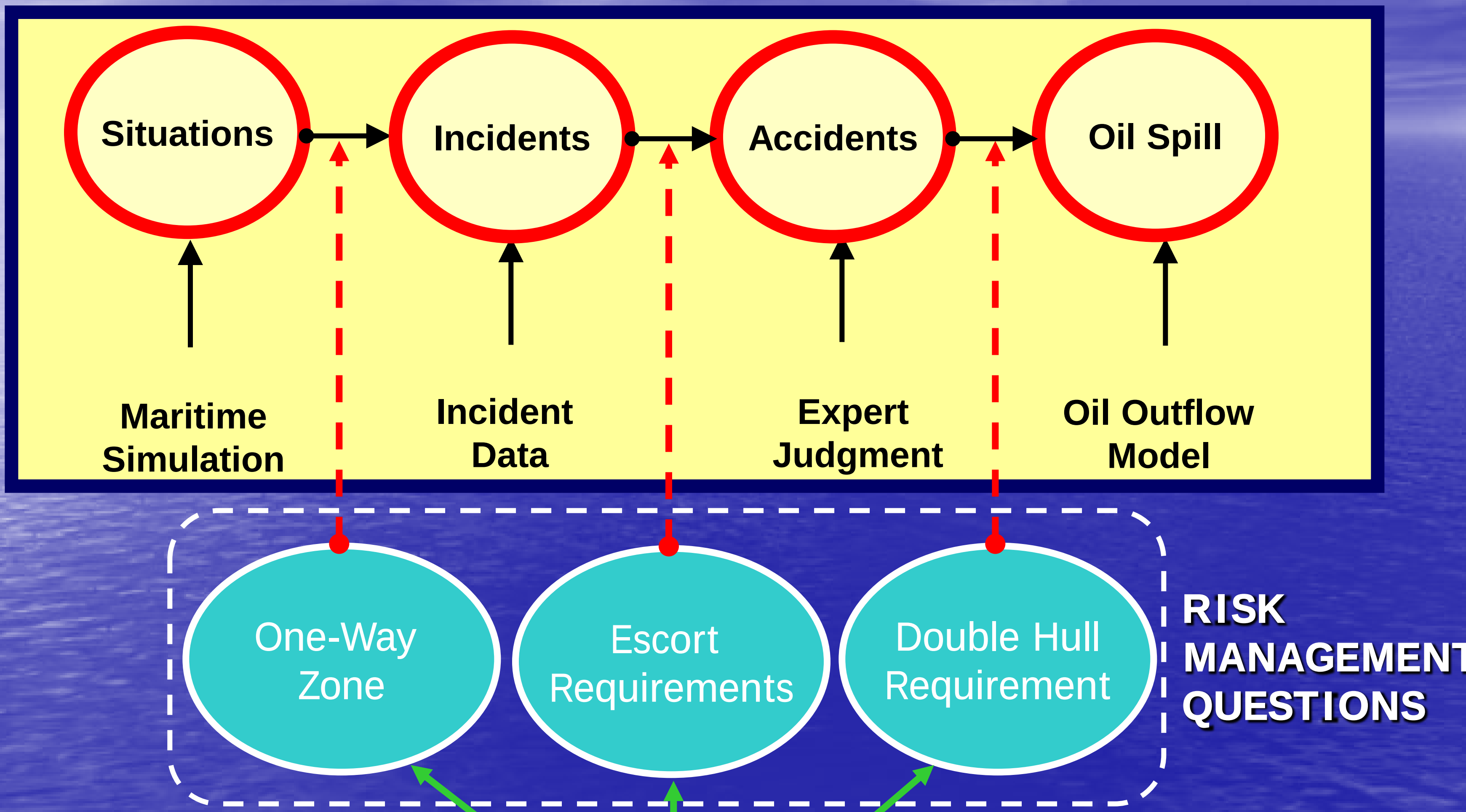
Consequence i

Complete Set

Use Kaplan's (1997) definition of system risk in:

"The Words of Risk Analysis", Risk Analysis 17 (4), 407-417

Risk Management of a Causal Chain



Kaplan's (1997) Risk Definition

$$R = \{< s_i, l_i, x_i >\}_c$$

Description of Case Study

- The analysis results herein evaluate the effectiveness of the three risk intervention measures on the previous slide by considering four scenarios of an MTS simulation of the geographic area within the bleu border on the next slide.

- The vessels of interest (VOI's) are **tankers, articulated tug barges and integrated tug barges** serving **six refineries within this geographic area**. The approximate locations of these refineries are identified on the next slide. (One of them in the south operates only as a petroleum tank farm since 1998).

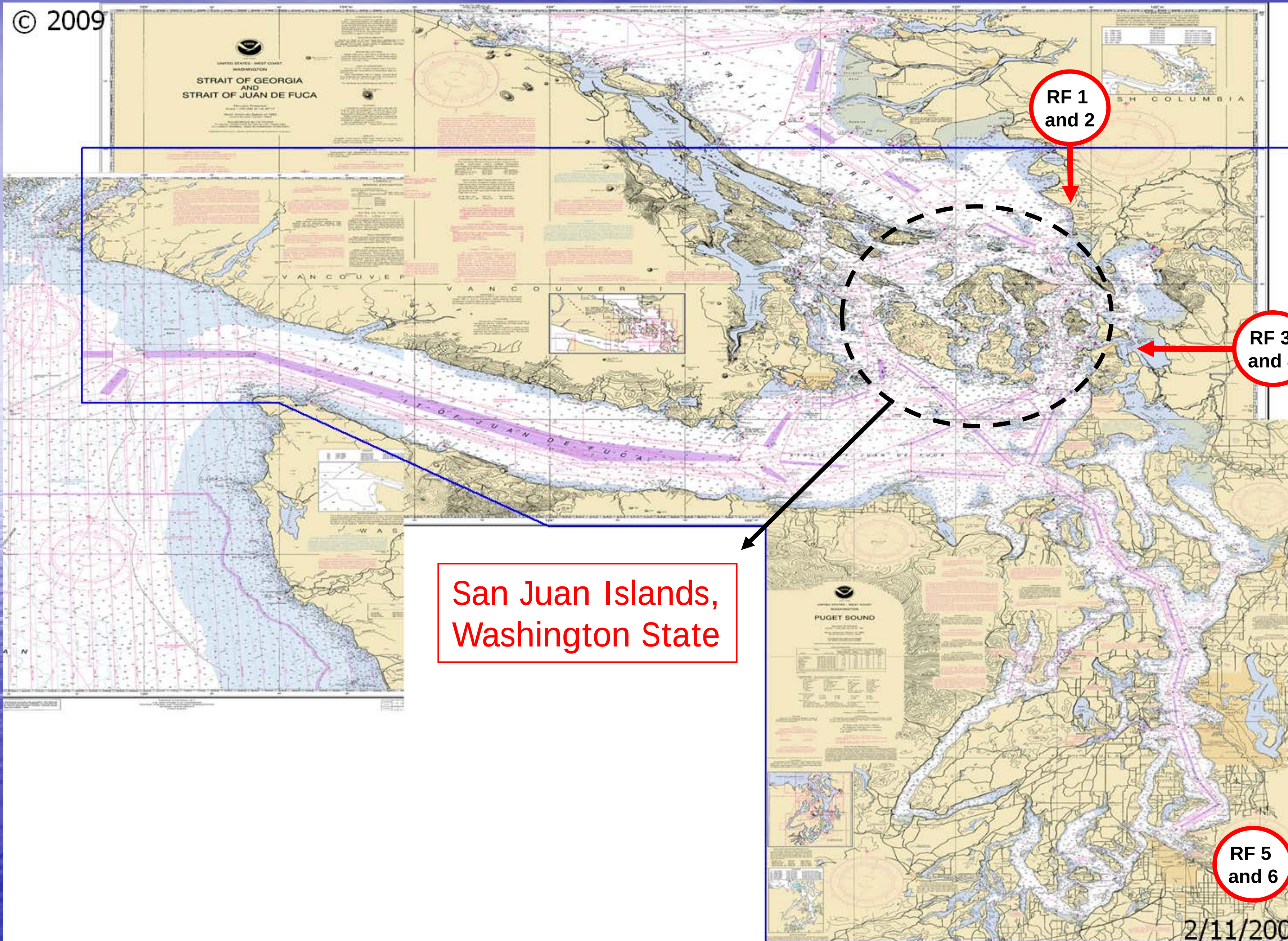
- **The four scenarios in question are fictitious scenarios that look back in time, not into the future**.

SCENARIO 1: Two-way traffic in Rosario Strait, No Escorting and all VOI's have a single hull.

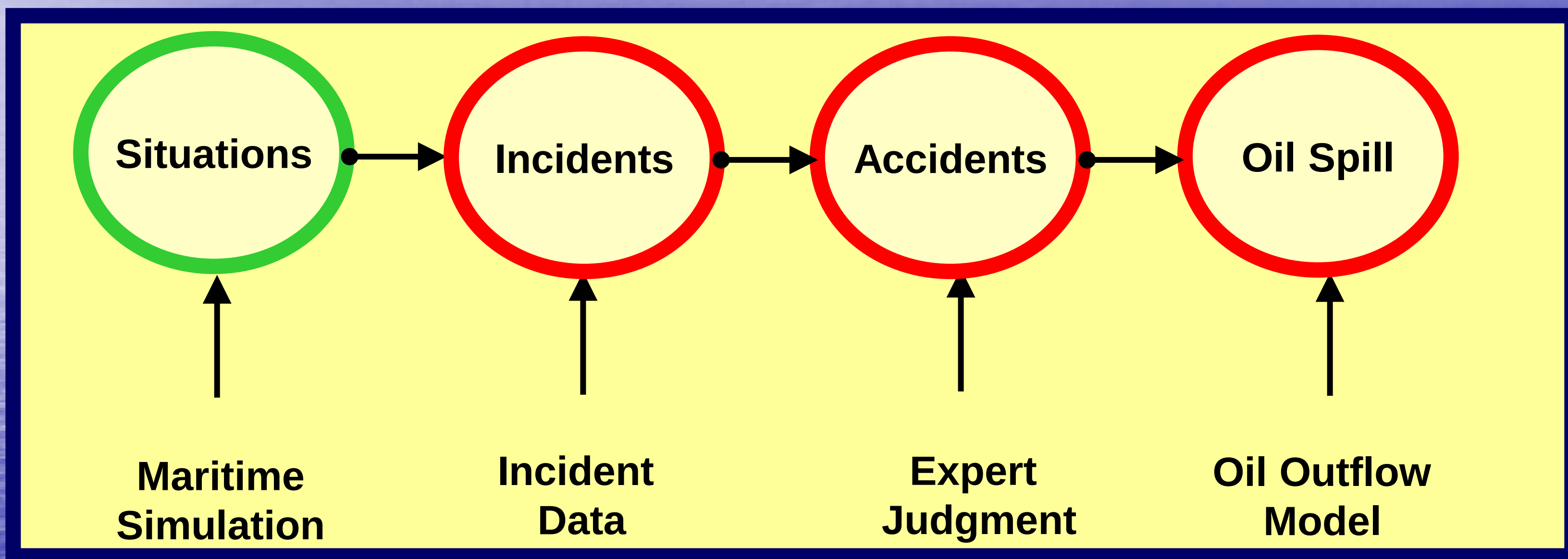
SCENARIO 2: One-way traffic in Rosario Strait, No Escorting and all VOI's have a single hull.

SCENARIO 3: One-way traffic in Rosario Strait, Escorting Scheme that mimics current regime in study area and all VOI's have a single hull.

SCENARIO 4: One-way traffic in Rosario Strait, Escorting Scheme that mimics current regime in study area and all VOI's have a double hull.


© 2009
STRAIT OF GEORGIA
AND
STRAIT OF JUAN DE FUCA
STRAIT OF GEORGIA
VANCOUVER
VANCOUVER I
STRAIT OF JUAN DE FUCA
BRITISH COLUMBIA
PUGET SOUND
RF 1
and 2
RF 3
and 4
RF 5
and 6
San Juan Islands,
Washington State
2/11/2009

Step 1: Generate Accident Scenarios

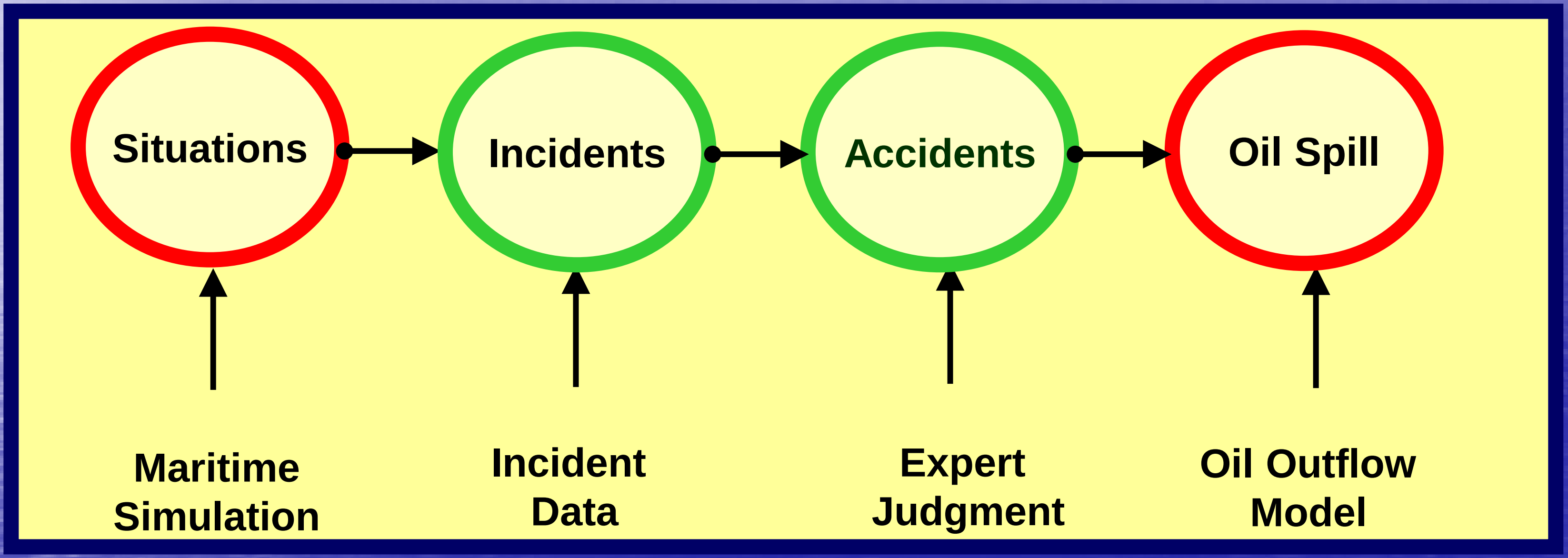


Joint work with:

VCU

VCU Personnel:
Dr. Jason R. W. Merrick,
Christina Werner

Step 2: Evaluate Accident Likelihood per Accident Scenario



Joint work with:

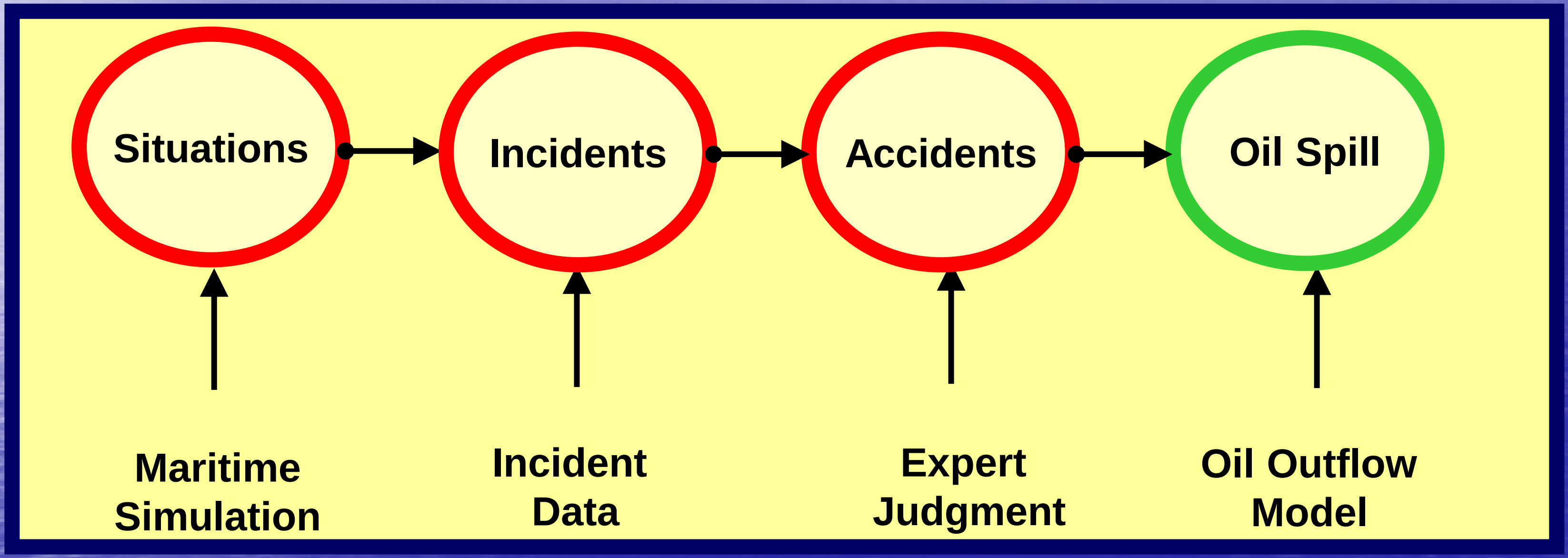
VCU Personnel:
Dr. Jason R. W. Merrick, and Team

VCU

RPI Personnel:
Dr. M. Grabowsku, and Team

Rensselaer

Step 3: Evaluate Consequence per Accident Scenario

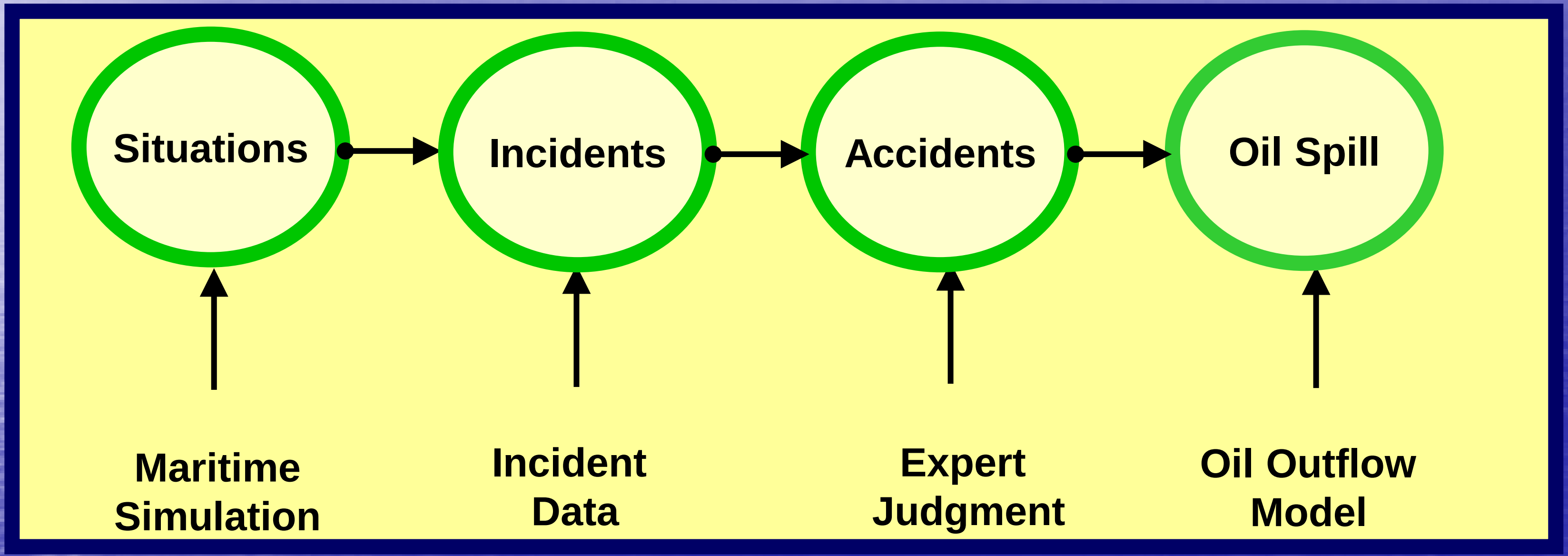


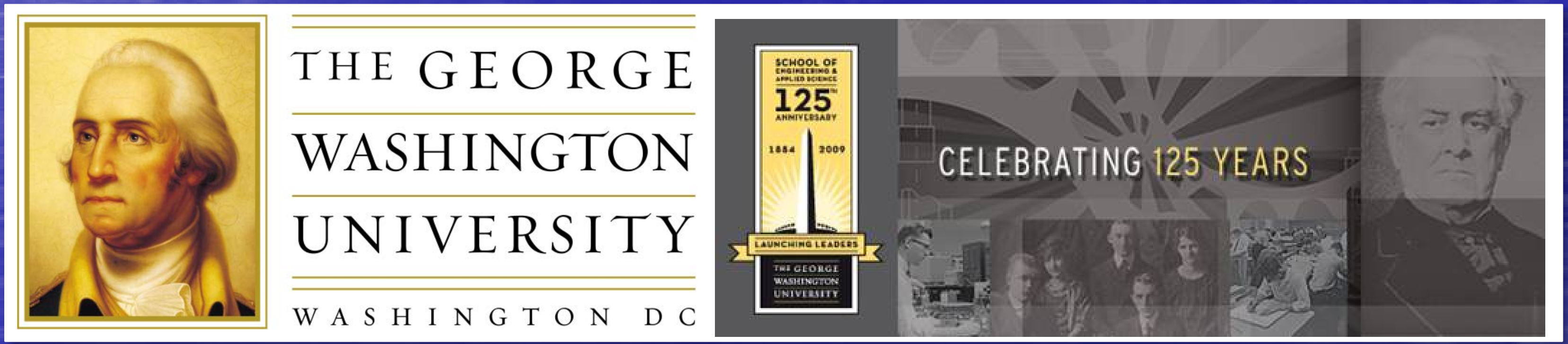
Joint work with:

Delft University of Technology

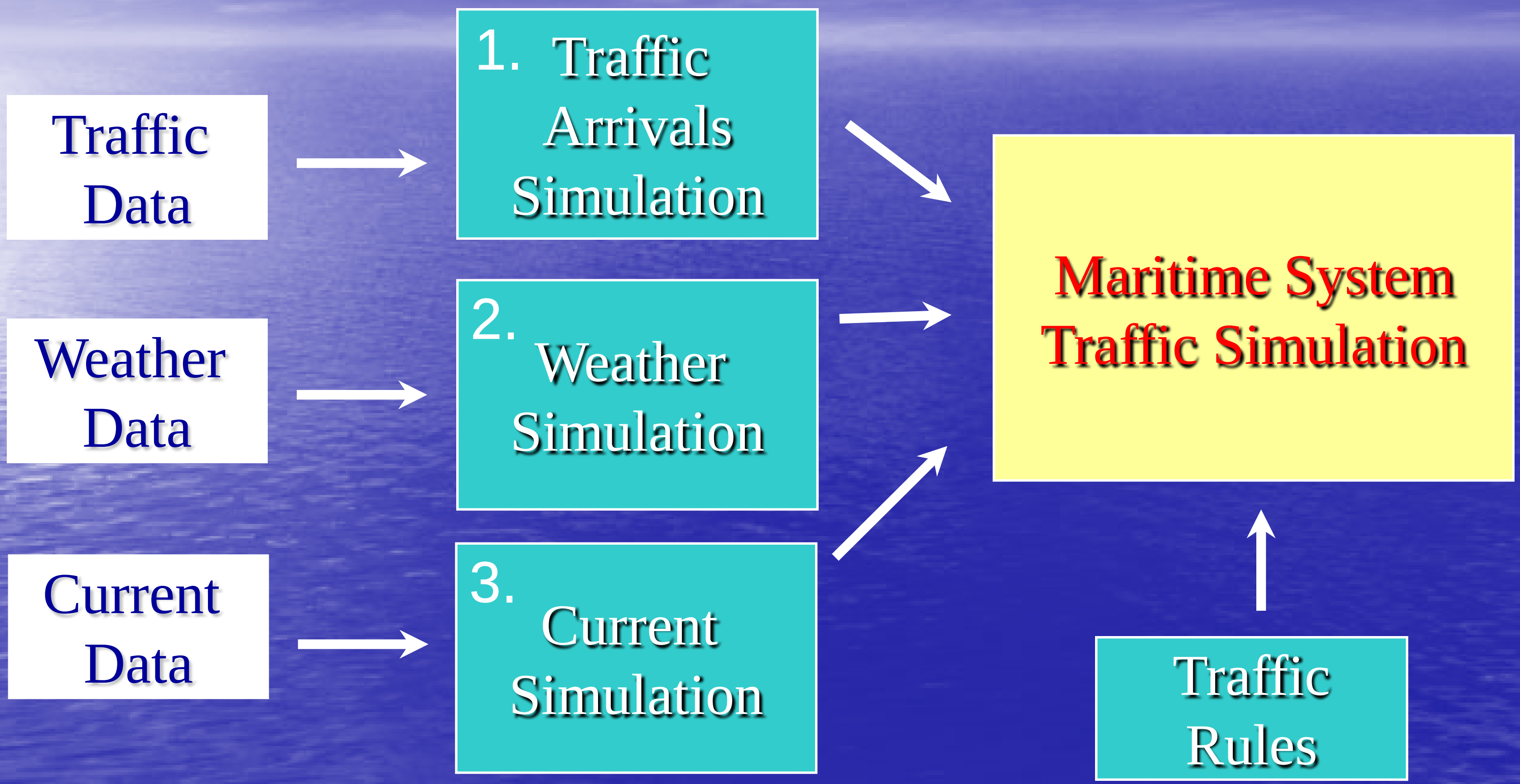
TU Delft Personnel:
Giel van de Wiel

Step 4: Integrate Previous 3 Steps





Step 1a: Model Maritime Traffic Simulation (MTS) Model



Required close cooperation with the USCG VTS and Puget Sound Harbor Safety Committee for data + validation

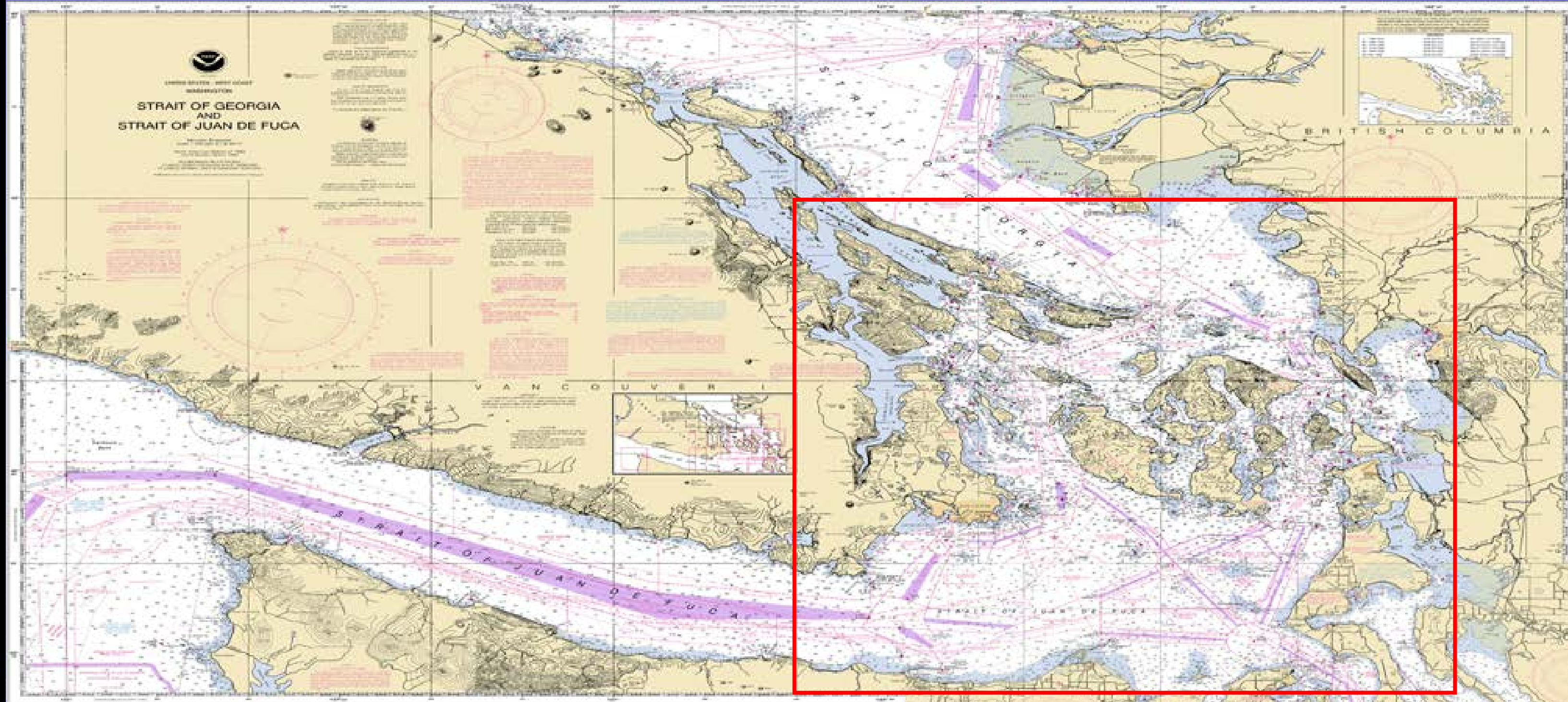
Route Modeling:
Assessment of Oil Spill Risk due to Potential Increased Vessel Traffic at Cherry Point, Washington

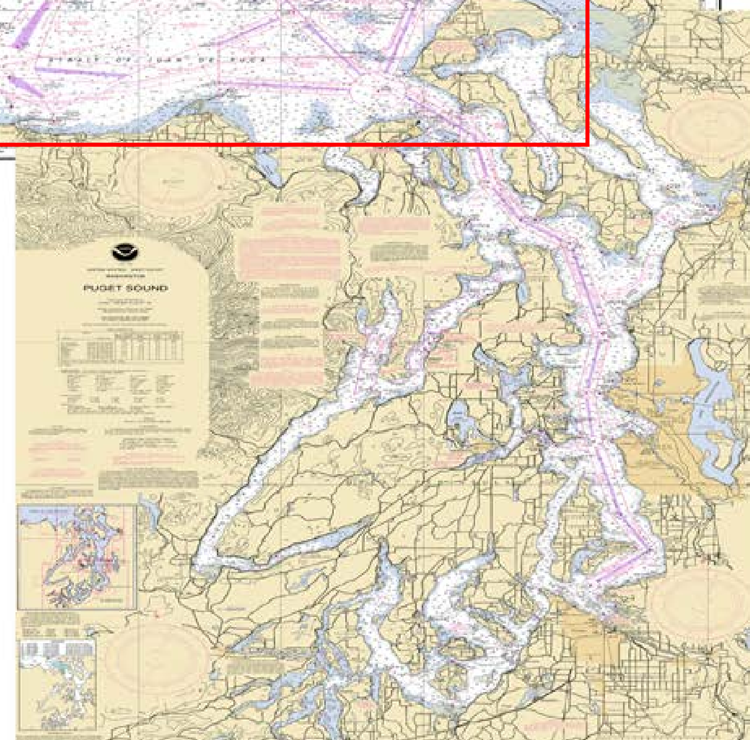
GWU Personnel:
Dr. Jack R. Harrald, Dr. J. Rene van Dorp, Dr. Greg Shaw,
Dr. Thomas A. Mazzuchi, Adil Caner Sener

RPI Personnel:
Dr. Martha Grabowski, Zhi Zhou

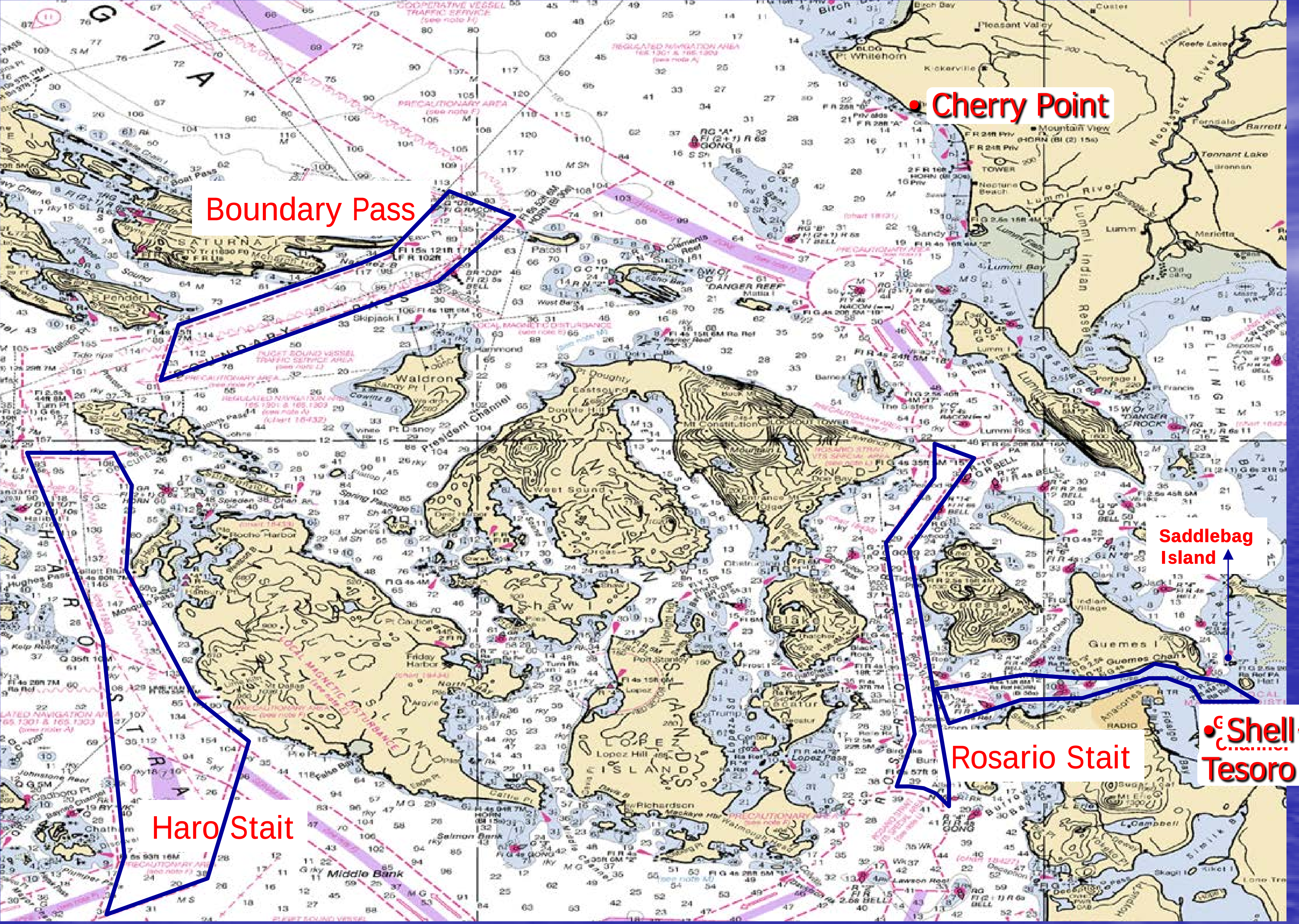
VCU Personnel:
Dr. Jason R. W. Merrick, Christina Werner

July 7, 2006





- Chart for the development of the Maritime Simulation
- For route presentation we shall zoom-in to the red border area


Cherry Point
Boundary Pass
Saddlebag Island
Shell
Tesoro
Rosario Stait
Haro Stait

Oil tankers

Inbound Tankers BP Cherry Point

Outbound Tankers BP Cherry Point

Inbound Tankers Ferndale

Outbound Tankers Ferndale

Inbound Tankers Shell + Tesoro

Outbound Tankers Shell + Tesoro

Container

Bulk Carrier

Chemical Carrier

RoRo Cargo

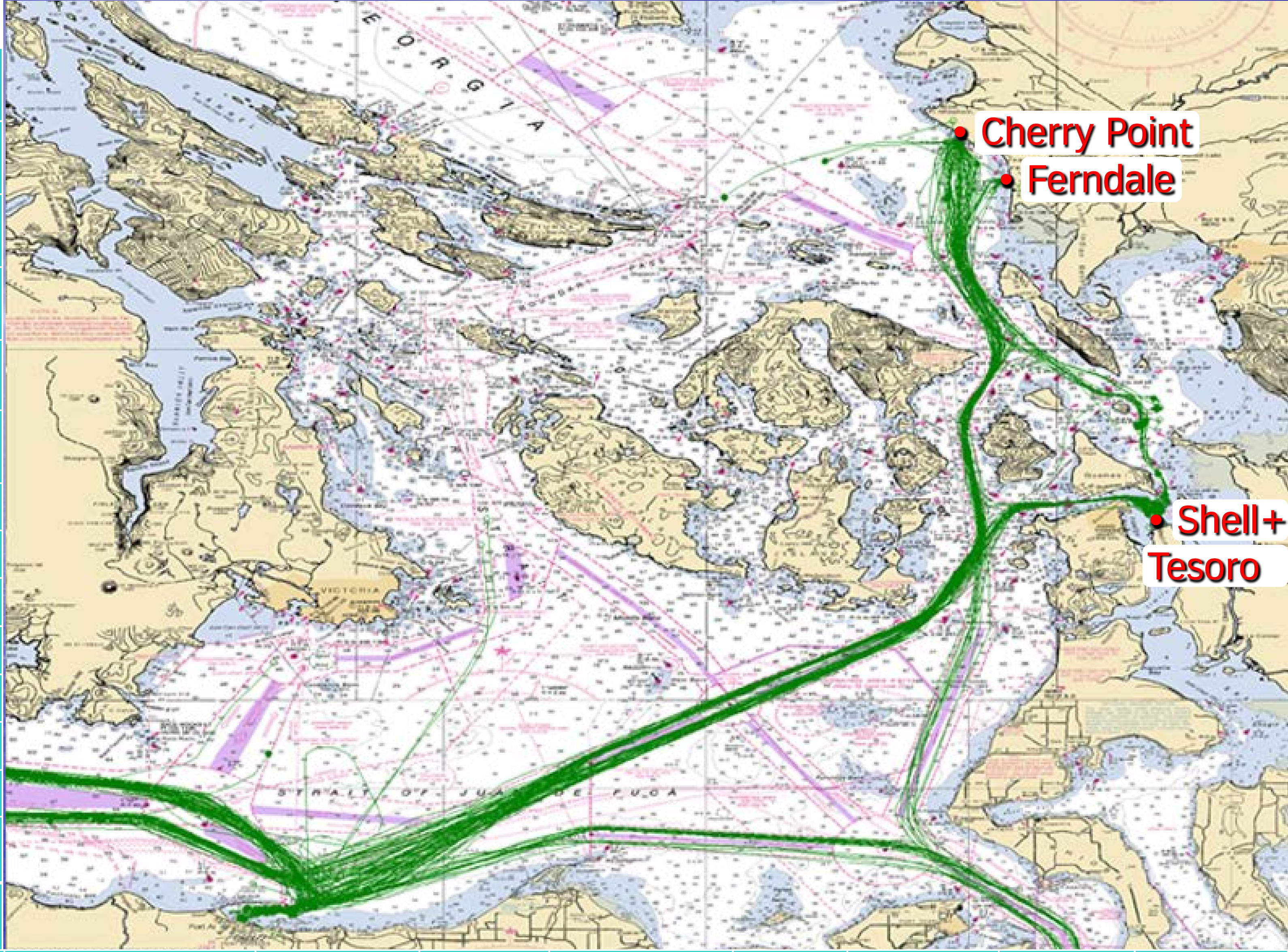
Liquid Gas Carrier

Tug Tow Barge

Supply Off Shore

Fish Factory

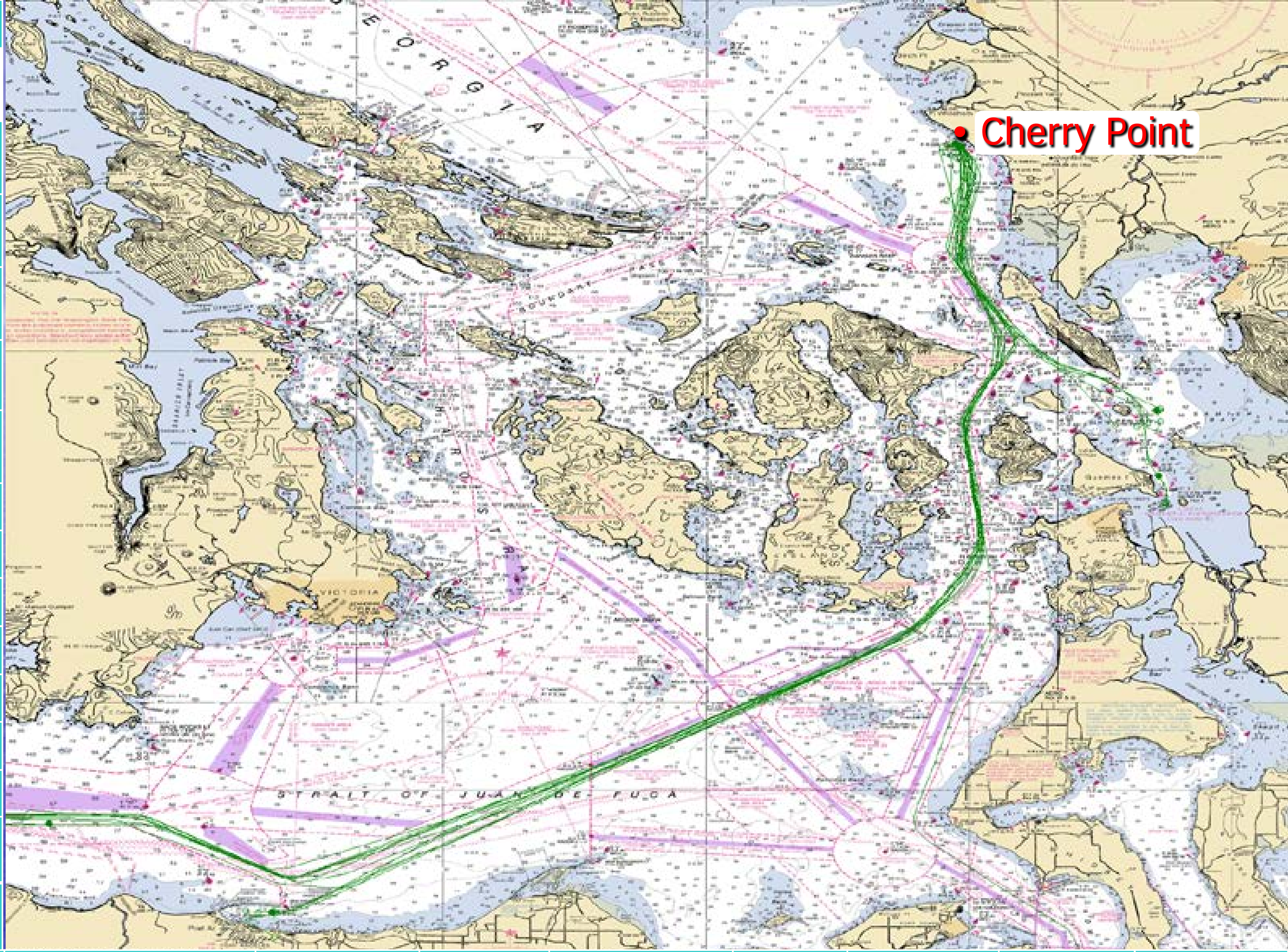
Fish Vessel



Local Ferries | Non Local Ferries | Passenger | Yachts | Survey Ships | USCG | Research | Navy | Unknown

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

Oil tankers
Inbound Tankers BP Cherry Point
Outbound Tankers BP Cherry Point
Inbound Tankers Ferndale
Outbound Tankers Ferndale
Inbound Tankers Shell + Tesoro
Outbound Tankers Shell + Tesoro
Container
Bulk Carrier
Chemical Carrier
RoRo Cargo
Liquid Gas Carrier
Tug Tow Barge
Supply Off Shore
Fish Factory
Fish Vessel



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Oil tankers

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Outbound Tankers BP Cherry Point

Inbound Tankers Ferndale

Outbound Tankers Ferndale

Inbound Tankers Shell + Tesoro

Outbound Tankers Shell + Tesoro

Container

Bulk Carrier

Chemical Carrier

RoRo Cargo

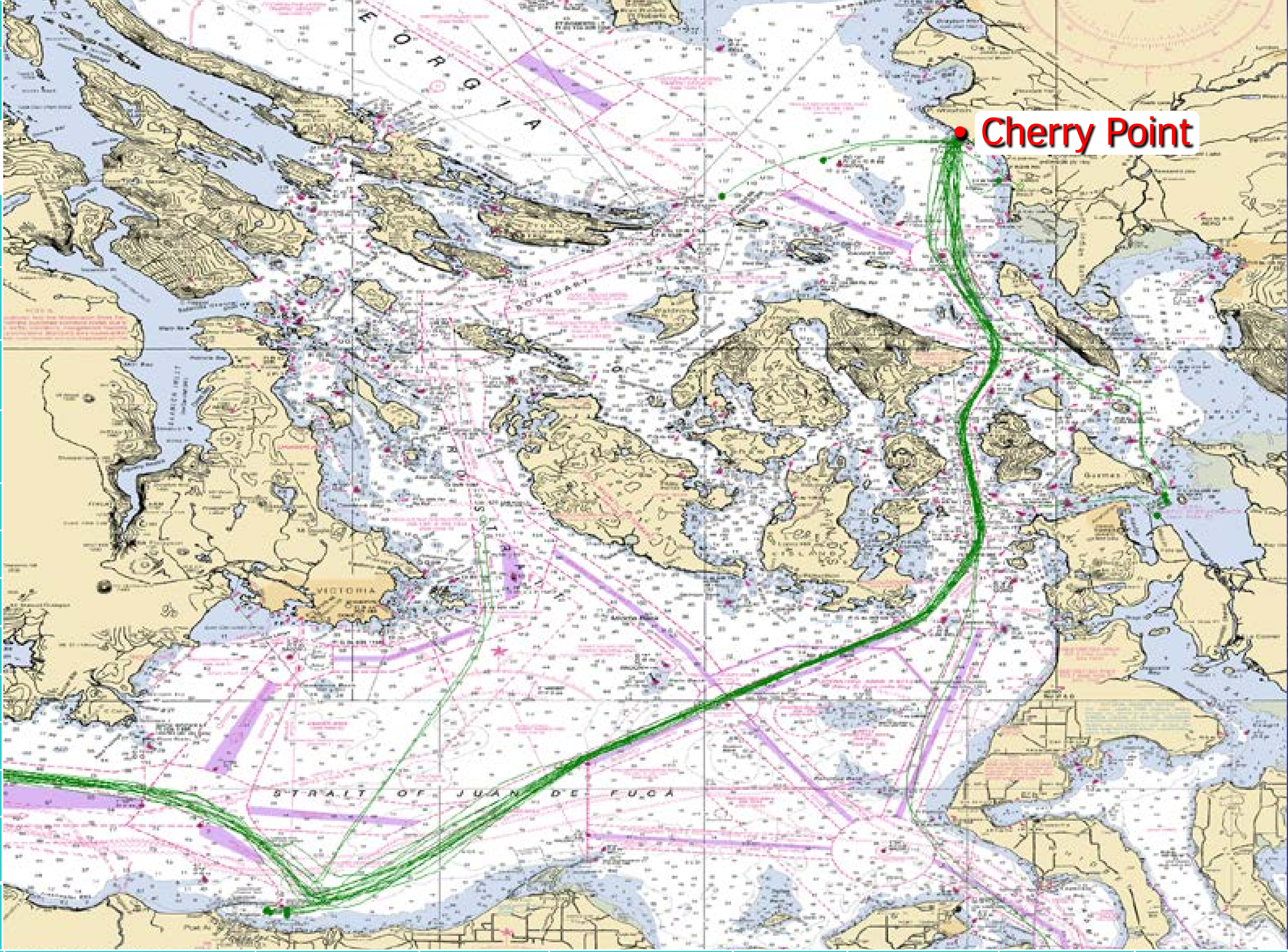
Liquid Gas Carrier

Tug Tow Barge

Supply Off Shore

Fish Factory

Fish Vessel



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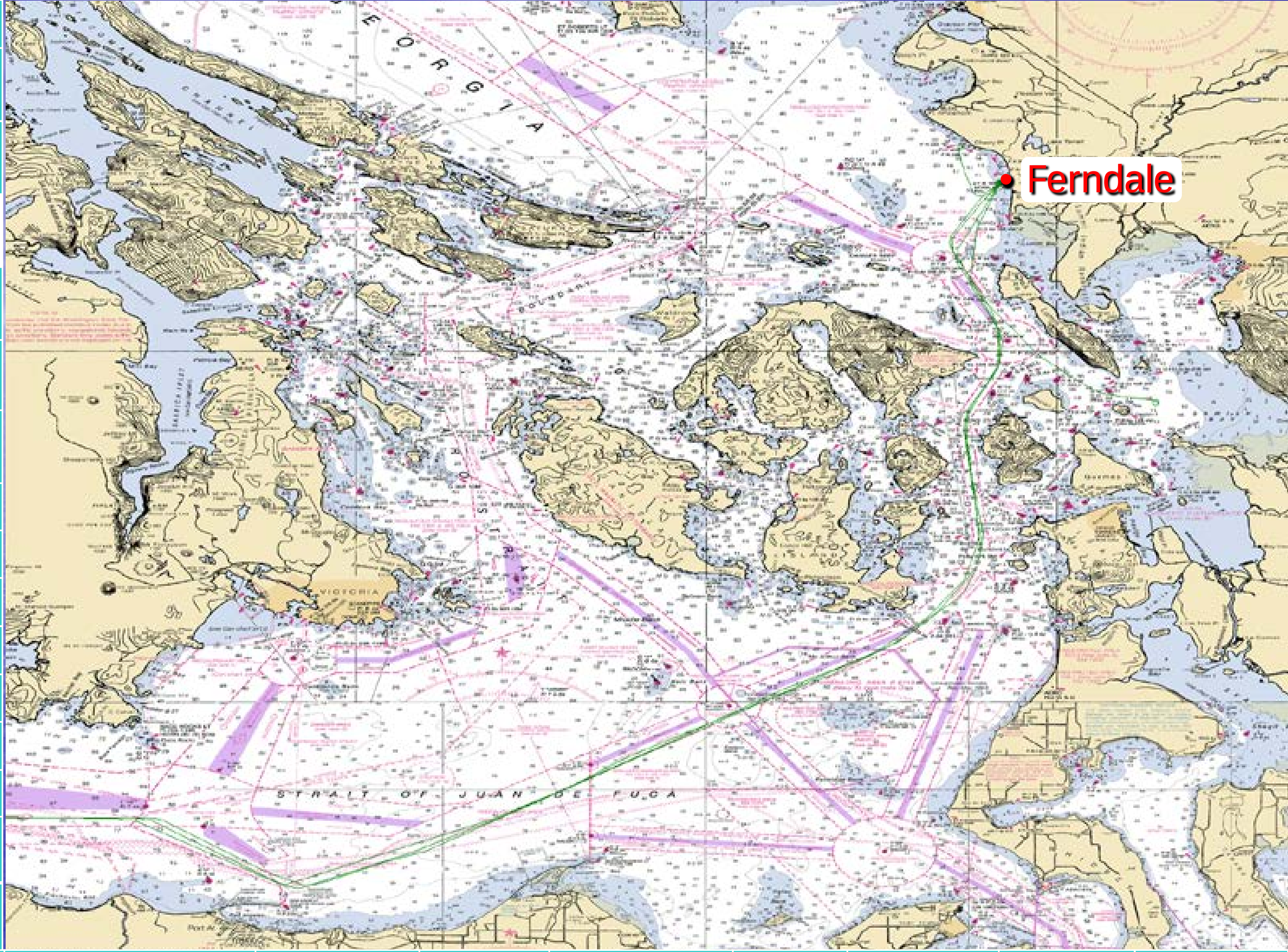
Outbound Tankers Ferndale
Inbound Tankers Shell + Tesoro
Outbound Tankers Shell + Tesoro
Container
Bulk Carrier
Chemical Carrier
RoRo Cargo
Liquid Gas Carrier
Tug Tow Barge
Supply Off Shore
Fish Factory
Fish Vessel



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Oil tankers

Inbound Tankers BP Cherry Point

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Inbound Tankers Ferndale

Outbound Tankers Ferndale

Inbound Tankers Shell + Tesoro

Outbound Tankers Shell + Tesoro

Container

Bulk Carrier

Chemical Carrier

RoRo Cargo

Liquid Gas Carrier

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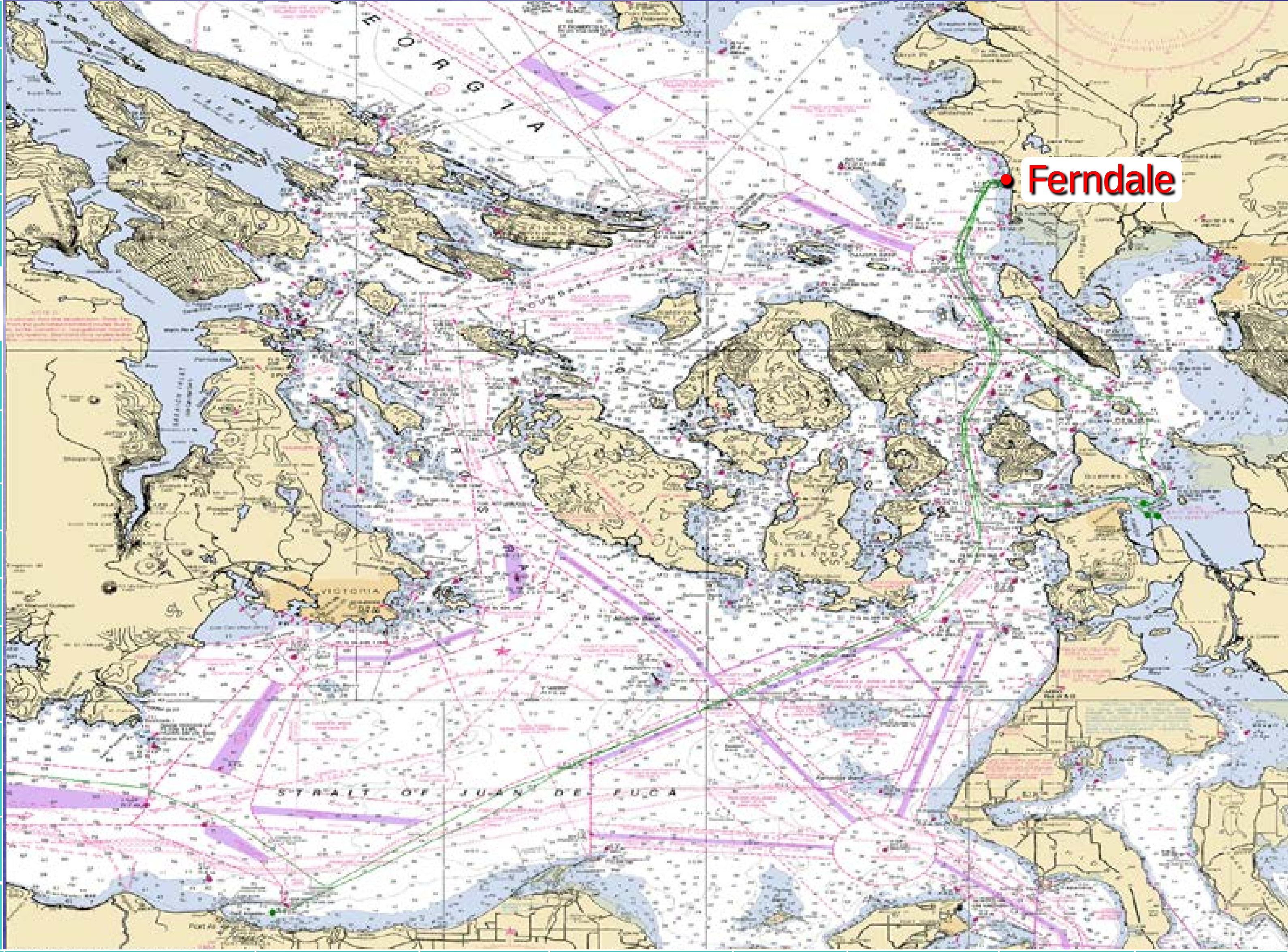
Supply Off Shore

Fish Factory

Fish Vessel



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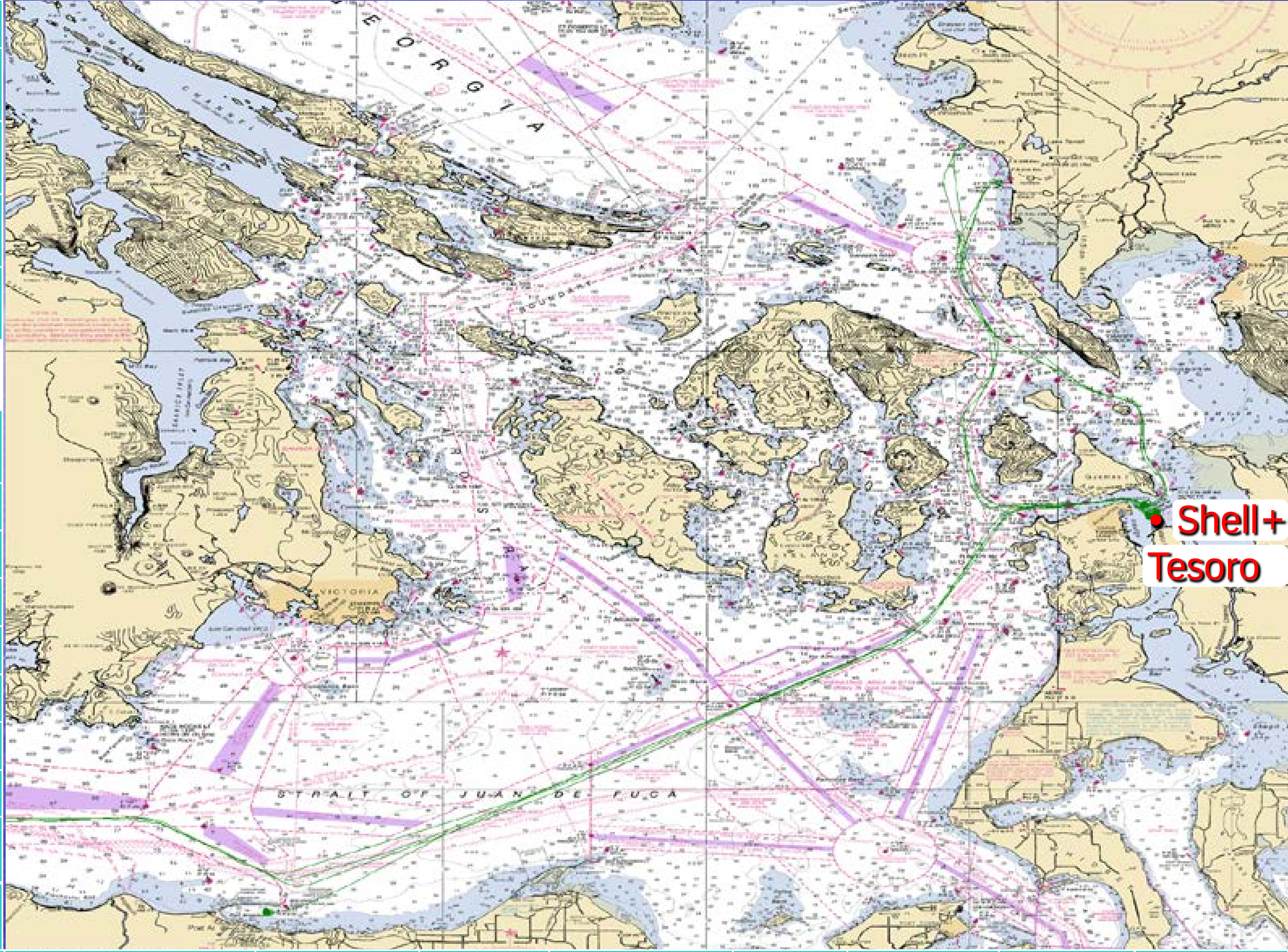
- Fish Factory
- Fish Vessel



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Outbound Tankers BP Cherry Point

Inbound Tankers Ferndale

Outbound Tankers Ferndale

Inbound Tankers Shell + Tesoro

Outbound Tankers Shell + Tesoro

Container

Bulk Carrier

Chemical Carrier

RoRo Cargo

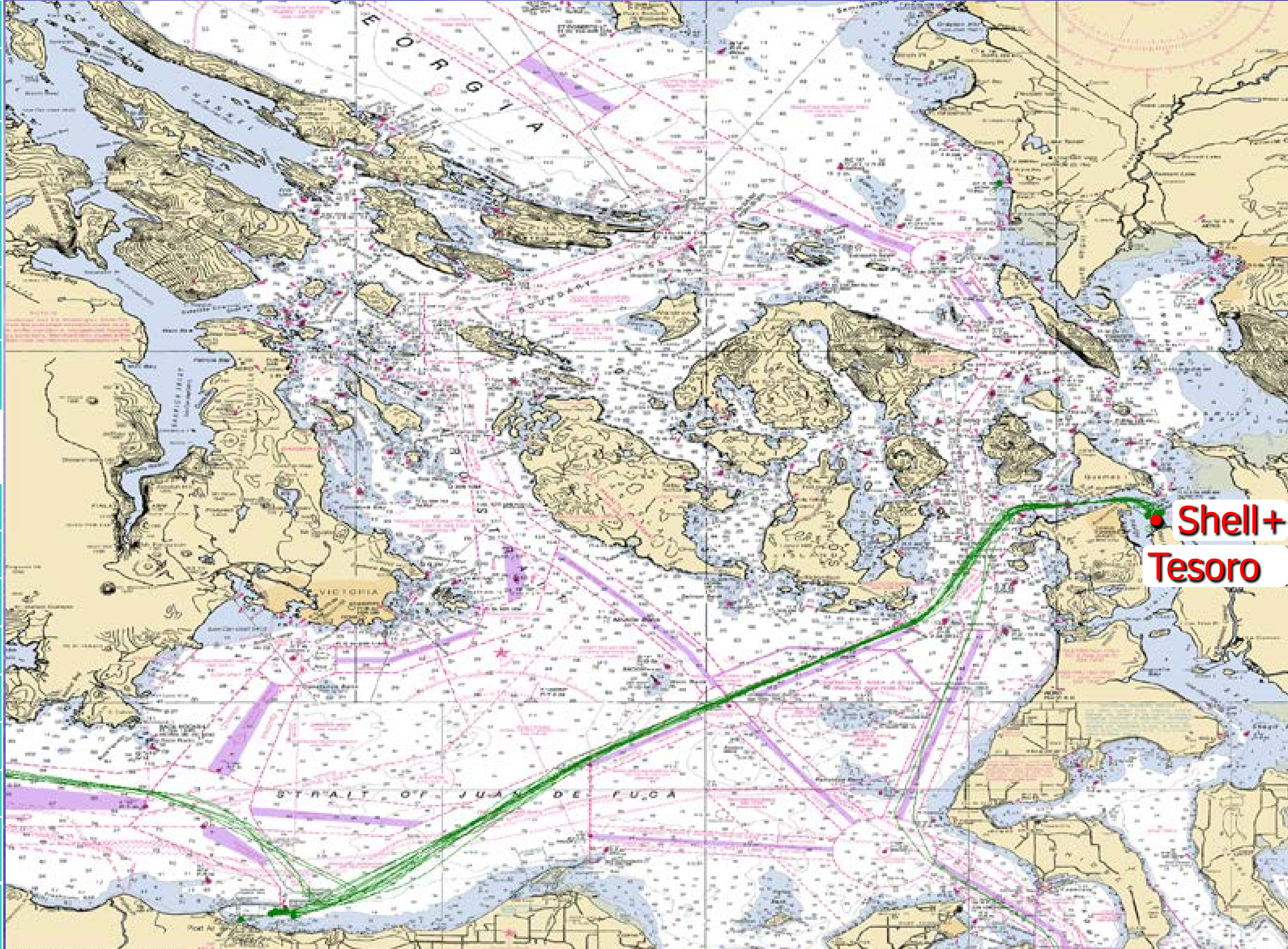
Liquid Gas Carrier

Tug Tow Barge

Supply Off Shore

Fish Factory

Fish Vessel



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Oil tankers

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Inbound Tankers Ferndale

Outbound Tankers Ferndale

Inbound Tankers Shell + Tesoro

Outbound Tankers Shell + Tesoro

Container

Bulk Carrier

Chemical Carrier

RoRo Cargo

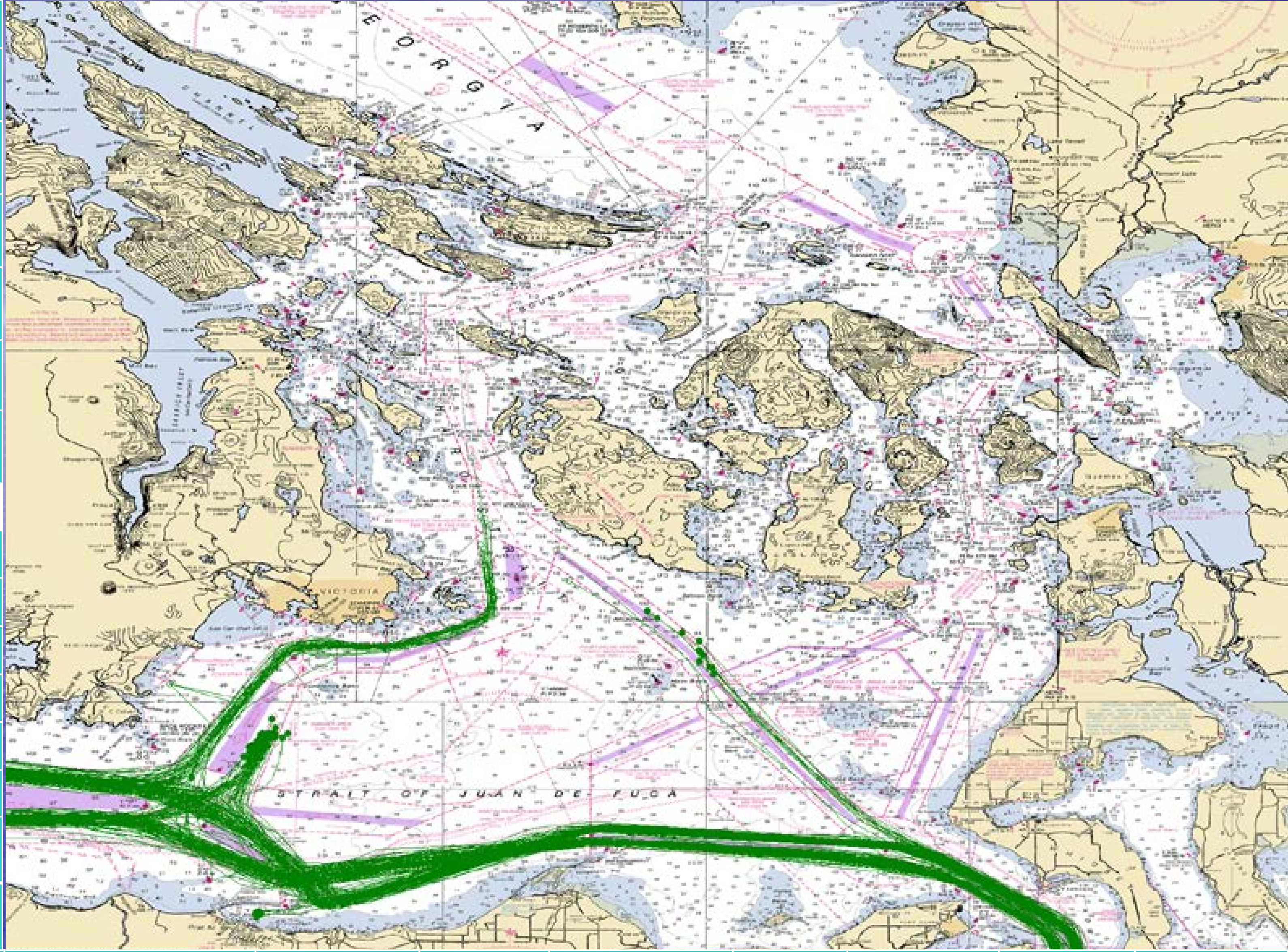
Liquid Gas Carrier

Tug Tow Barge

Supply Off Shore

Fish Factory

Fish Vessel



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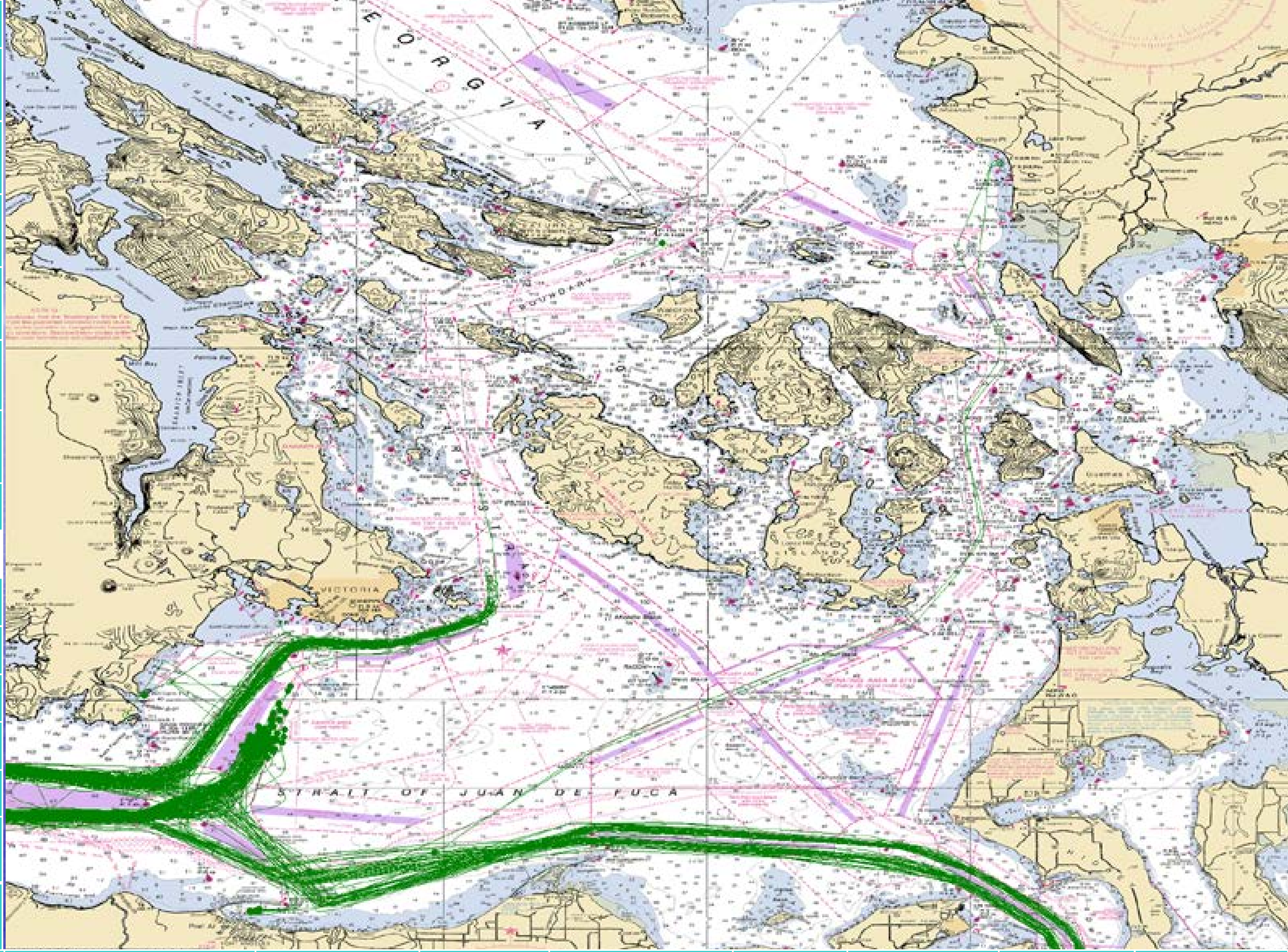

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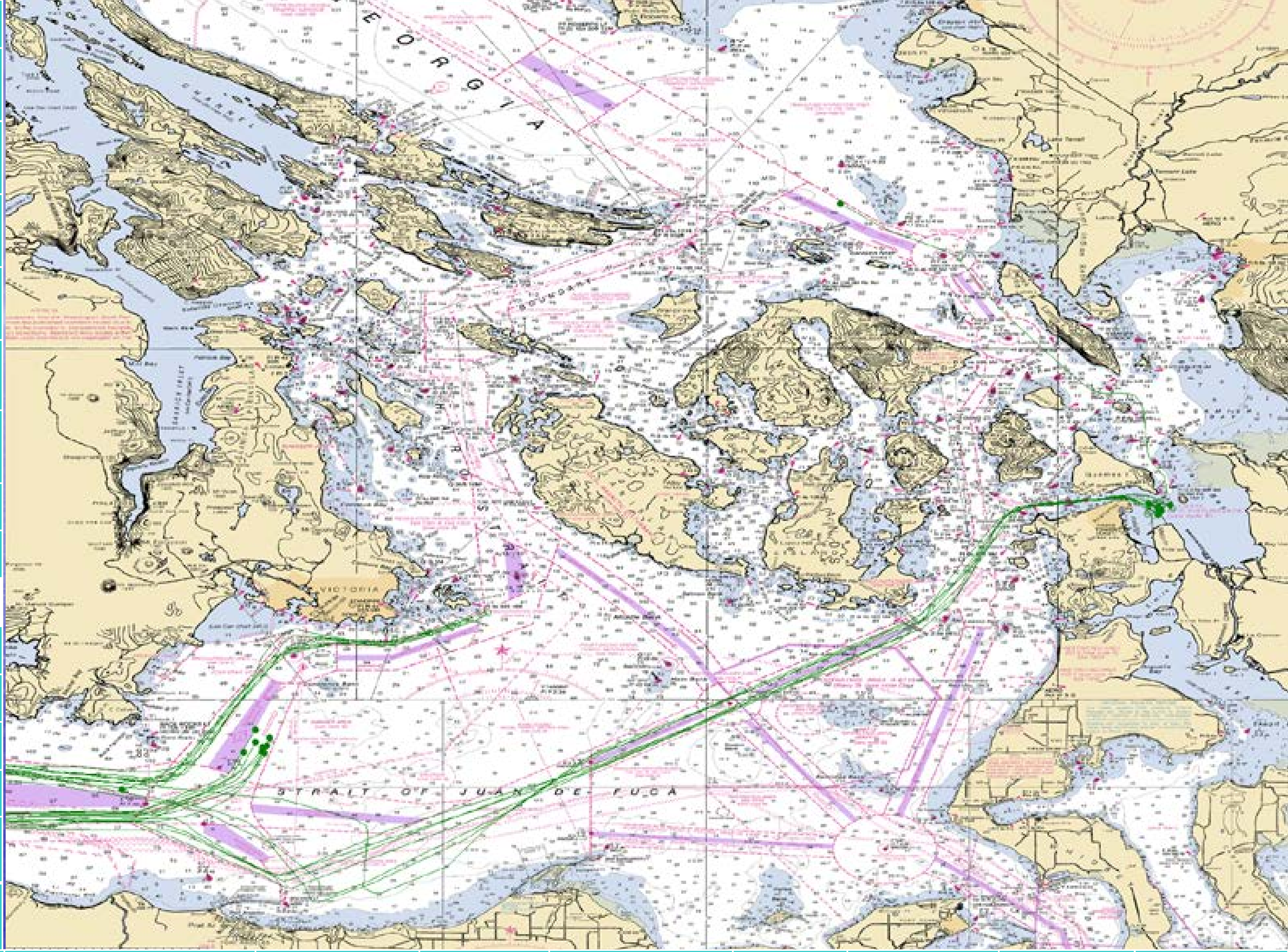
Fish Factory

Fish Vessel



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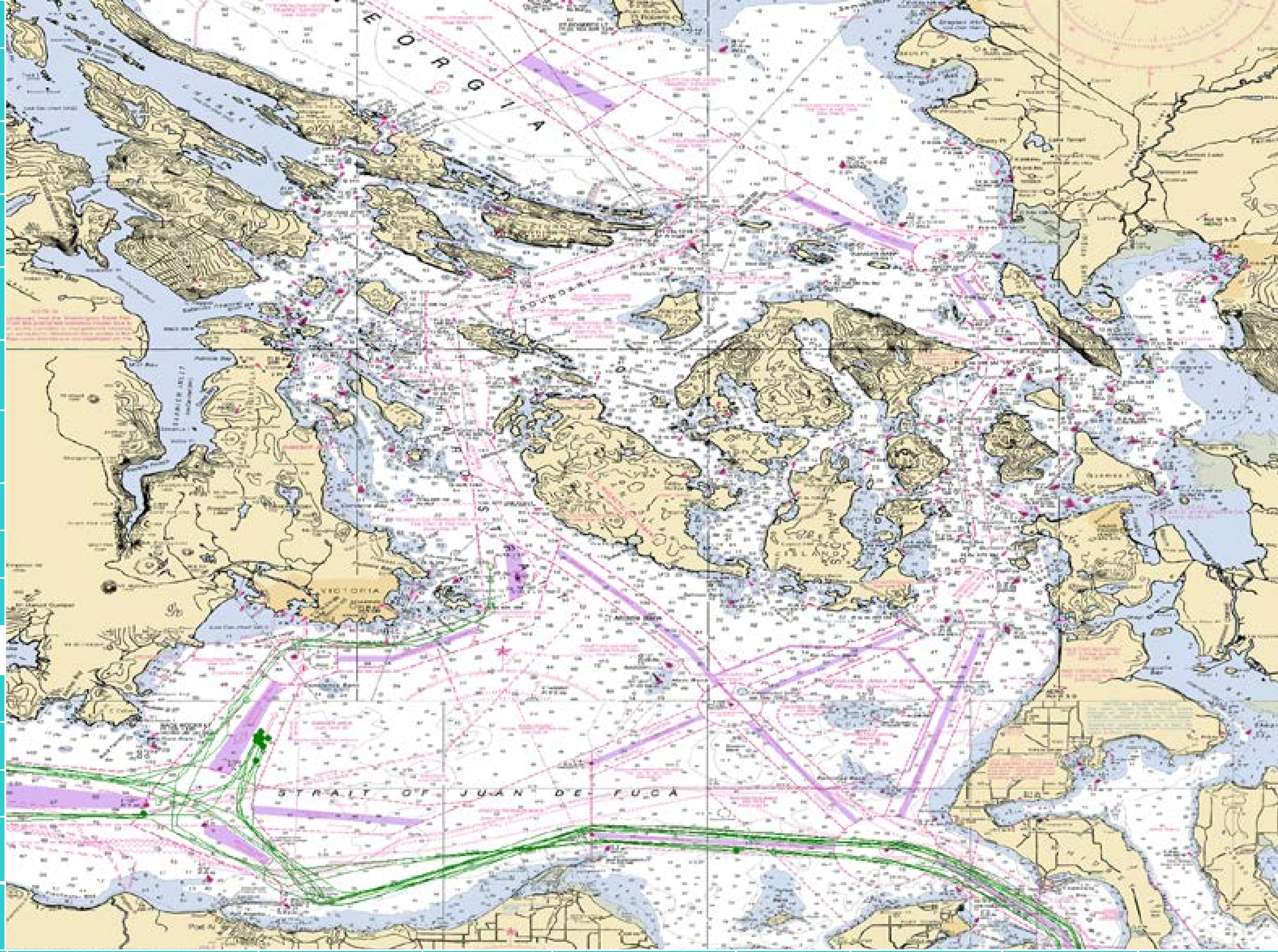

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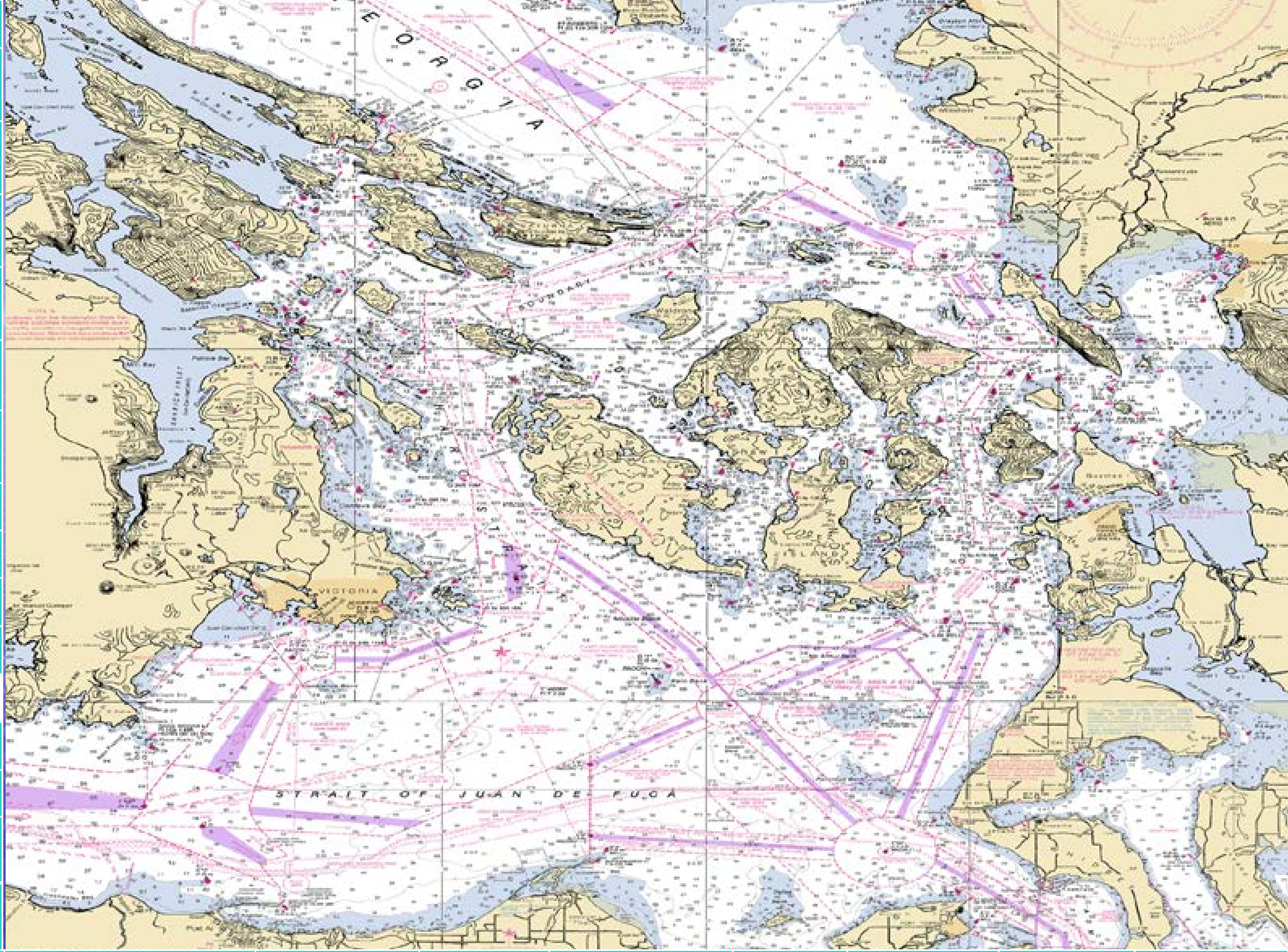

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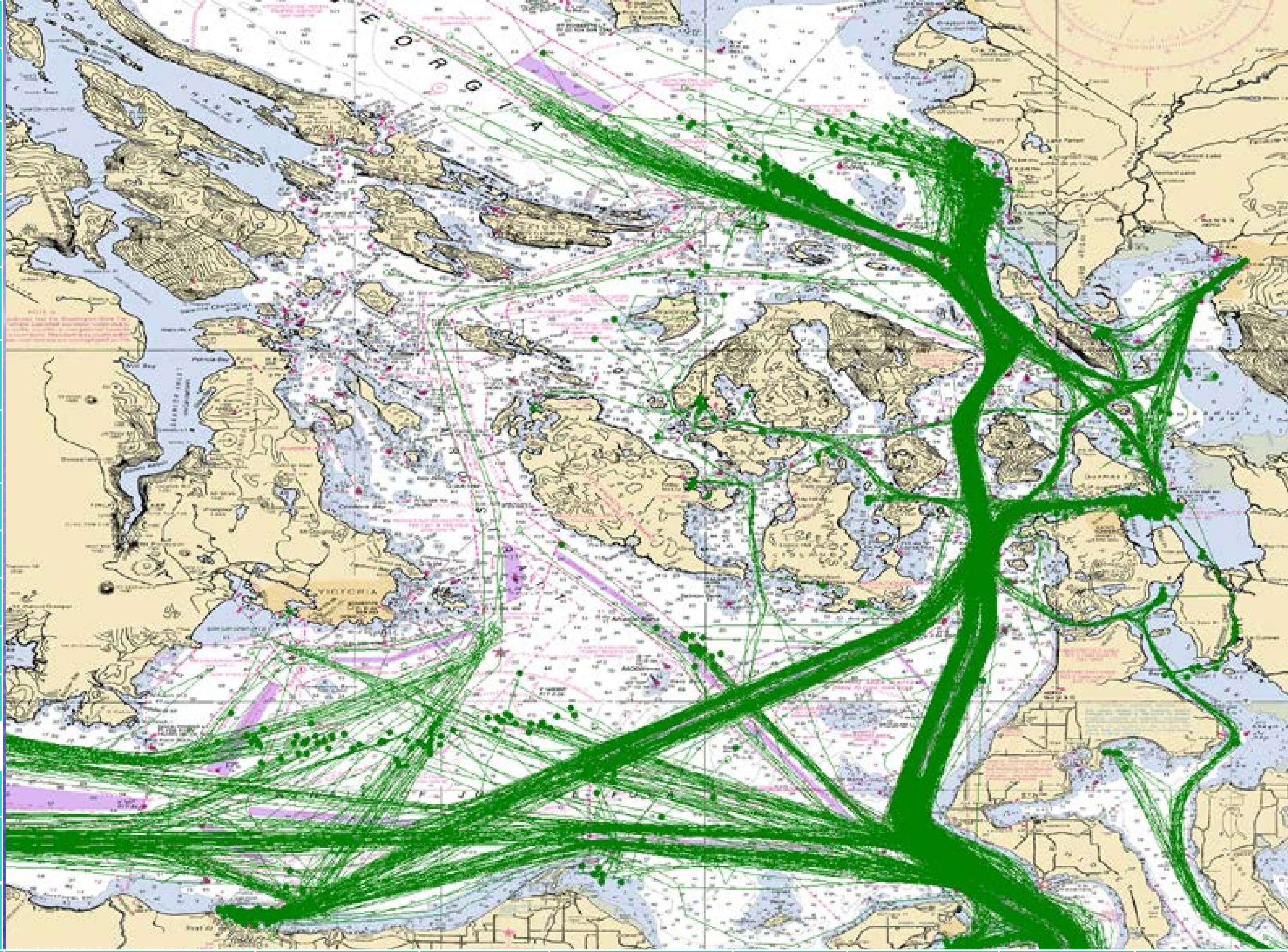

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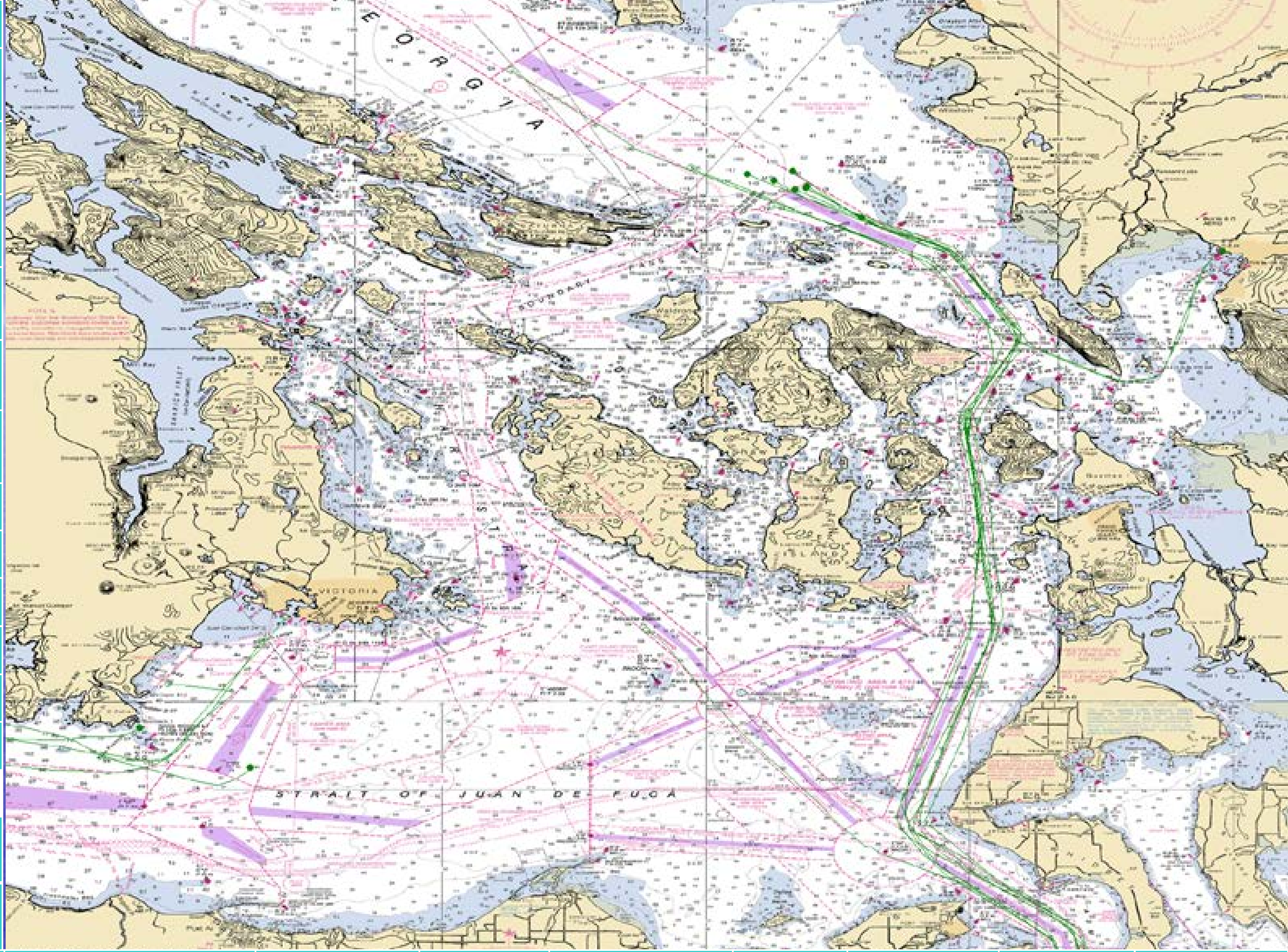

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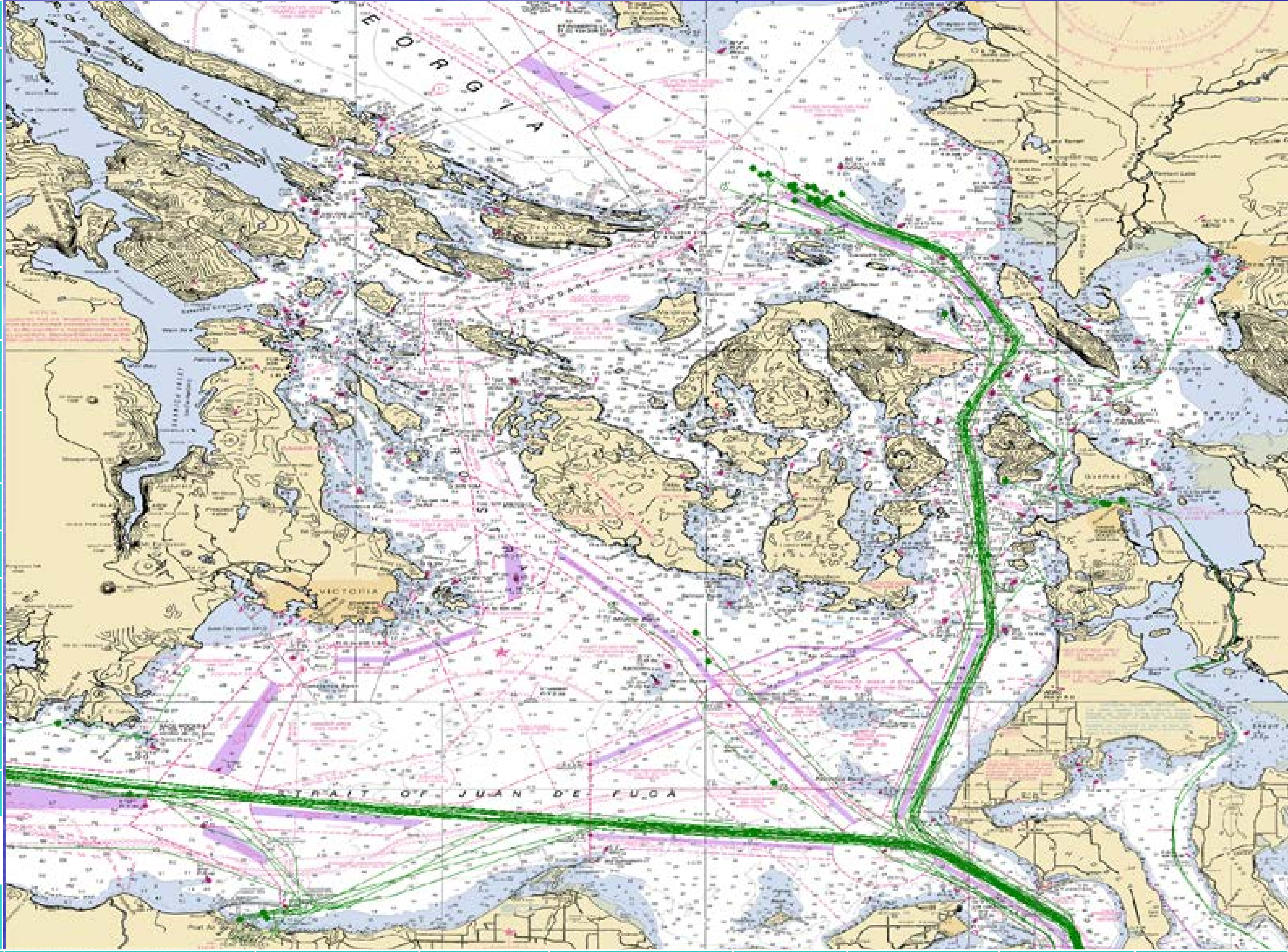
GEORGIA
VICTORIA
STRAIT OF JUAN DE FUCA

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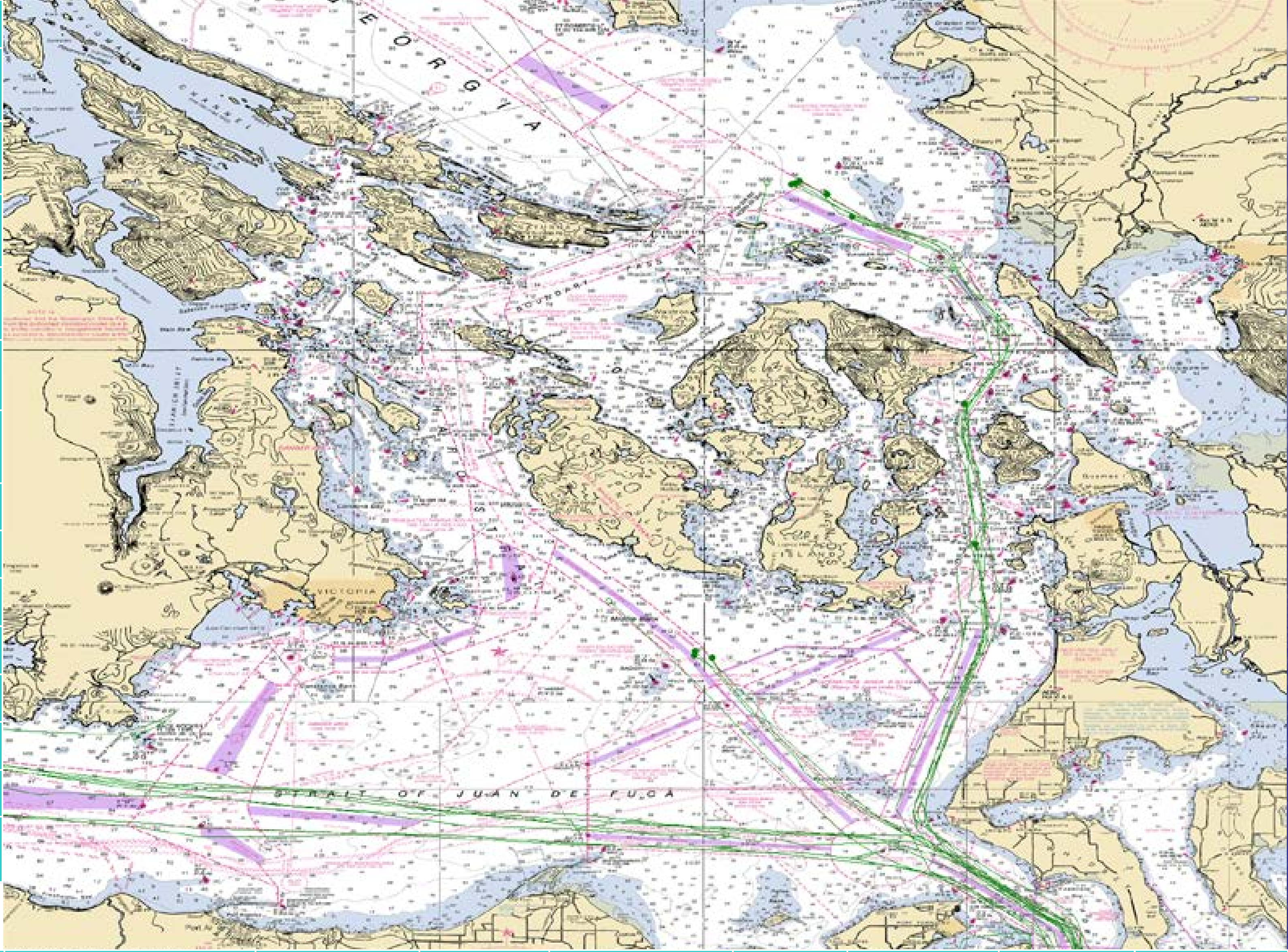

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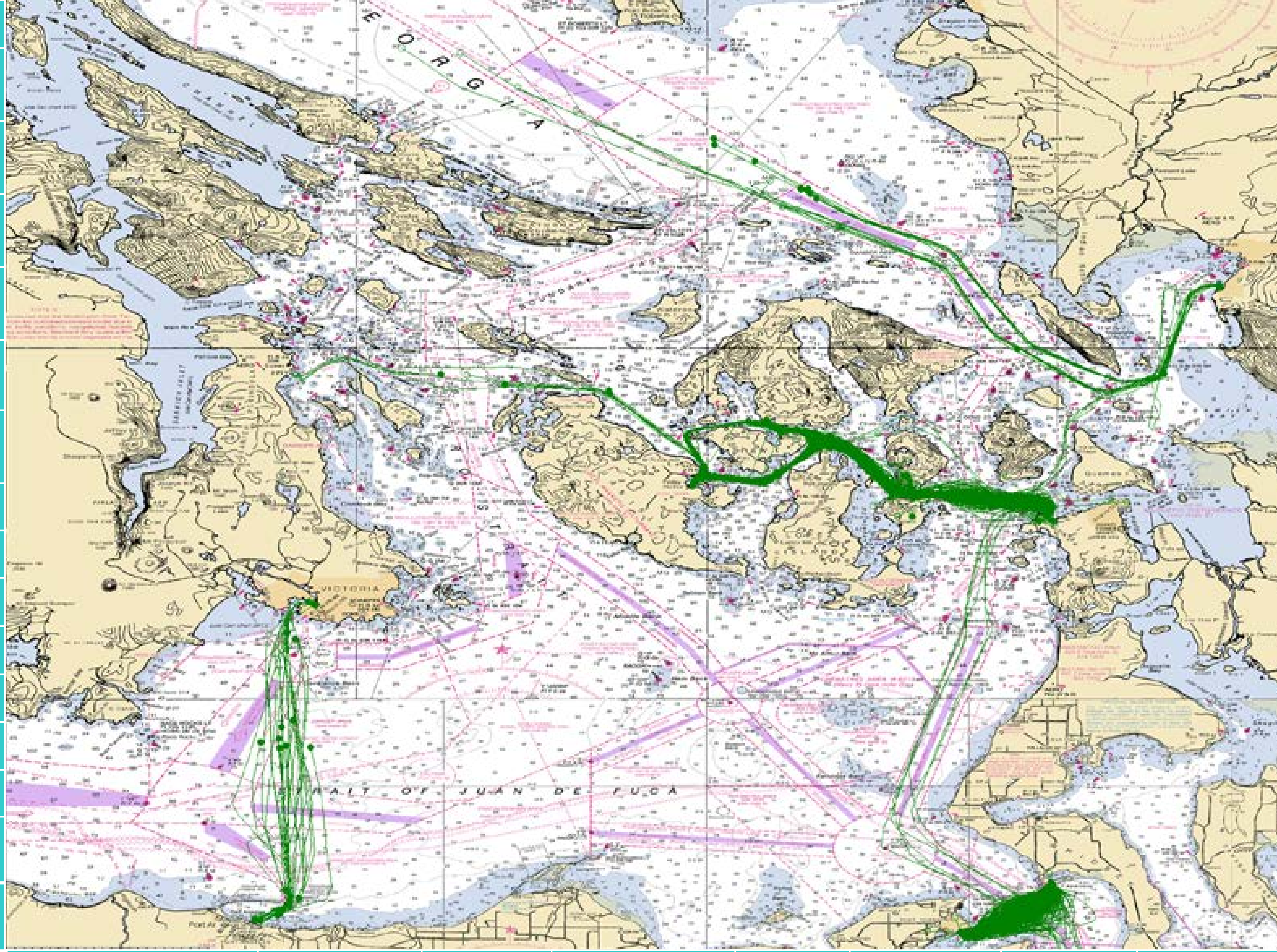

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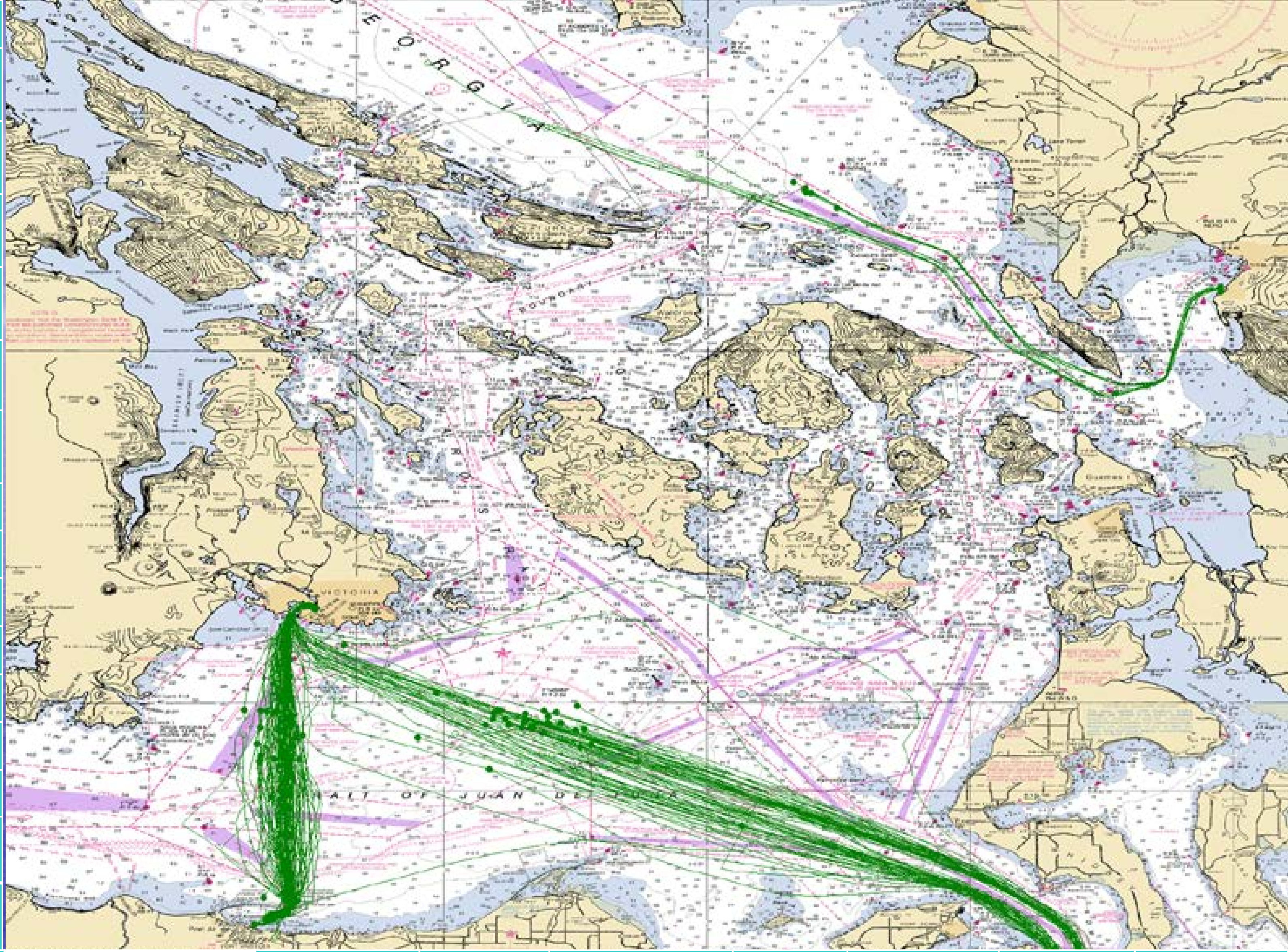
Fish Vessel



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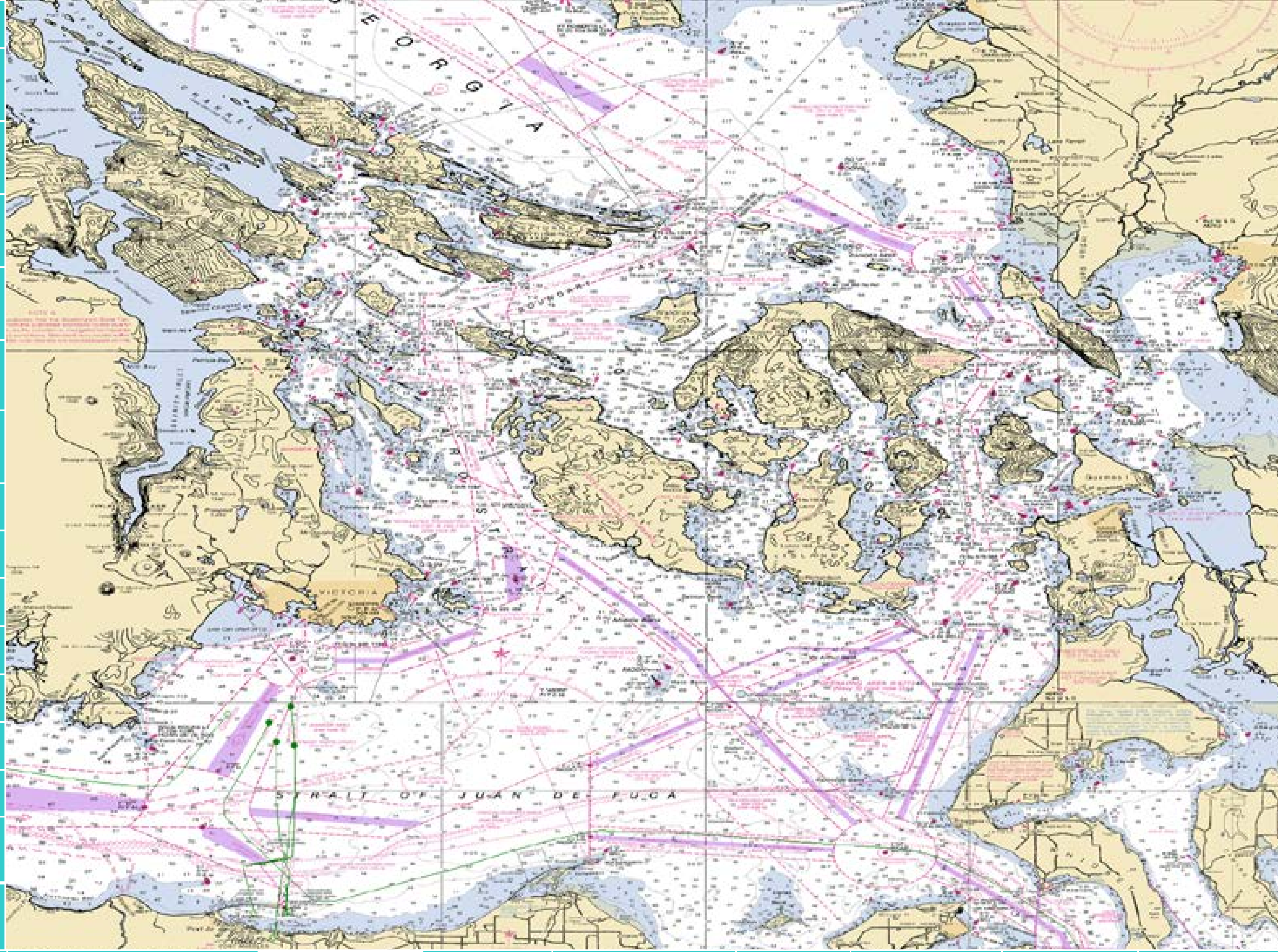

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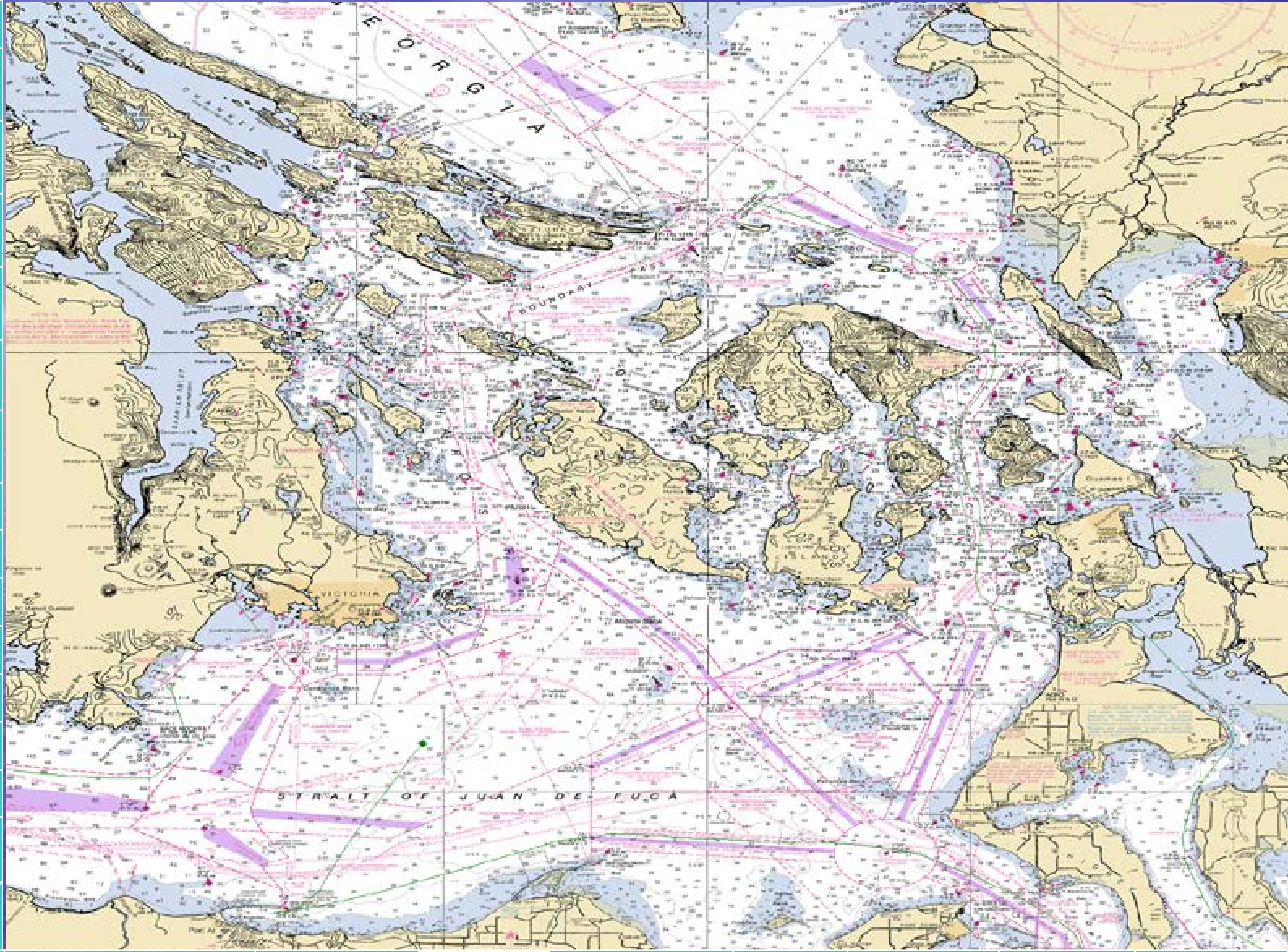
- Outbound Tankers Ferndale
- Inbound Tankers Shell + Tesoro
- Outbound Tankers Shell + Tesoro
- Container
- Bulk Carrier
- Chemical Carrier
- RoRo Cargo
- Liquid Gas Carrier
- Tug Tow Barge
- Supply Off Shore
- Fish Factory
- Fish Vessel



Local Ferries | Non Local Ferries | Passenger | Yachts | Survey Ships | USCG | Research | Navy | Unknown

1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25

Oil tankers

Inbound Tankers BP Cherry Point

Outbound Tankers BP Cherry Point

Inbound Tankers Ferndale

Outbound Tankers Ferndale

Inbound Tankers Shell + Tesoro

Outbound Tankers Shell + Tesoro

Container

Bulk Carrier

Chemical Carrier

RoRo Cargo

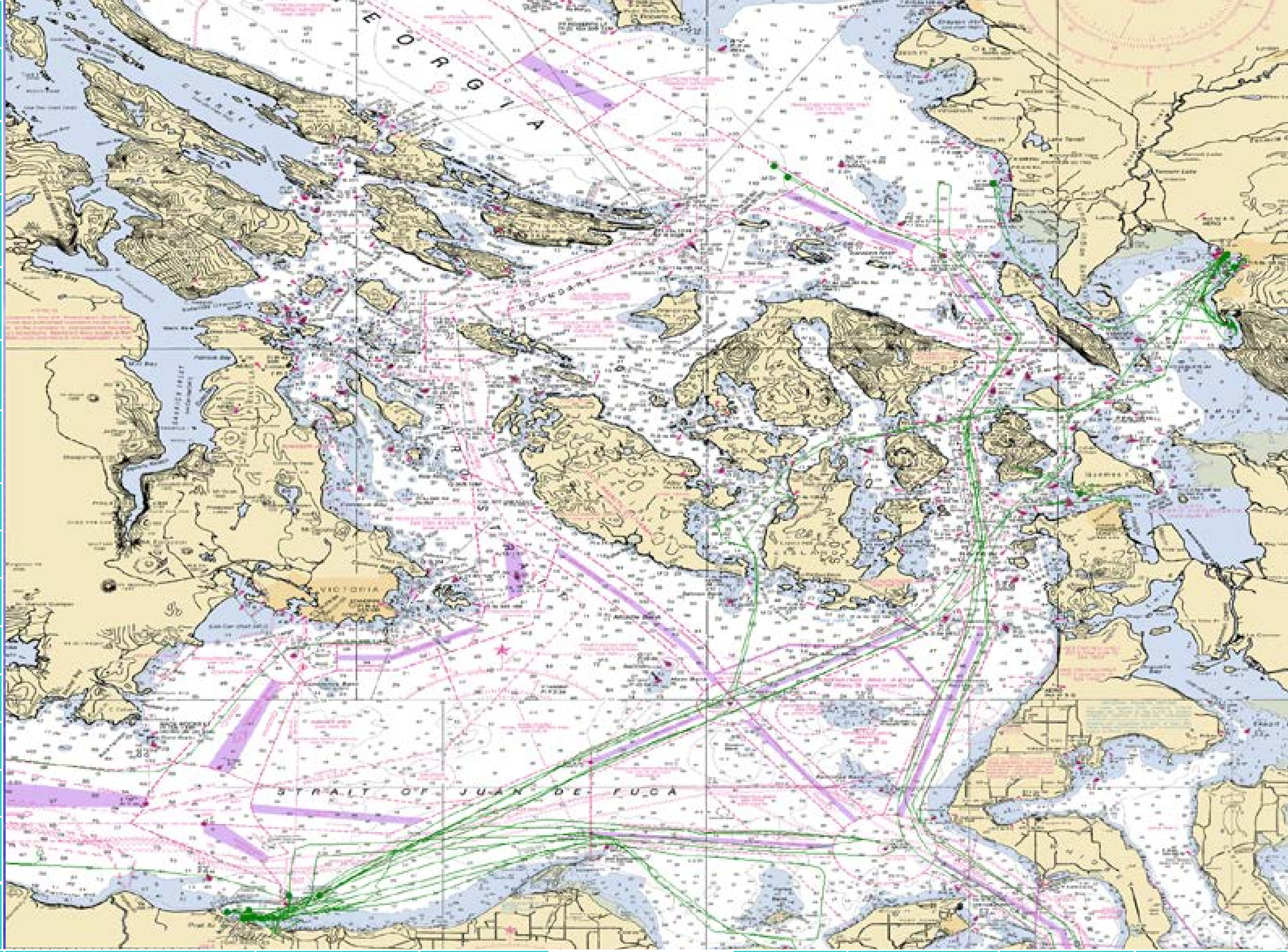
Liquid Gas Carrier

Tug Tow Barge

Supply Off Shore

Fish Factory

Fish Vessel



Local Ferries | Non Local Ferries | Passenger | Yachts | **Survey Ships** | USCG | Research | Navy | Unknown

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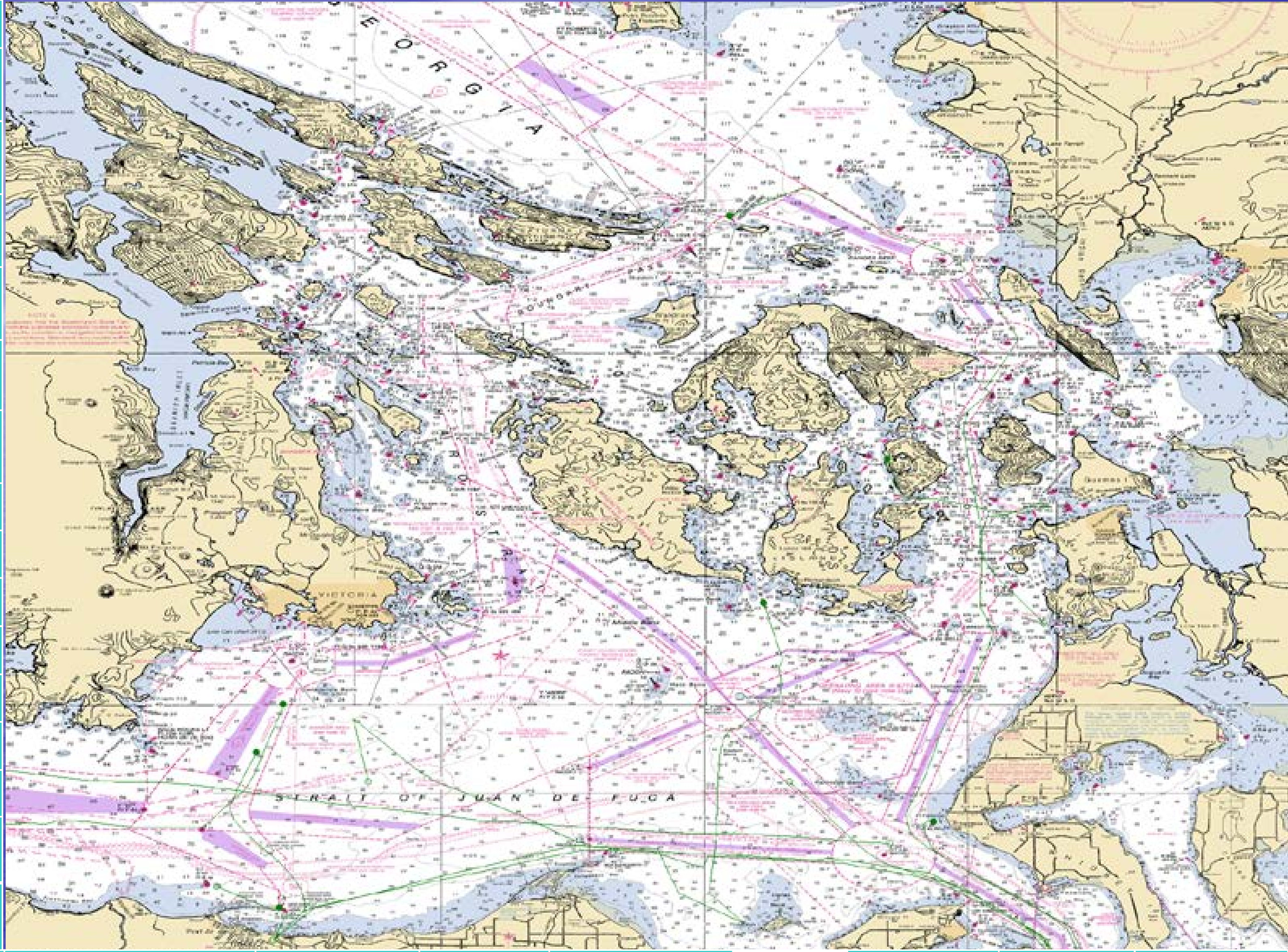

Local Ferries | Non Local Ferries | Passenger | Yachts | Survey Ships | USCG | Research | Navy | Unknown

1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25

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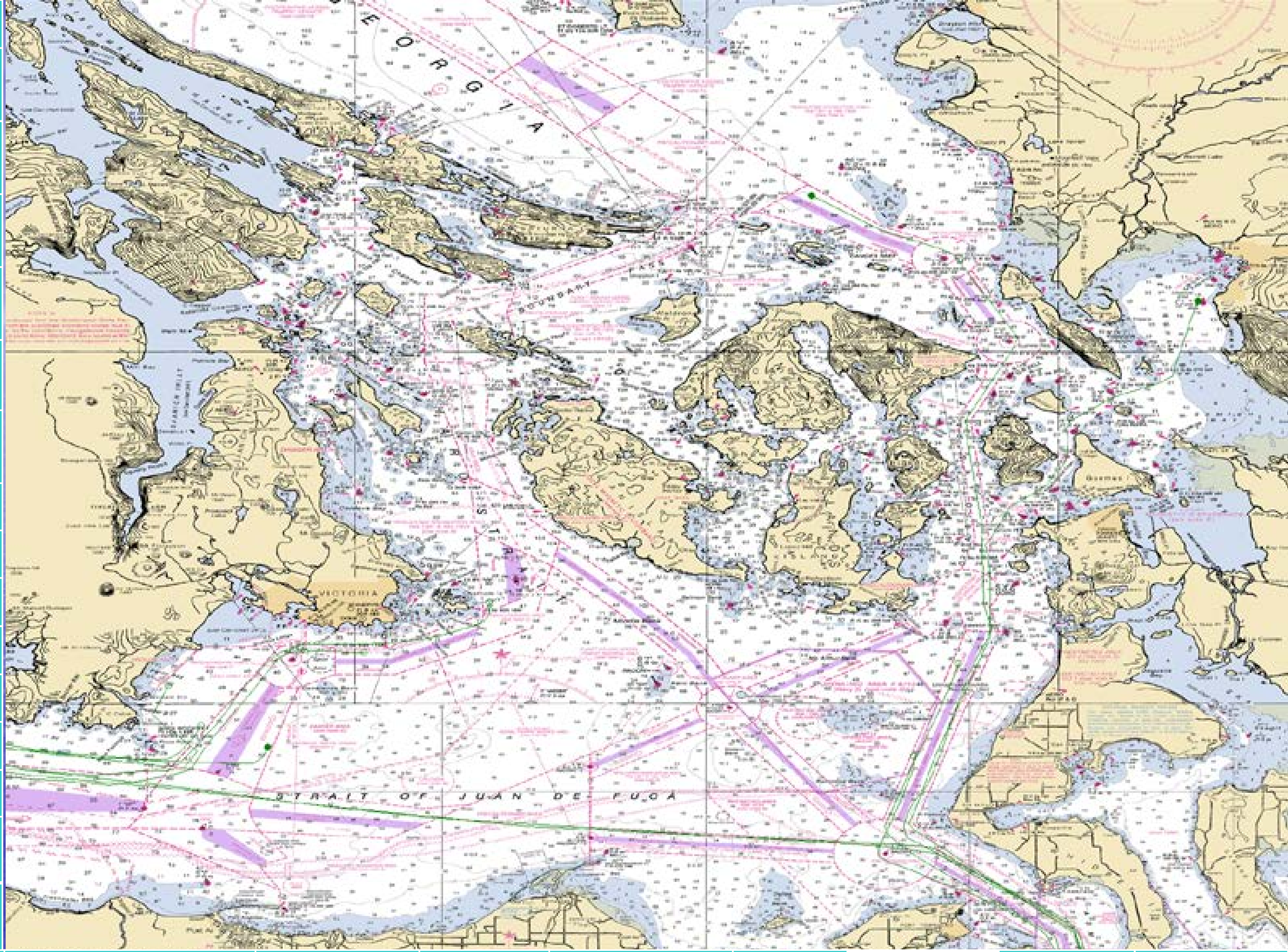

Local Ferries | Non Local Ferries | Passenger | Yachts | Survey Ships | USCG | Research | Navy | Unknown

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

Oil tankers

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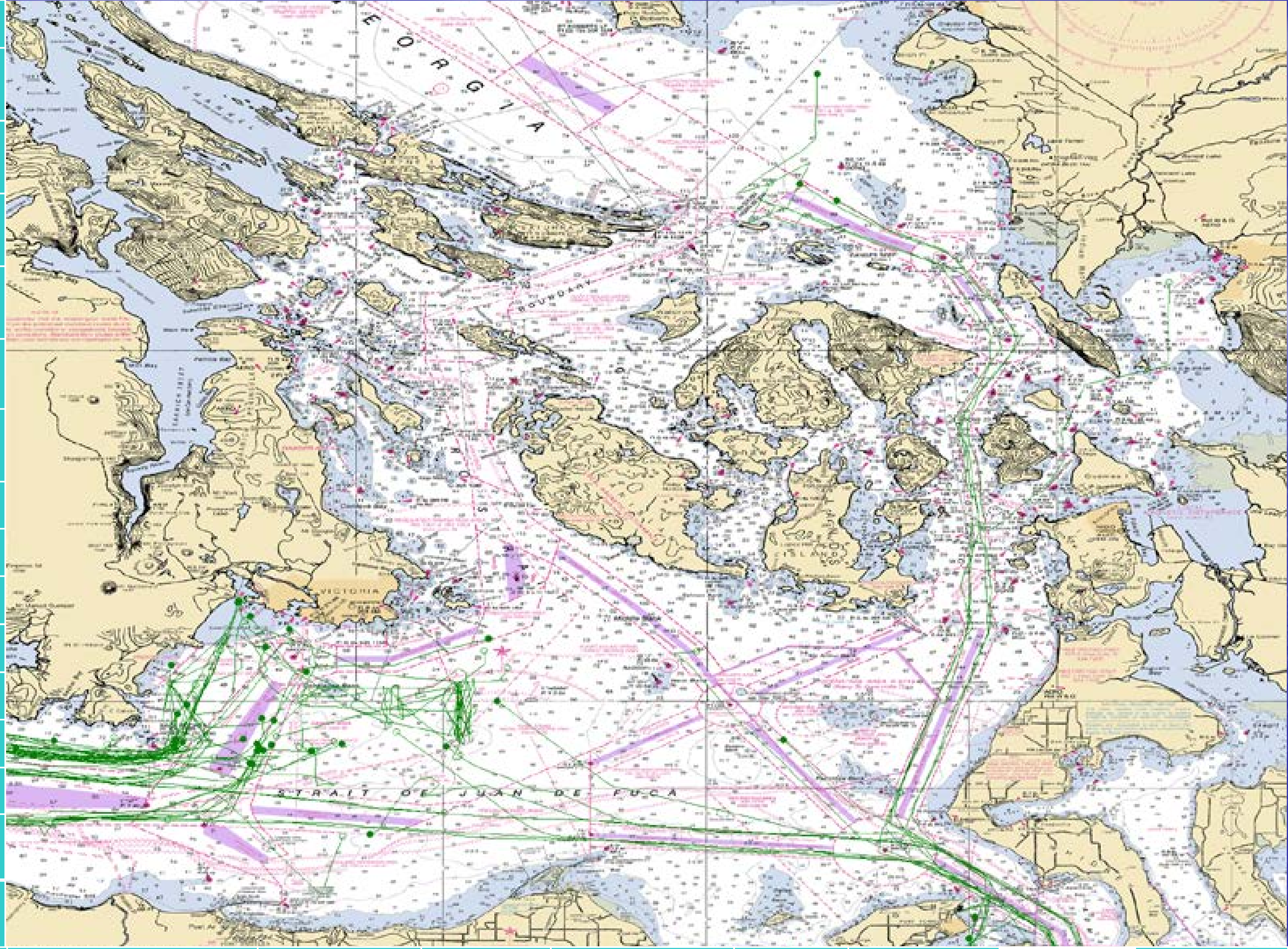

Local Ferries | Non Local Ferries | Passenger | Yachts | Survey Ships | USCG | Research | Navy | Unknown

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

Oil tankers

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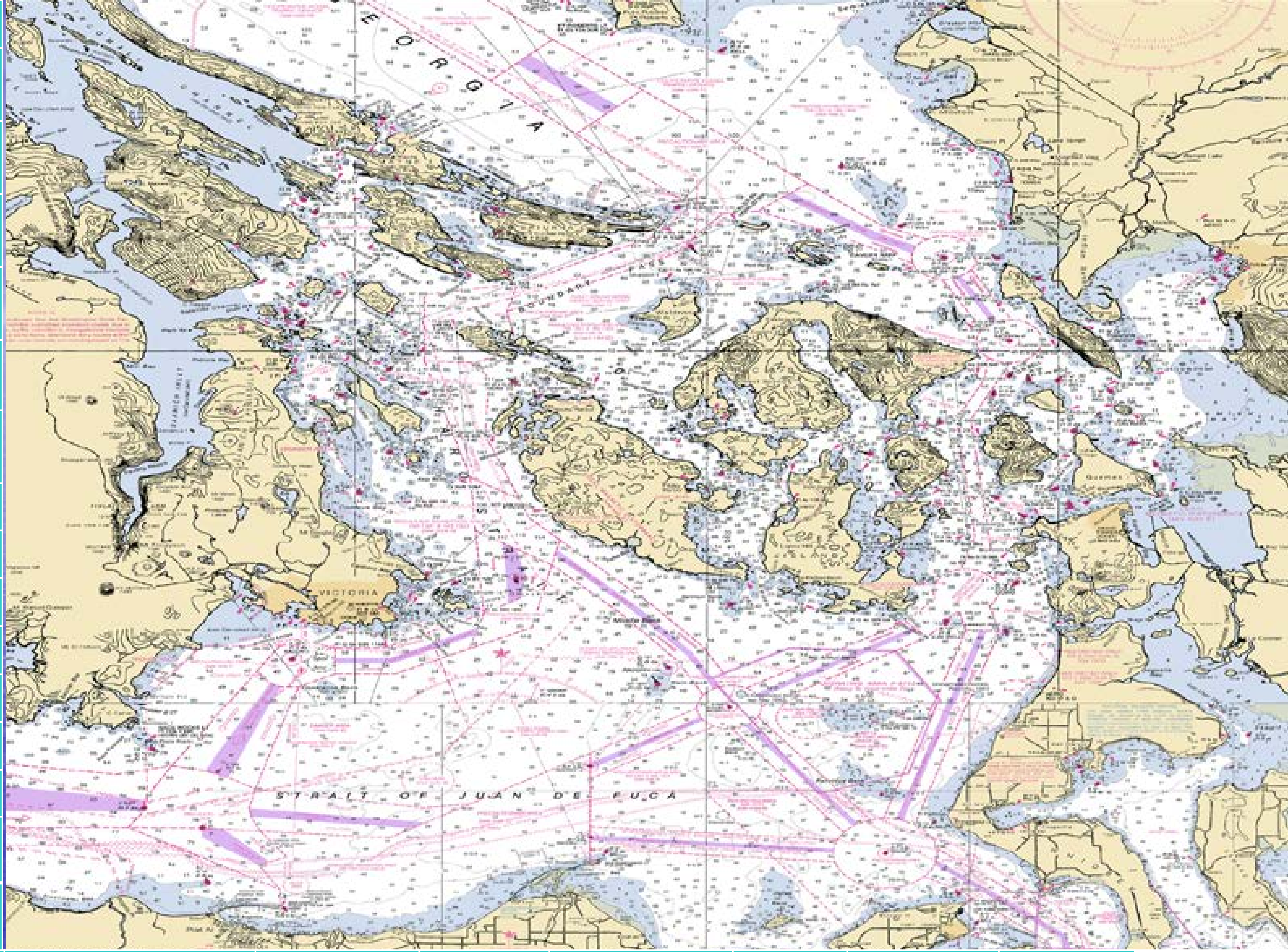
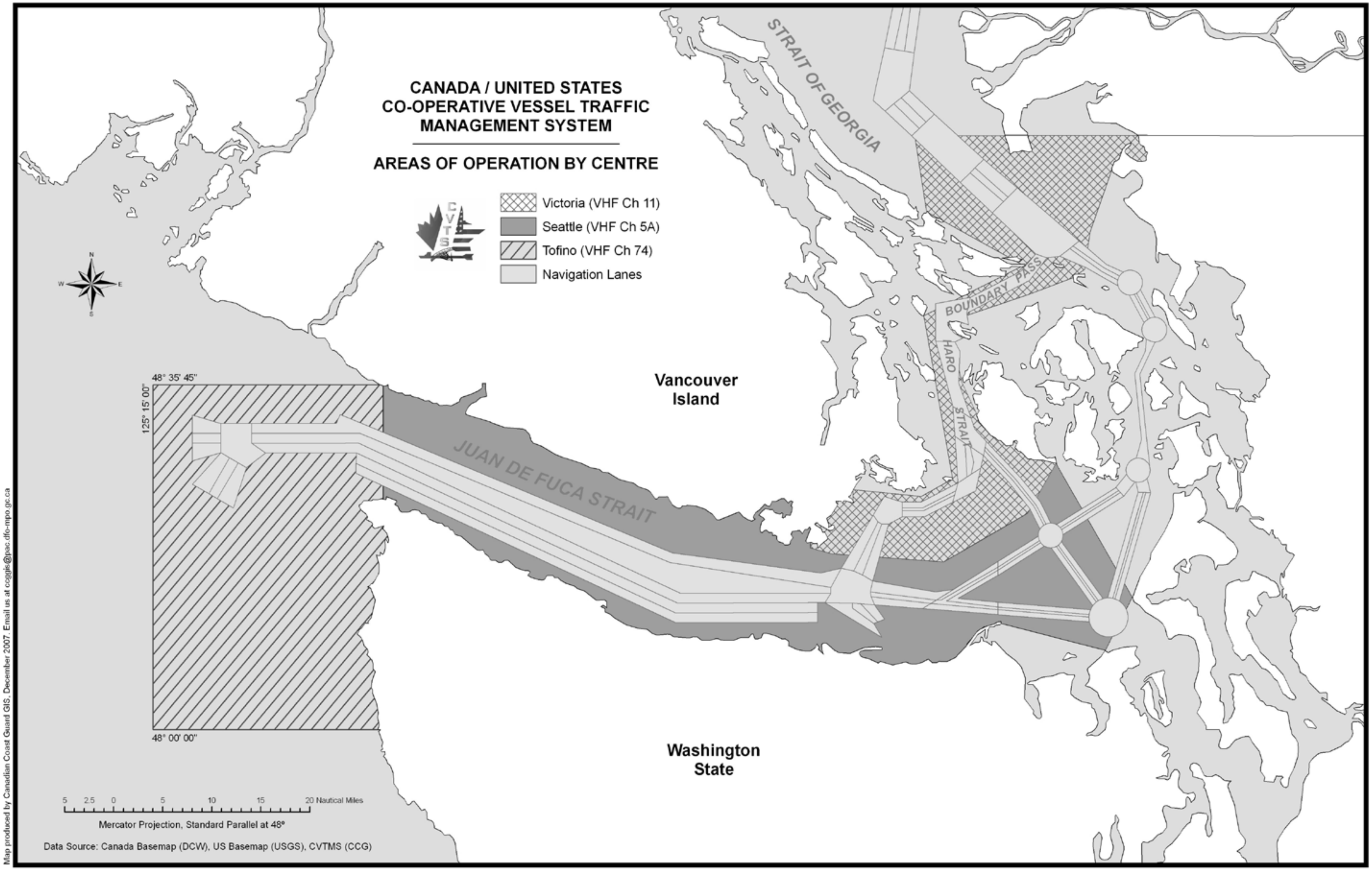


Local Ferries | Non Local Ferries | Passenger | Yachts | Survey Ships | USCG | Research | Navy | Unknown

1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25

The Vessel Traffic Operation Support System (VTOSS)

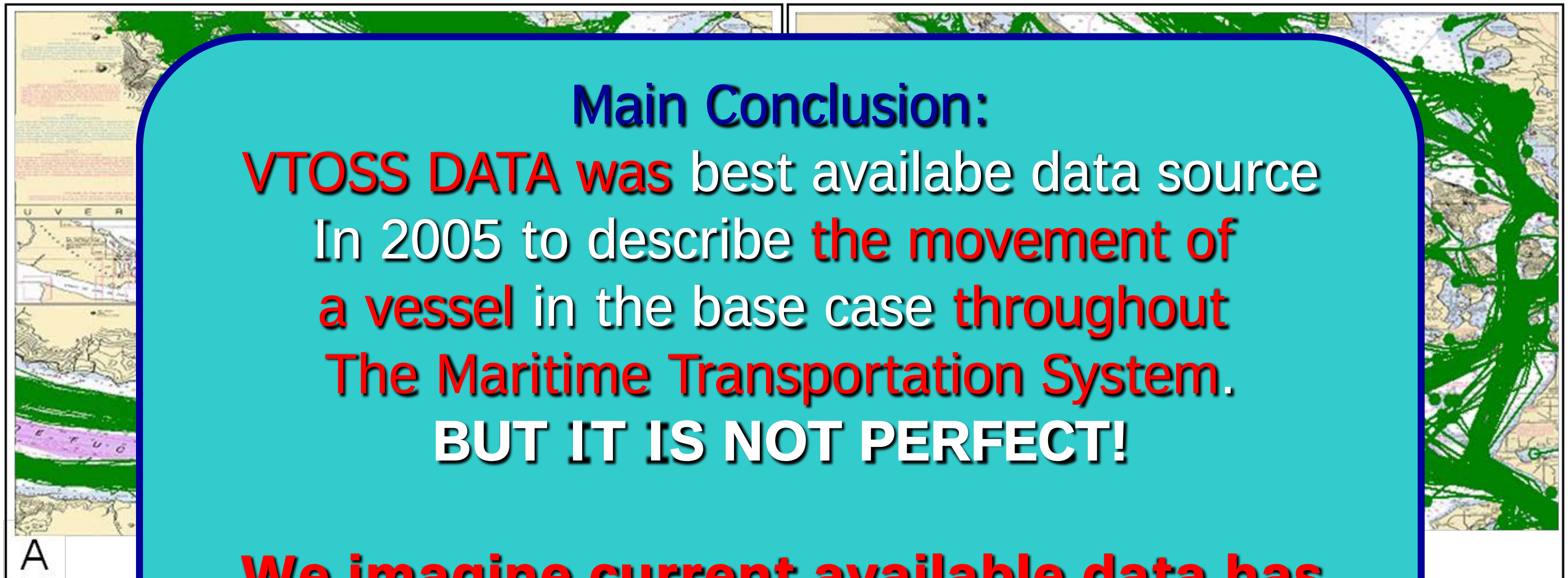


Main Data Source for VTS Responding Traffic for VTRA Simulation Construction was the VTOSS Database:

NAME	LAST_UDDTG	VSL_ID	CALLSIGN	LLOYDS_ID	FLAG	SATCOMNUM	TYPE_ENC	TYPE_DEC	POS_LAT	POS_LONG	POS_SRC	CVTS_ZONE	FROM_AT	NEXT_TO
ITB BALTIMORE	200503112017	2005111414	WXKM	8001189	US		OT	OIL TANKER	48.233	123.715	AIS	PUG	SAN F	SEAT
ITB BALTIMORE	200503112022	2005111414	WXKM	8001189	US		OT	OIL TANKER	48.233	123.686	AIS	PUG	SAN F	SEAT
ITB BALTIMORE	200503112028	2005111414	WXKM	8001189	US		OT	OIL TANKER	48.234	123.655	AIS	PUG	SAN F	SEAT
ITB BALTIMORE	200503112034	2005111414	WXKM	8001189	US		OT	OIL TANKER	48.232	123.628	AIS	PUG	SAN F	SEAT
ITB BALTIMORE	200503112037	2005111414	[illegible]	[illegible]	US		[illegible]	[illegible]	[illegible]	[illegible]	AIS	PUG	SAN F	SEAT
ITB BALTIMORE	200503112043	2005111414	WXKM	8001189	US		OT	OIL TANKER	48.229	123.594	AIS	PUG	SAN F	SEAT
ITB BALTIMORE	200503112046	2005111414	WXKM	8001189	US		OT	OIL TANKER	48.228	123.588	AIS	PUG	SAN F	SEAT
ITB BALTIMORE	200503112051	2005111414	WXKM	8001189	US		OT	OIL TANKER	48.225	123.572	AIS	PUG	SAN F	SEAT
ITB BALTIMORE	200503112057	2005111414	WXKM	8001189	US		OT	OIL TANKER	48.221	123.546	AIS	PUG	SAN F	SEAT
ITB BALTIMORE	200503112103	2005111414	WXKM	8001189	US		OT	OIL TANKER	48.213	123.522	AIS	PUG	SAN F	SEAT

VTOSS DATABASE

From this VTOSS Database routes and input files were constructed that describe vessel movements arrivals to routes:



Main Conclusion:

VTOSS DATA was best availabe data source In 2005 to describe the movement of a vessel in the base case throughout The Maritime Transportation System.

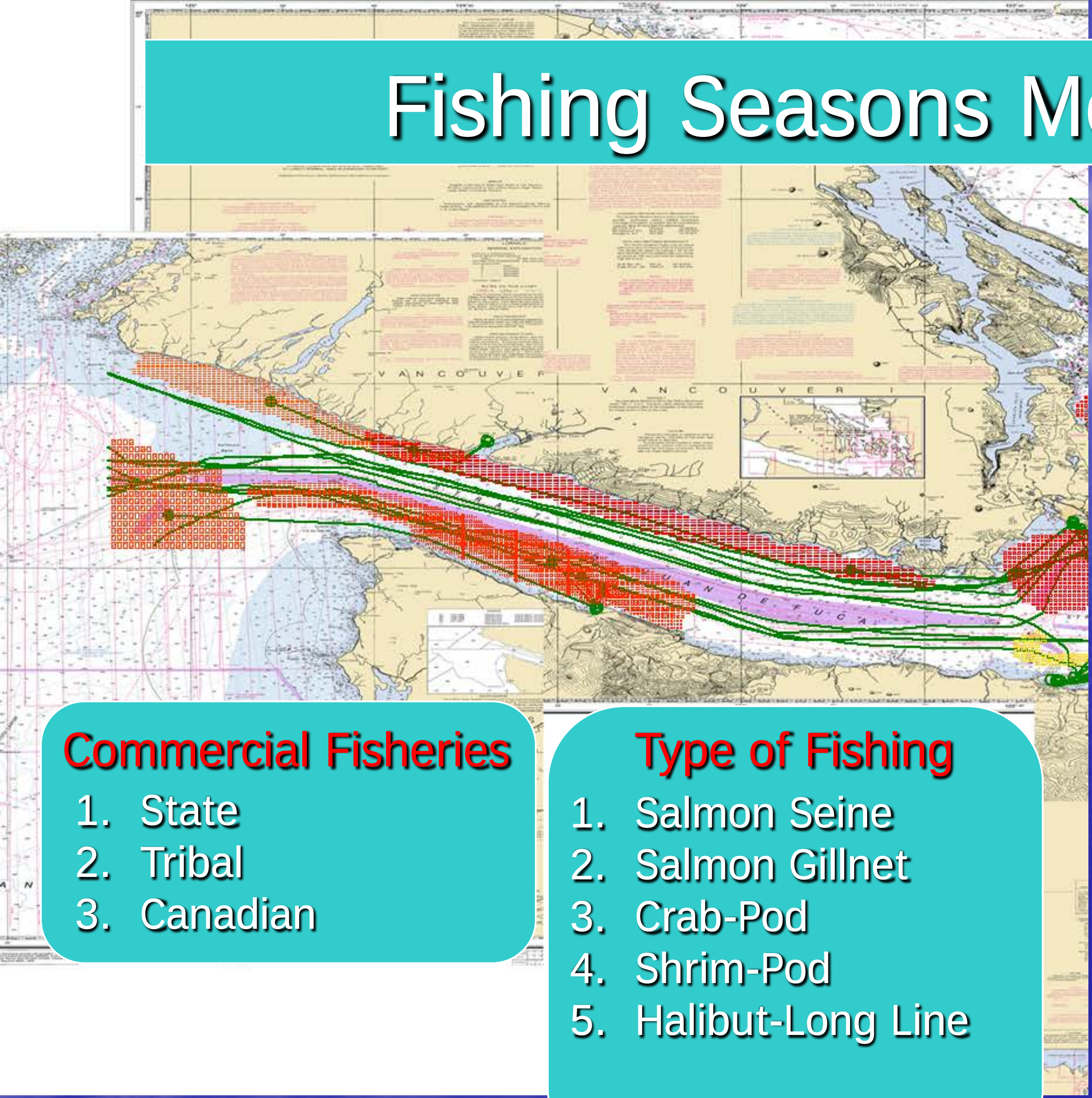
BUT IT IS NOT PERFECT!

We imagine current available data has improved

Vessel Name												Beam	Draft
ITB BALTIMORE	CAL										9	32.23	12.8
ITB BALTIMORE	SEAT										9.9	32.23	12.8
ITB BALTIMORE	CHERRY										179.9	32.23	12.8
ITB BALTIMORE	CALIF	CHERRY PT	3/25/05 6:26 AM	9.18	3012560	Product	ITB	48067	DB/SS	10357	179.9	32.23	12.8
ITB BALTIMORE	CHERRY PT	CALIF	3/26/05 10:41 PM	1.17	3001714	Product	ITB	48067	DB/SS	10357	179.9	32.23	12.8
ITB BALTIMORE	CALIF	CHERRY PT	4/6/05 9:10 PM	10.47	3012560	Product	ITB	48067	DB/SS	10357	179.9	32.23	12.8
ITB BALTIMORE	CHERRY PT	CALIF	4/8/05 2:14 PM	1.20	3001714	Product	ITB	48067	DB/SS	10357	179.9	32.23	12.8
ITB BALTIMORE	CALIF	CHERRY PT	4/19/05 3:21 PM	10.58	3012560	Product	ITB	48067	DB/SS	10357	179.9	32.23	12.8
ITB BALTIMORE	CHERRY PT	CALIF	4/21/05 1:10 AM	0.90	3001714	Product	ITB	48067	DB/SS	10357	179.9	32.23	12.8

VTS responding traffic moves over constructed traffic routes according to their arrivals in the VTOSS database

Fishing Seasons Modeling



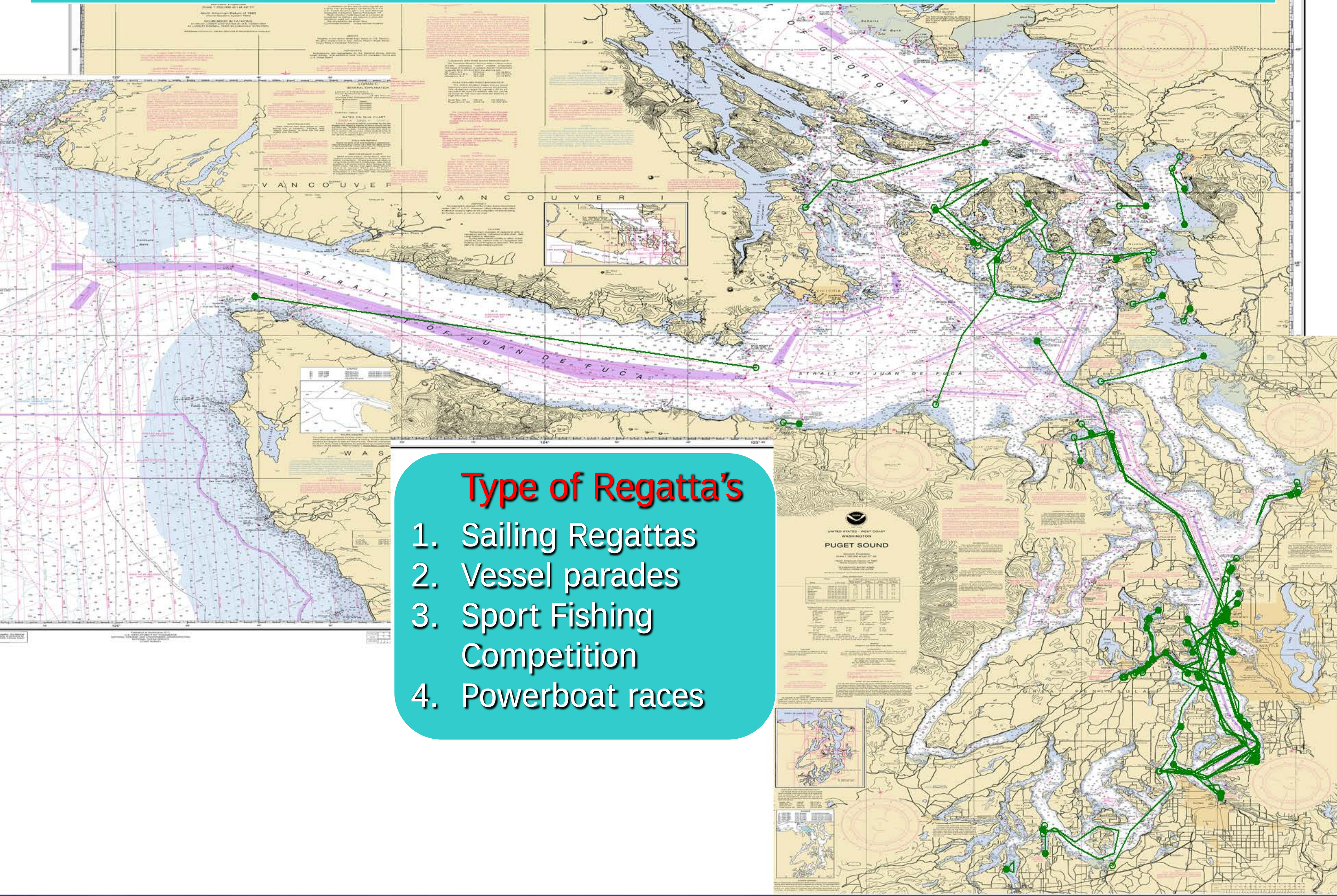
Commercial Fisheries

1. State
2. Tribal
3. Canadian

Type of Fishing

1. Salmon Seine
2. Salmon Gillnet
3. Crab-Pod
4. Shrim-Pod
5. Halibut-Long Line

USCG Permitted Non-Commercial Traffic



Type of Regatta's

1. Sailing Regattas
2. Vessel parades
3. Sport Fishing Competition
4. Powerboat races

Whale Watching – Sound Watch Data

The movements of whale watching vessels are determined by the movements of the orca pods. The Sound Watch data gives the location of the orcas and then the number of vessels within a 2 mile radius of them. We move the orcas in the simulation and then add a swarm whale watching vessels around them. The number of vessels in the swarm is varied over time according to the counts in the Sound Watch data.

Wind/Visibility/Current Model Presentation:
Assessment of Oil Spill Risk due to Potential Increased Vessel Traffic at Cherry Point, Washington

GWU Personnel:
Dr. Jack R. Harrald, Dr. J. Rene van Dorp, Dr. Greg Shaw,
Dr. Thomas A. Mazzuchi, Adil Caner Sener

RPI Personnel:
Dr. Martha Grabowski, Zhi Zhou, Michael Steward

VCU Personnel:
Dr. Jason R. W. Merrick, Kristina Werner

July 28, 2008

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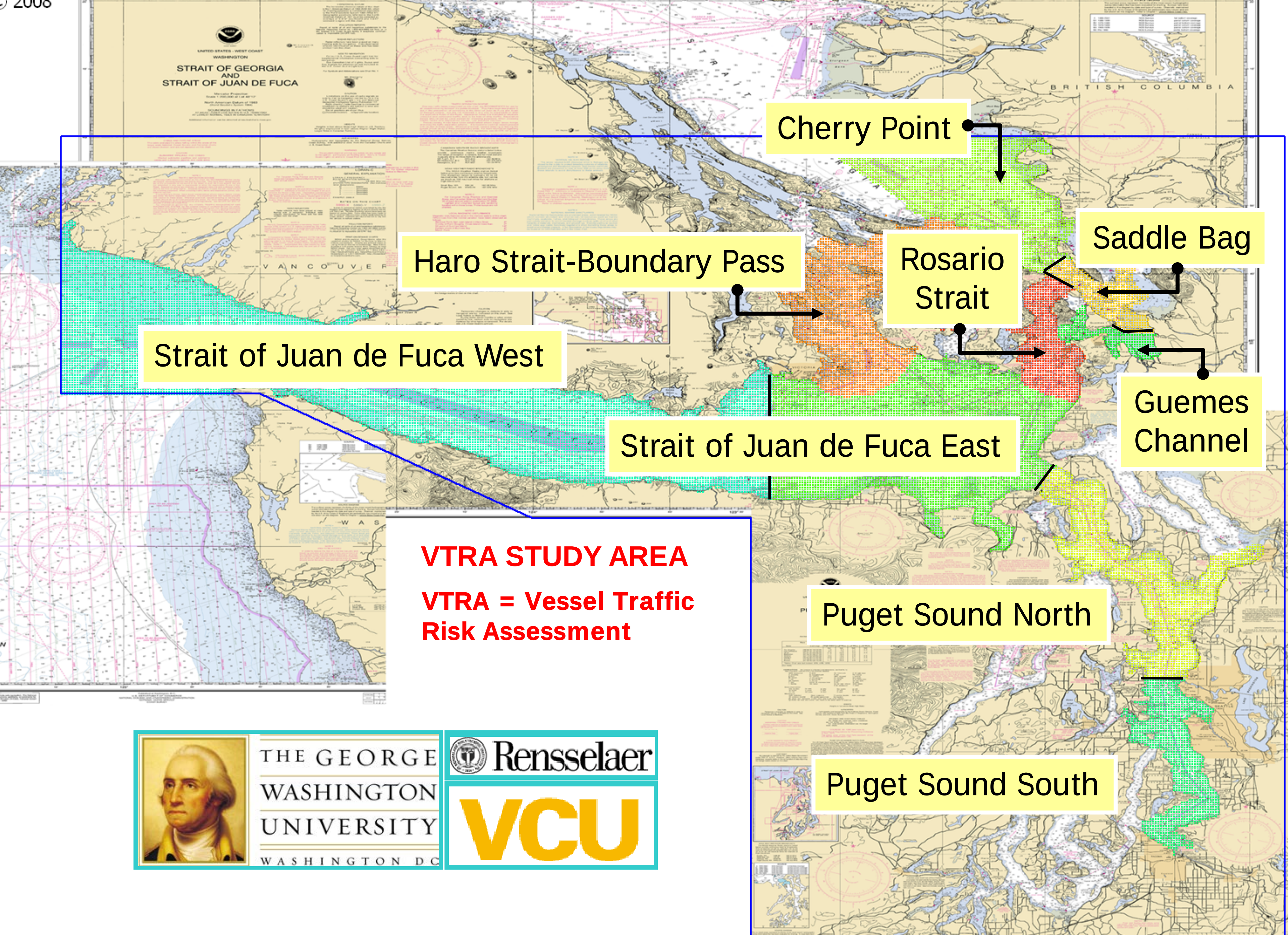

VTRA STUDY AREA

VTRA = Vessel Traffic Risk Assessment

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Wind Model Presentation:

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

GWU Personnel:
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Dr. Thomas A. Mazzuchi, Adil Caner Sener

RPI Personnel:
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VCU Personnel:
Dr. Jason R. W. Merrick, Kristina Werner

December 7, 2006

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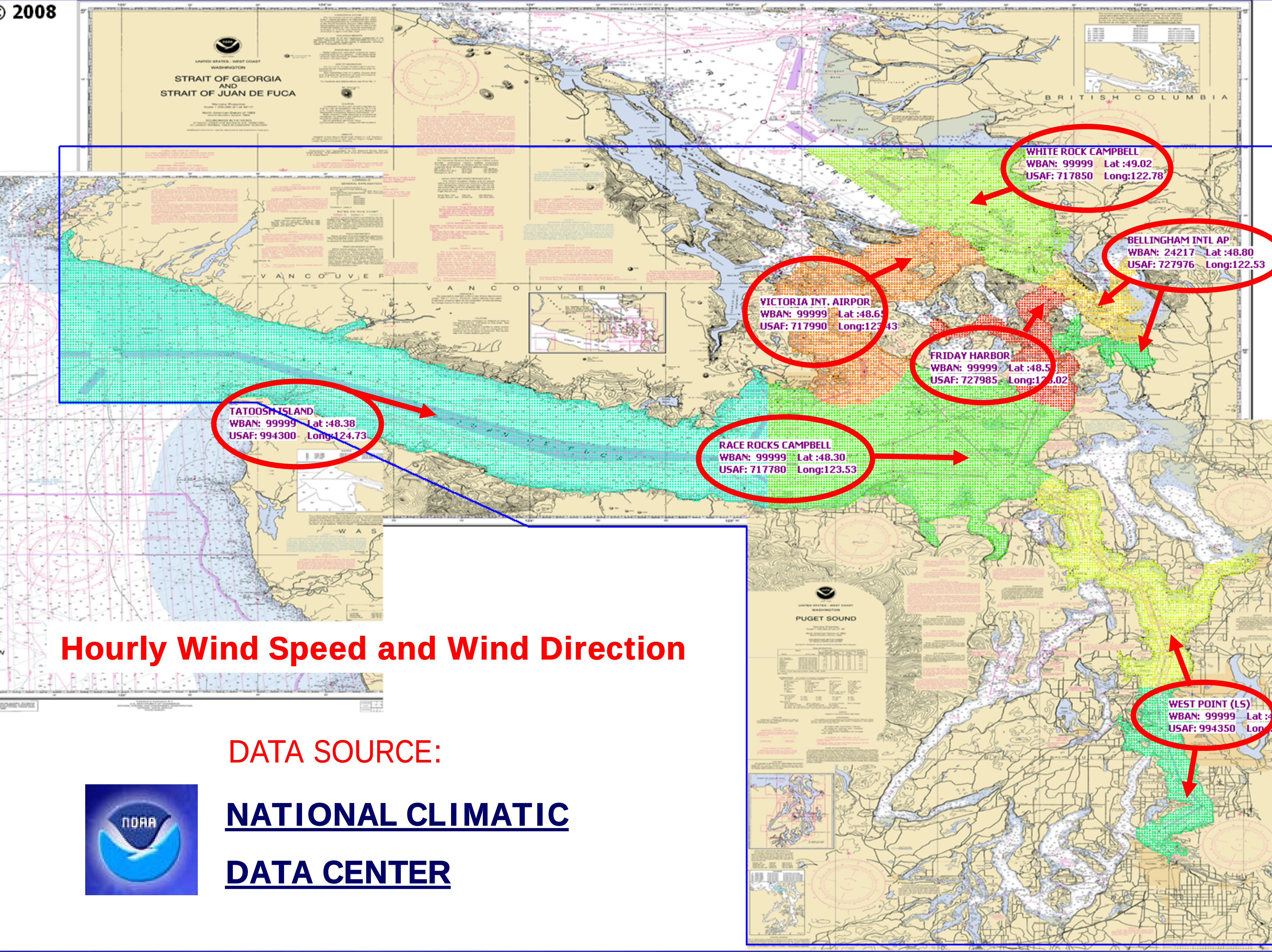
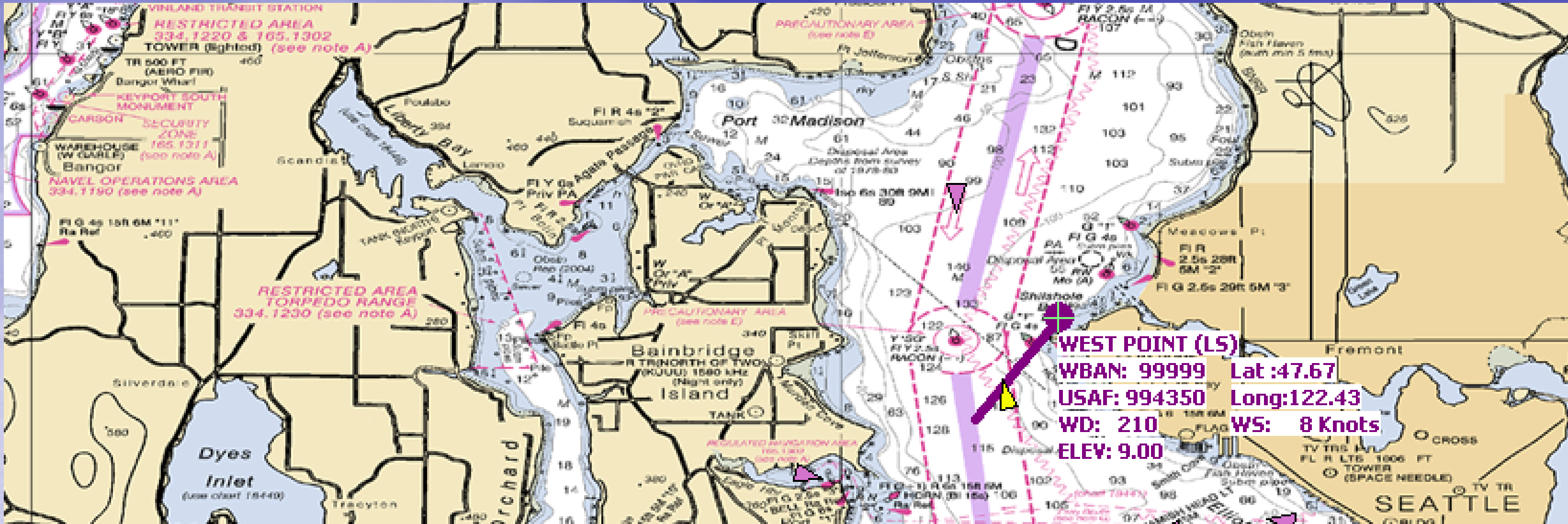


Hourly Wind Speed and Wind Direction

DATA SOURCE:

NATIONAL CLIMATIC DATA CENTER



Data base - Wind

YY	MM	DD	HH	BH WD	BH WS	FH WD	FH WS	RR WD	RR WS	TI V
2005	3	6	20	40	6	30	3	40	10	
2005	3	6	21	10	6	30	5	60	12	
2005	3	6	22	10	5	30	5	70	10	
2005	3	6	23	50	7	90	3	70	8	
2005	3	7	0	30	5	10	4	50	6	
2005	3	7	1	30	5	10	0	60	8	
2005	3	7	2	360	0	10	0	70	7	
2005	3	7	3	360	0	360	3	70	8	
2005	3	7	4	360	0	360	3	30	10	
2005	3	7	5	360	0	360	4	30	7	
2005	3	7	6	290	3	360	0	40	5	
2005	3	7	7	290	0	360	0	250	1	
2005	3	7	8	290	0	360	0	250	7	
2005	3	7	9	280	3	360	0	250	7	
2005	3	7	10	280	0	360	3	260	7	
2005	3	7	11	280	0	360	0	270	8	
2005	3	7	12	280	0	230	4	270	11	

VISIBILITY Model Presentation:
Assessment of Oil Spill Risk due to Potential Increased Vessel Traffic at Cherry Point, Washington

GWU Personnel:
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Dr. Thomas A. Mazzuchi, Adil Caner Sener

RPI Personnel:
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December 7, 2006

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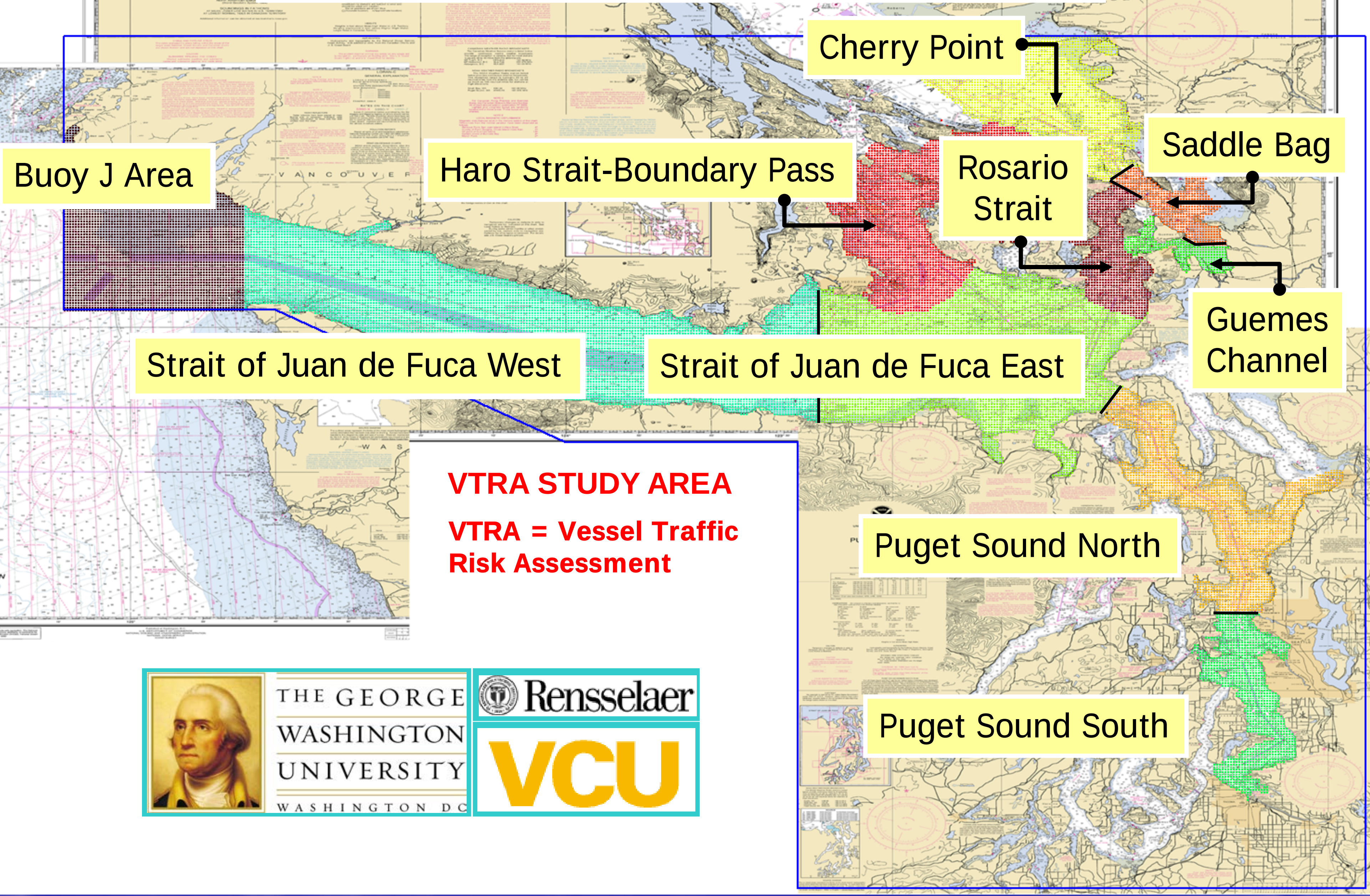
Definition of Visibility Locations



VTRA STUDY AREA

VTRA = Vessel Traffic Risk Assessment

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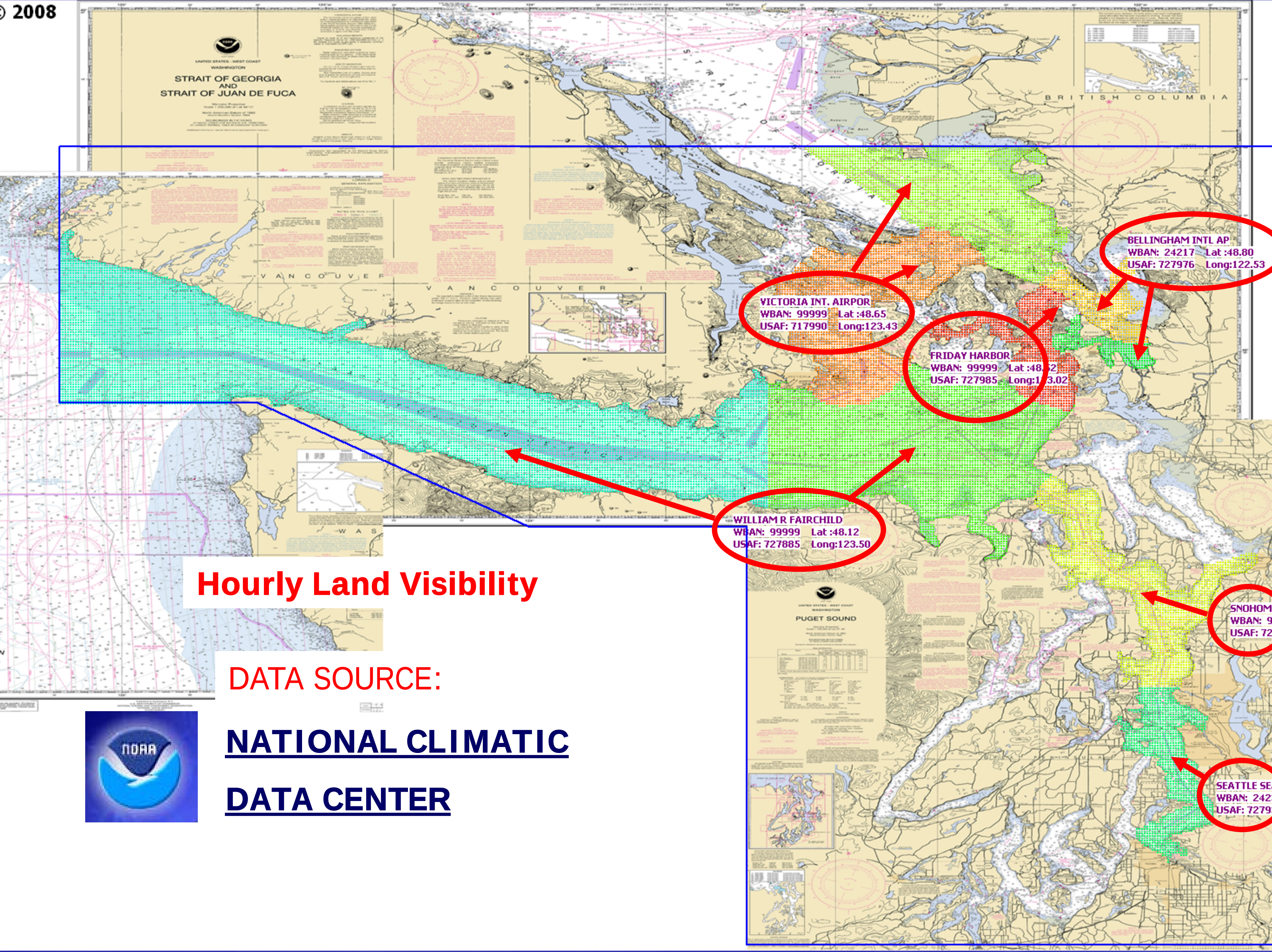


Hourly Land Visibility

DATA SOURCE:

NATIONAL CLIMATIC DATA CENTER

Visibility Model

- Any time there is bad land visibility (less than 0.5 nautical mile) we assume that there is bad visibility on the water as well.

- Even when we have good land visibility it is possible that we have poor visibility on the water (vessels are required to operate their fog signals). We need a separate Sea Visibility Model to model such a weather phenomenon.

Sea Visibility Model

W = Water Surface Temperature (^oC)   D = Dew Point Temperature (^oC)

WS = Wind Speed

$$\text{Sea Visibility} = \begin{cases} \text{Bad when } (D - W) \approx \Delta \text{ and } WS \approx \text{up to 3 Beaufort} \\ \text{Good} \quad \text{Otherwise} \end{cases}$$

Good = More than 0.5 nautical mile

Bad = Less than 0.5 nautical mile

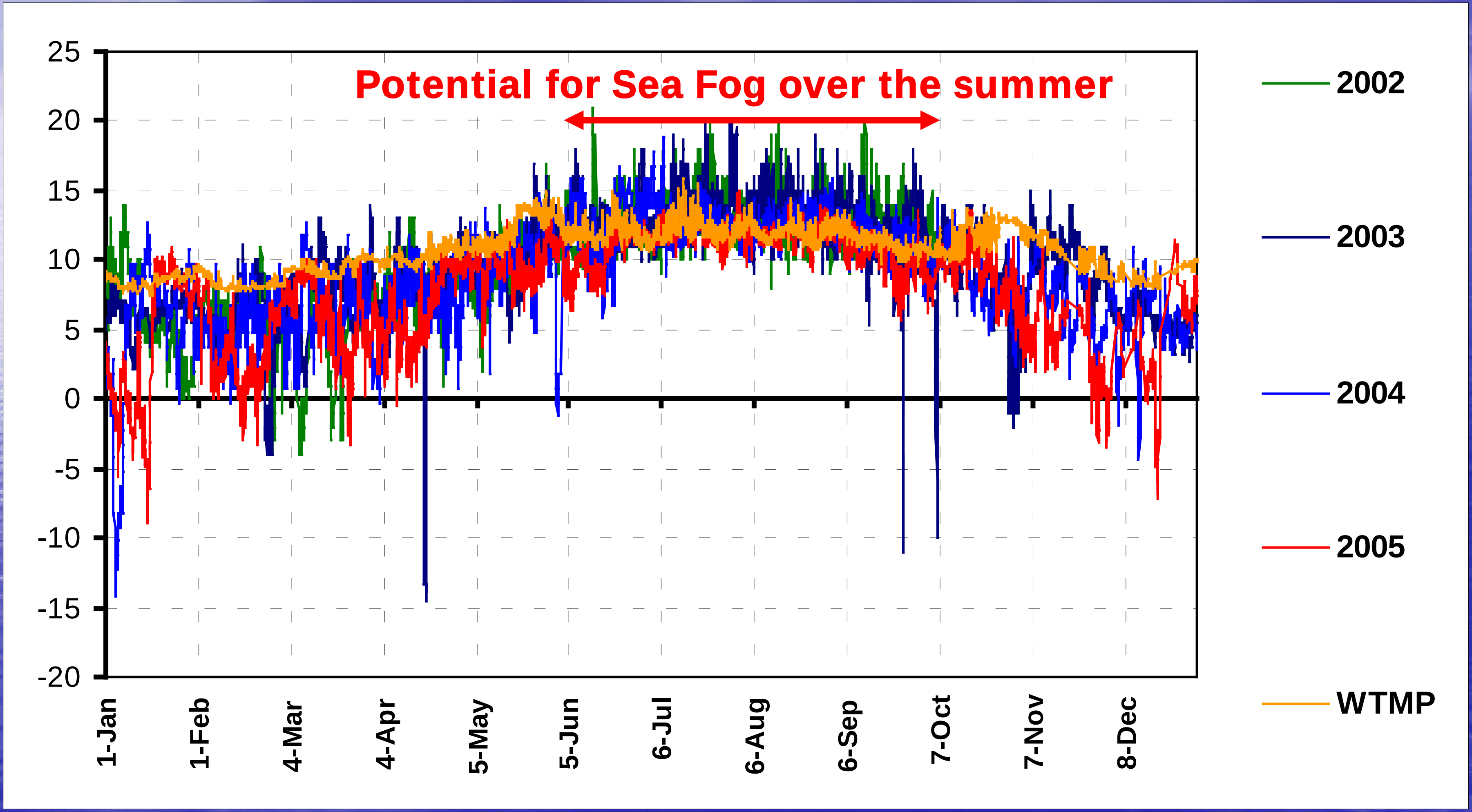
Δ between 0 and 2 Celsius (Patches of Fog)

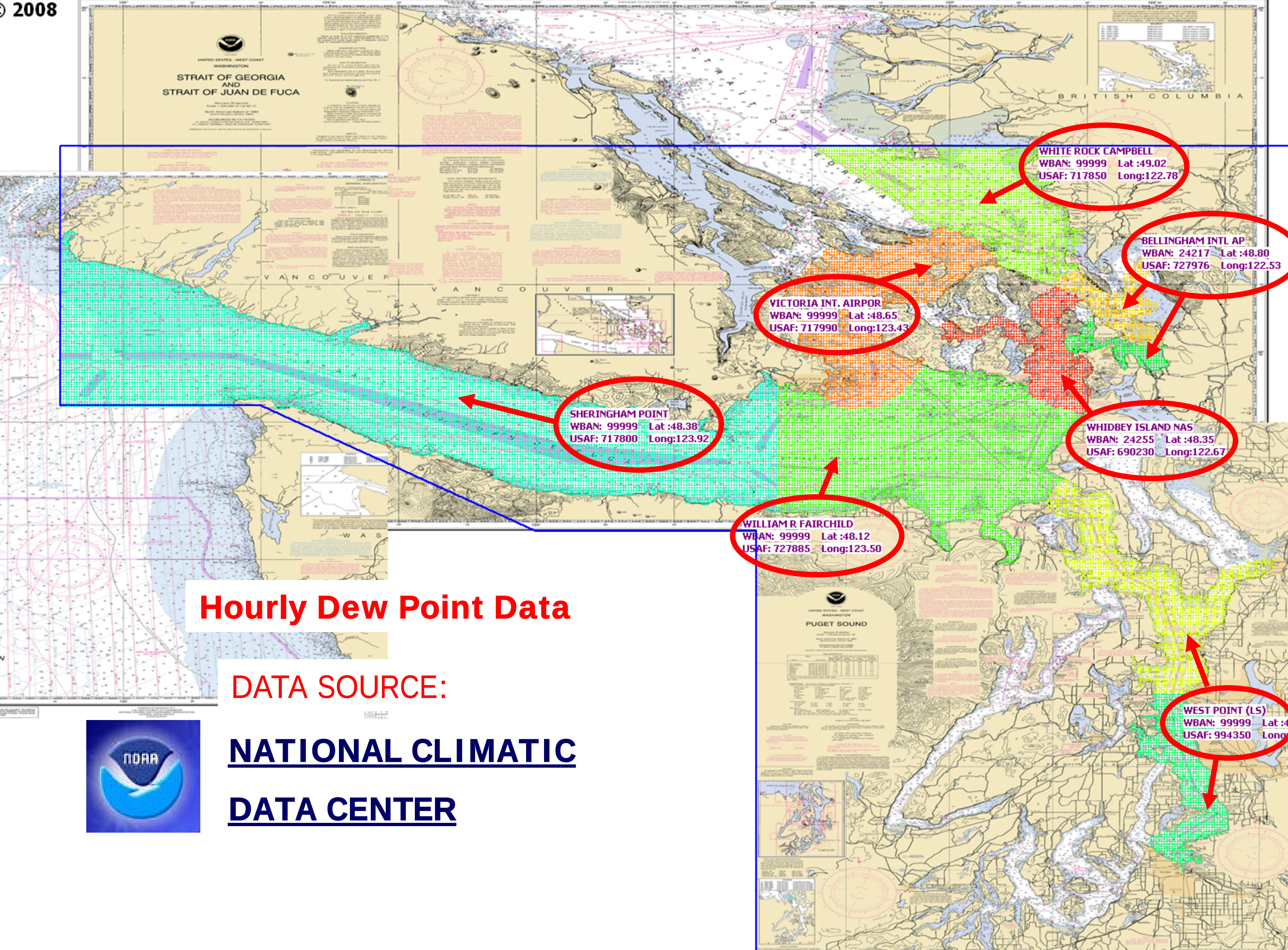
Δ larger than 2 Celsius dense fog

Breeze up to 3 Beaufort ≈ 4-7 knots

Reference : Ray Sanderson, **Meteorology at Sea,** Stanford Maritime Limited, 1982

Time Series of WTMP and DEWPT For West Strait of Juan de Fuca





Hourly Dew Point Data

DATA SOURCE:

NATIONAL CLIMATIC DATA CENTER

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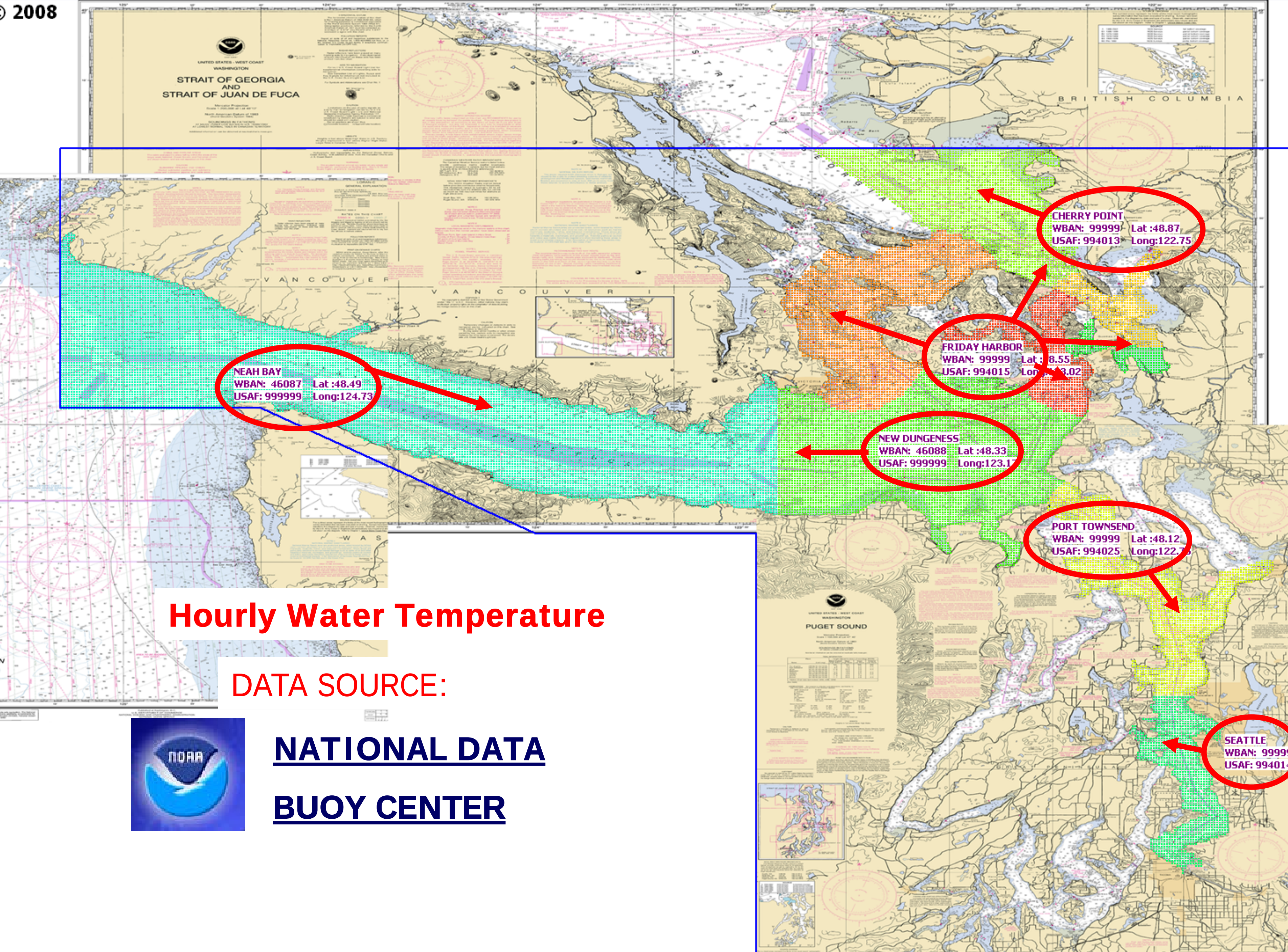
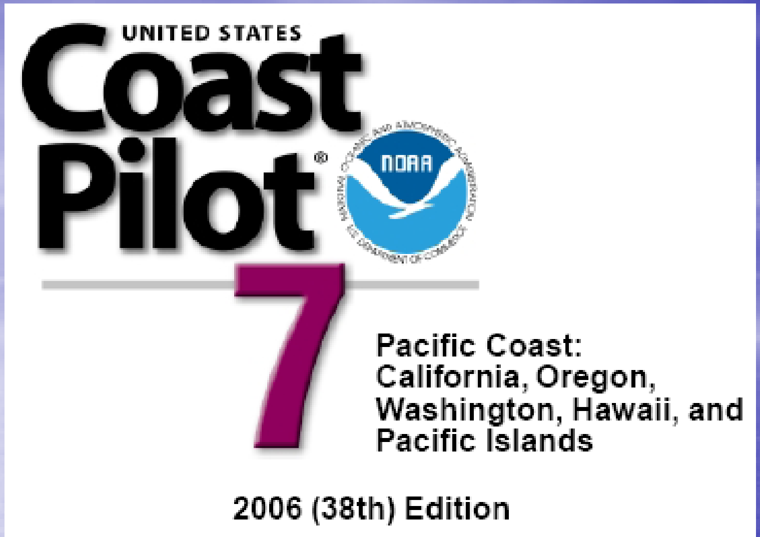


Hourly Water Temperature

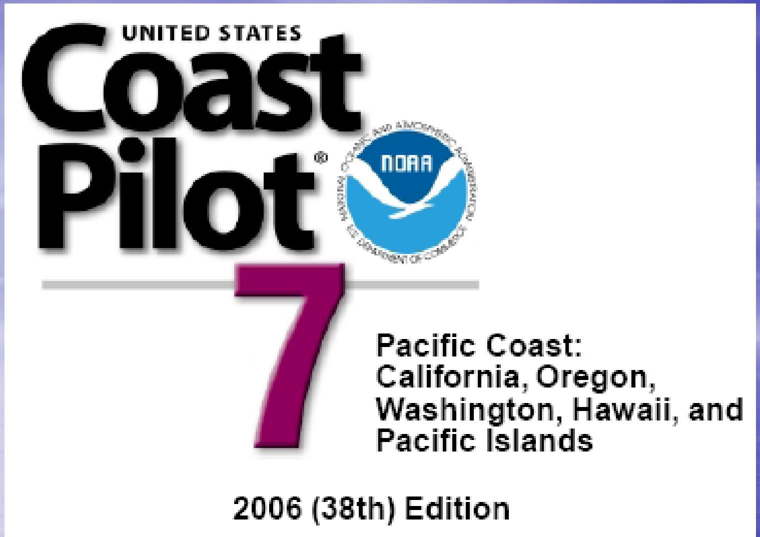
DATA SOURCE:

NATIONAL DATA BUOY CENTER



We calibrate to 54 days at 0.75 mile and at 50 days annually at 0.5 miles in West Strait of Juan de Fuca

" In few parts of the world is the vigilance more called upon than when entering the Strait of Juan de Fuca from the Pacific in fog. Sea fog is the most common type, and it is at its worst from about July through October. Local land fog extends the visibility hazard into the winter. Fog is most frequent at the West end of the Strait. Here, visibilities drop to less than **0.75 mile on about 55 days** annually, compared to about 35 days in the East end."



We calibrate to 35 days at 0.75 mile and at 31 days annually at 0.5 miles in East Strait of Juan de Fuca

" In few parts of the world is the vigilance more called upon than when entering the Strait of Juan de Fuca from the Pacific in fog. Sea fog is the most common type, and it is at its worst from about July through October. Local land fog extends the visibility hazard into the winter. Fog is most frequent at the West end of the Strait. Here, visibilities drop to less than **0.75 mile** on about 55 days annually, compared to **about 35 days in the East end**."

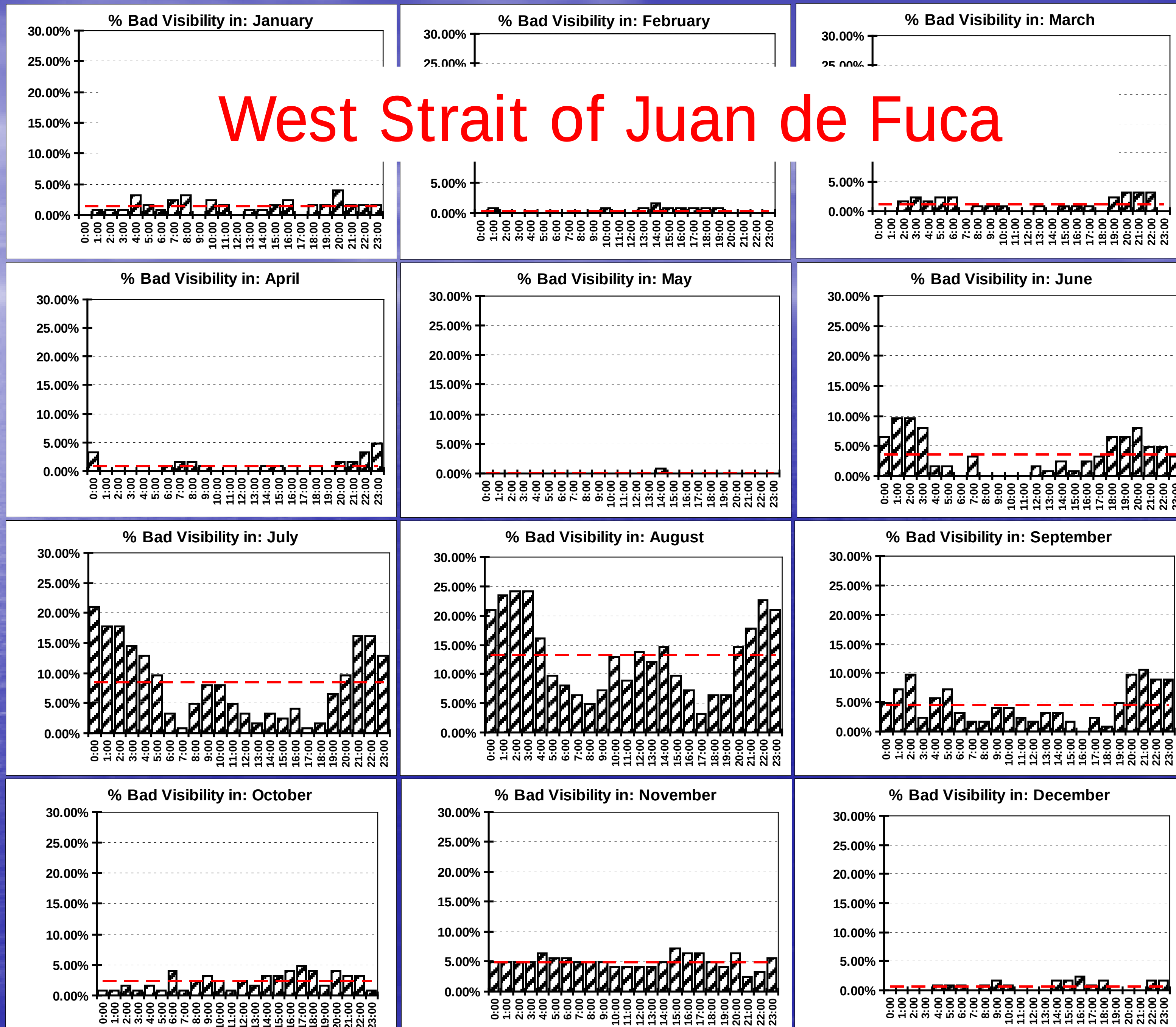
West Strait of Juan de Fuca

1st Q

2nd Q

3rd Q

4th Q



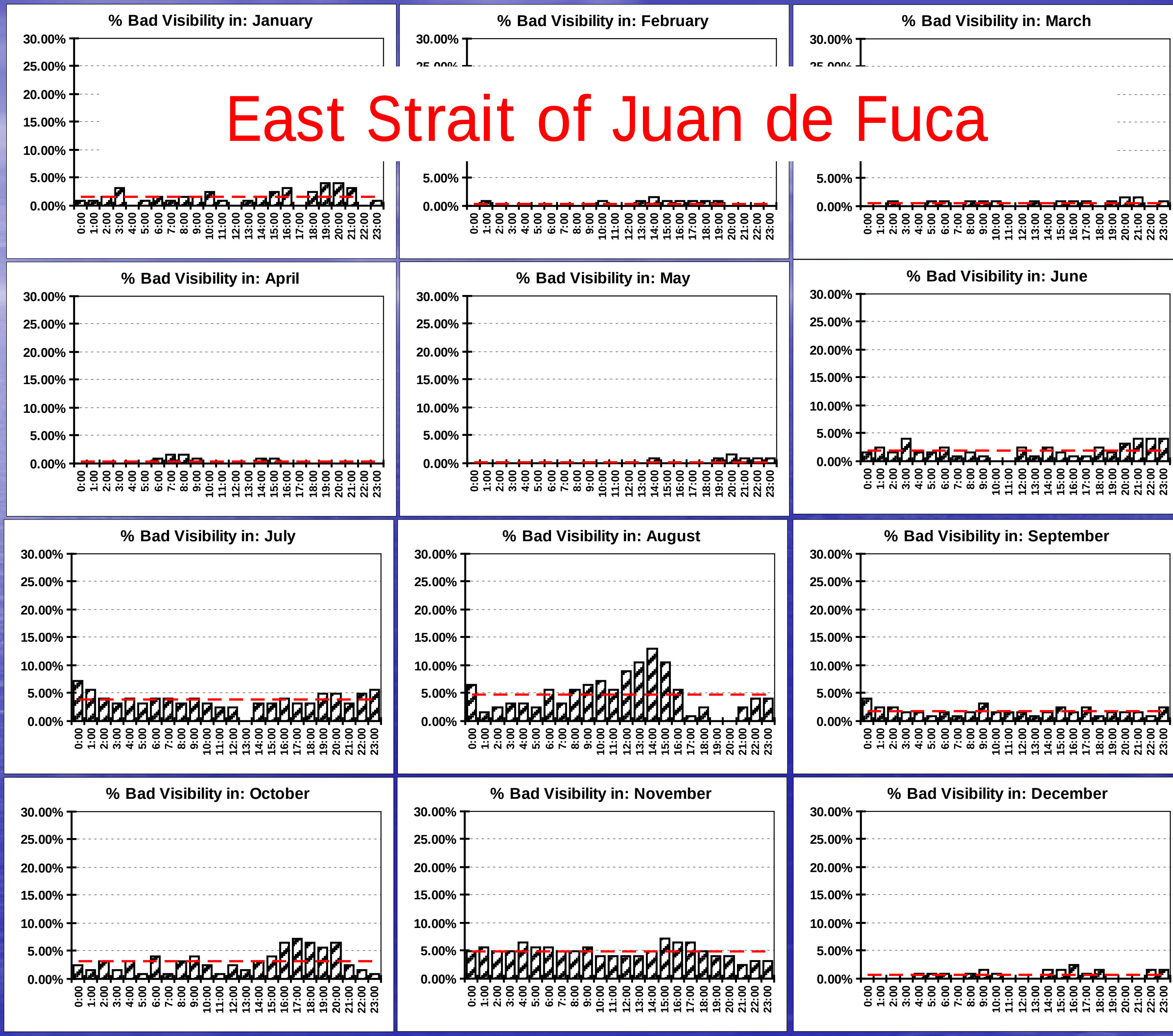
East Strait of Juan de Fuca

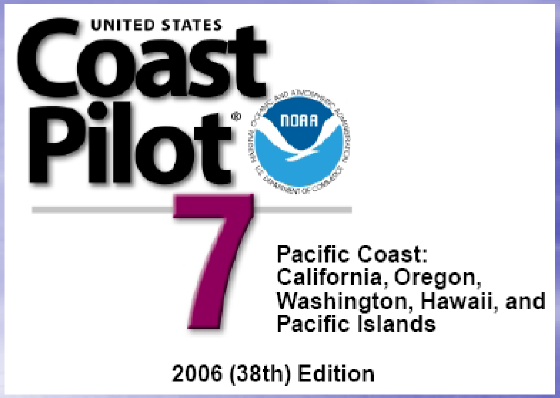
1st Q

2nd Q

3rd Q

4th Q





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	US Coast Pilot # Bad Visibility Days	Average 2002-2005 **Simulation** # Bad Visibility Days
West Strait of Juan De Fuca	55	54
East Strait of Juan de Fuca	35	35
Cherry Point	20	20
Puget Sound North	25 to 40	28
Puget Sound South	25 to 40	26
Haro Strait Boundary Pass	Expert Judgment	19
Rosario Strait	Expert Judgment	25
Guemes Channel	Expert Judgment	18
Saddle Bag	Expert Judgment	18

Further Refine with Expert Judgment

No anecdotal data from US Coast Pilot for locations: Haro St- B. Pass, Rosario Strait, Saddle Bag and Guemes Channel.

We use a questionnaire to refine visibility in the San Juan Islands area, since NOAA weather observations themselves do not allow us to model their particulars.

EXAMPLE QUESTION

Please compare the two locations in terms of the percentage of time that vessel operate in restricted visibility (I.e. vessel are required to use their fog signal) in the specified quarter.

FIRST QUARTER: Jan - Feb - March

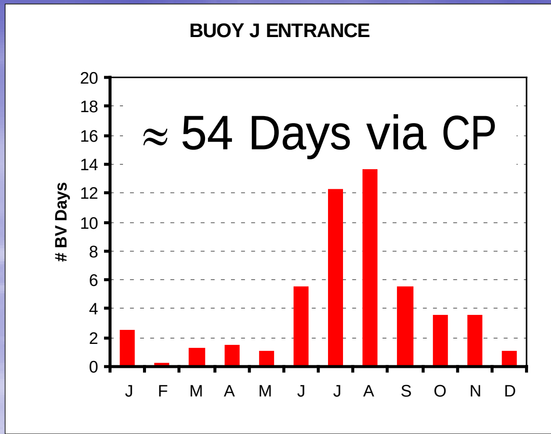
Location
Haro St. - B. Pass
Left Hand Side More

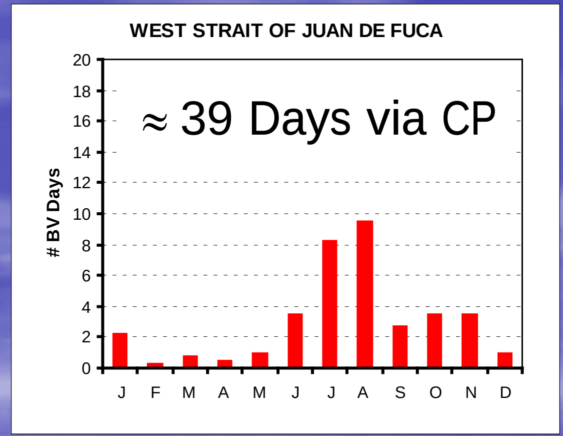
Location
Rosario Strait
Right Hand Side More

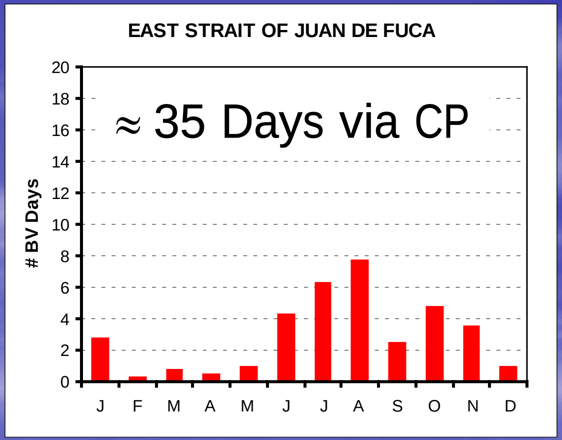
9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

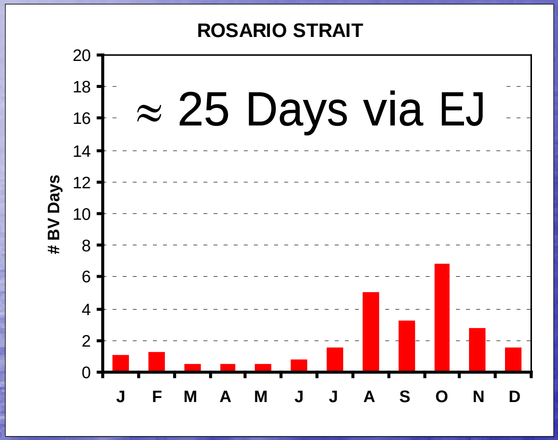
1 Same amount of time
3 Three times more
5 Five times more
7 Seven times more
9 Nine times or more

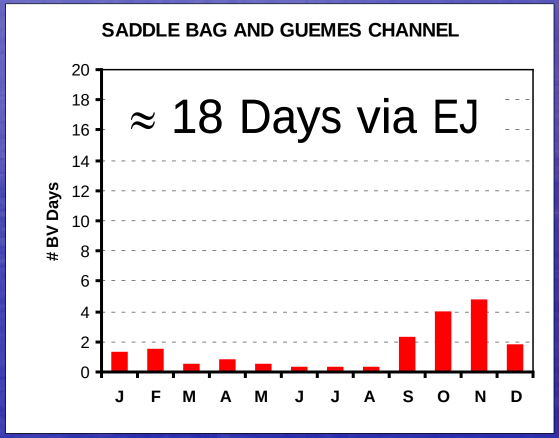
Bad Visibility Days by Month

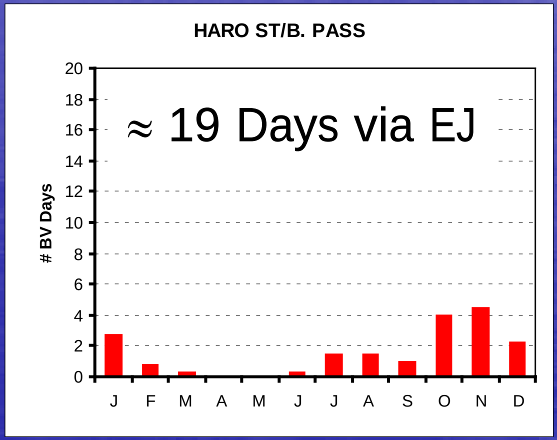


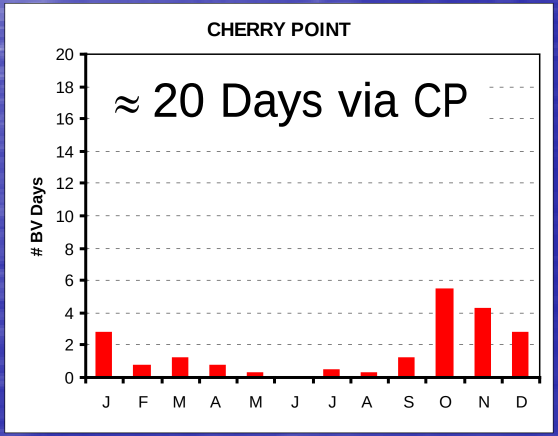


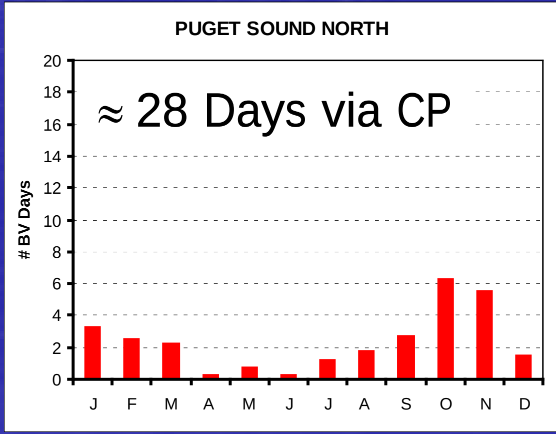


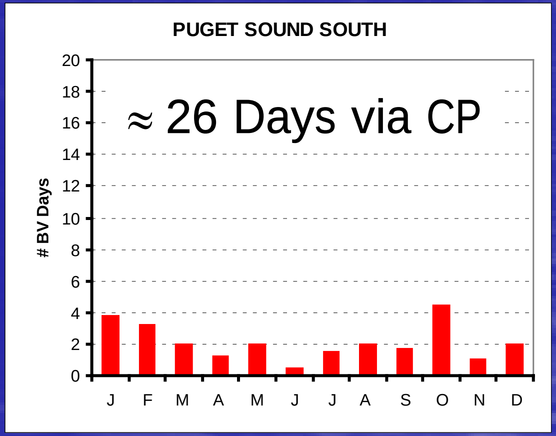












Current Model Presentation:
Assessment of Oil Spill Risk due to Potential Increased Vessel Traffic at Cherry Point, Washington

GWU Personnel:
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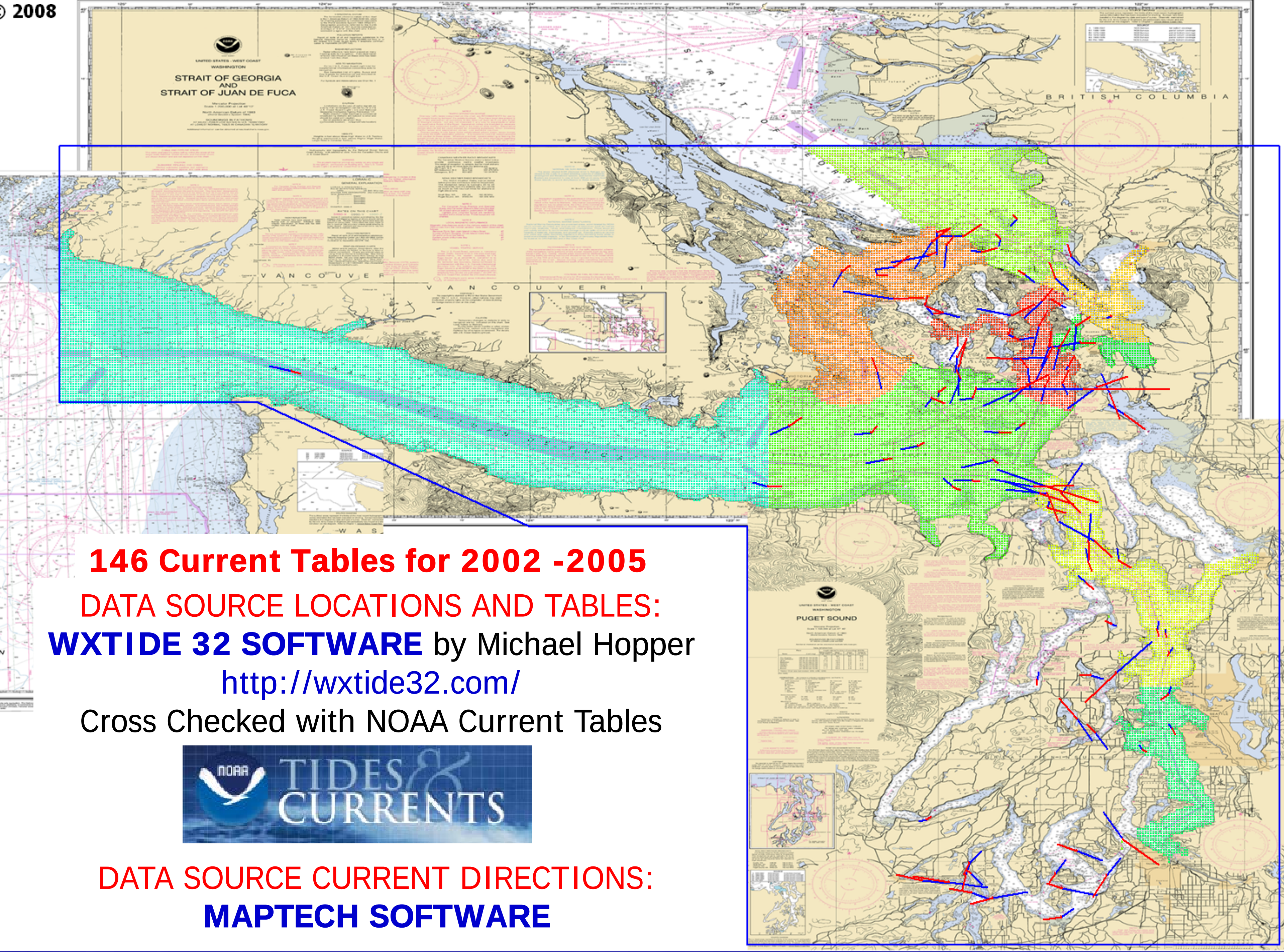


146 Current Tables for 2002 -2005

DATA SOURCE LOCATIONS AND TABLES:

WXTIDE 32 SOFTWARE by Michael Hopper

http://wxtide32.com/

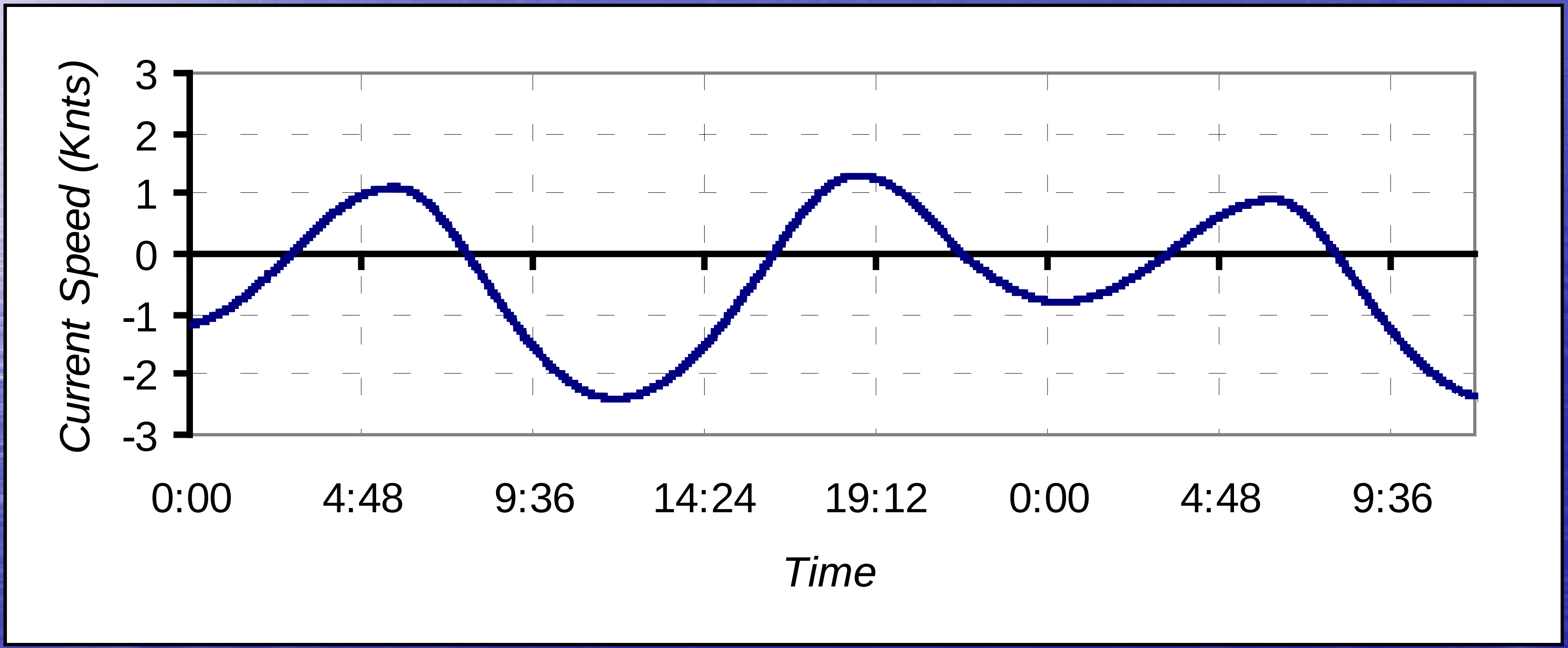
Cross Checked with NOAA Current Tables

DATA SOURCE CURRENT DIRECTIONS:

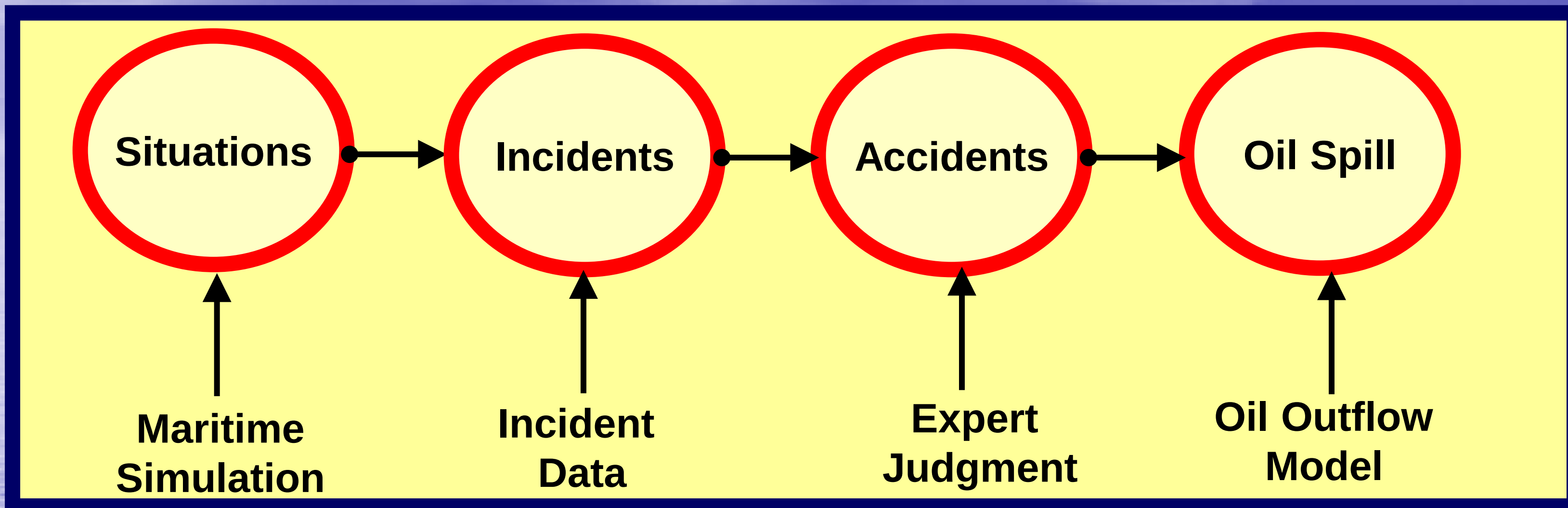
MAPTECH SOFTWARE

ID	Name	Lat	Long	RS	FD	ED	HTTM	HTHM	HTMM	HTM	LTTM	LTHM	LTMM	LTM	MF	ME
1	Admiralty Head	48.1500	122.700	2	145	25	+	0	03	1.29	+	0	07	1.2	2.1	3.1
2	Admiralty Inlet	48.0333	122.633	2	179	3	+	0	00	1	+	0	00	1	1.6	2.6
3	Agate Pass 1	47.7167	122.550	2	230	32	-	1	00	0.8	+	0	59	0.69	0	0
4	Agate Pass 2	47.7128	122.565	2	216	37	+	0	53	2	+	0	47	1.39	3.3	3.6
5	Alden Point	48.7578	122.980	107	25	185	+	0	26	0.89	+	0	53	1.1	1	2.1
6	Alki Point	47.5755	122.428	2	160	330	+	0	44	0.3	+	0	39	0.2	0.5	0.5
7	Apple Cove Point	47.8167	122.466	2	168	8	+	0	11	0.3	+	0	29	0.3	0.5	0.8
8	Balch Passage	47.1875	122.697	126	296	107	-	1	07	0.4	+	0	40	0.8	1.1	2.2
9	Barnes Island	48.6858	122.788	107	315	140	+	1	20	0.6	+	0	08	0.5	0.6	0.9
10	Bellingham Channel	48.5603	122.663	107	45	185	-	0	08	1.1	+	0	51	1.2	1.2	2.2
11	Blake Island	47.5250	122.499	2	131	326	-	2	37	0.2	+	0	25	0.2	0.3	0.5
12	Boundary Pass	48.6953	123.235	107	41	203	-	0	34	1.6	+	0	02	1.39	0.7	1.6
13	Burrows Bay	48.4628	122.682	107	22	209	+	0	48	0.89	+	0	43	0.2	1	0.4
14	channel	47.4667	122.700	107	304	96	+	0	34	2	+	0	57	0.69	0	0
15	Burrows Island Light	48.4833	122.733	107	15	200	+	0	03	1	+	0	16	1.1	1.1	2.1
16	Bush Point Light	48.0333	122.616	2	144	309	+	0	21	1.1	+	0	35	1.1	1.7	2.9
17	Cattle Point 1	48.4338	122.947	108	340	195	+	0	20	0.3	+	0	01	0.89	0.8	2.4
18	Cattle Point 2	48.4000	123.000	2	46	187	-	0	52	0.4	+	0	42	0.2	0.6	0.4
19	Cattle Point 3	48.3833	123.016	2	120	210	+	1	11	0.6	+	0	44	0.3	0.9	0.9
20	Clark Island	48.7333	122.766	107	335	150	+	1	14	0.6	+	0	02	0.6	0	0
21	Colville Island 1	48.4000	122.816	107	55	235	+	0	31	1	+	0	07	1.2	1.1	2.3
22	Colville Island 2	48.4167	122.783	107	55	215	-	0	14	1.39	+	0	14	1	1.6	1.9
23	Crane Island	48.5895	122.998	108	288	75	+	0	35	0.2	+	0	07	0.1	0.4	0.3
24	Dana Passage	47.1633	122.867	126	249	76	+	0	09	0.5	+	0	12	0.8	1.5	2.2
25	Deception Island 1	48.4197	122.698	107	17	161	+	1	14	0.6	-	1	23	0.5	1.3	1.1
26	Deception Island 2	47.4000	122.700	107	35	210	-	0	04	1.2	-	2	29	0.6	0	0
27	Deception Island 3	48.4125	122.739	107	15	190	-	0	50	0.8	+	0	34	0.69	0.9	1.3
28	Deception Pass	48.4062	122.643	28	90	270	+	0	00	1	+	0	00	1	5.2	6.6
29	Discovery Island 1	48.3833	123.200	2	25	250	+	0	15	0.6	+	0	04	0.89	0	0
30	Discovery Island 2	48.4500	123.150	2	345	170	+	1	03	0.8	+	0	59	0.6	1.3	1.6

Modeled Harmonic Curve betweem Eb, Slack, Flood, Eb, Slack, Flood, etc.



An Oil Spill is a series of cascading events referred to as a Causal Chain



$$R = \{< s_i, l_i, x_i >\}_c$$

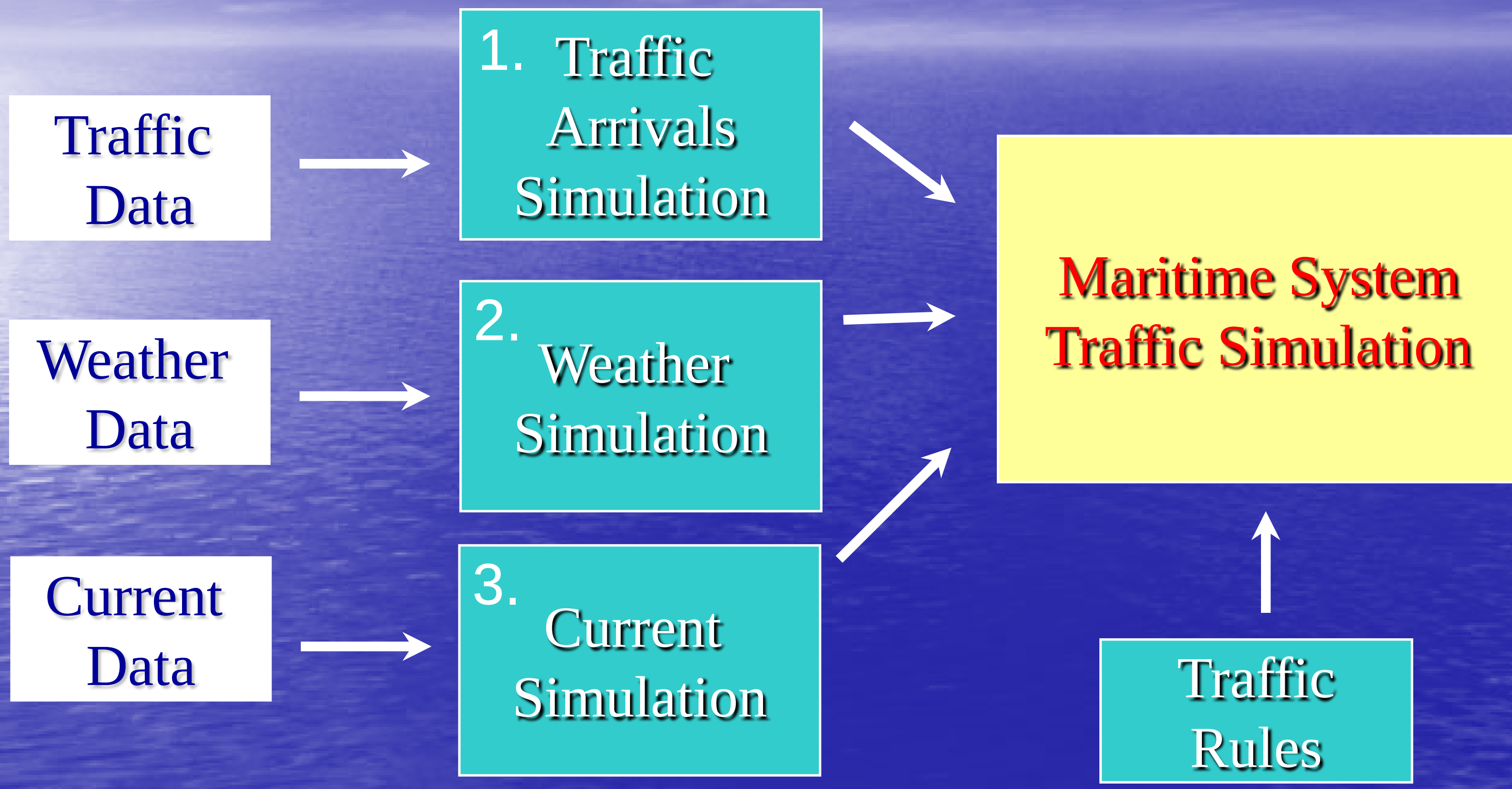
Scenario i
Likelihood i
Consequence i
Complete Set

Use Kaplan's (1997) definition of system risk in:

"The Words of Risk Analysis", Risk Analysis 17 (4), 407-417

Step 1b: Generate Accident Scenarios

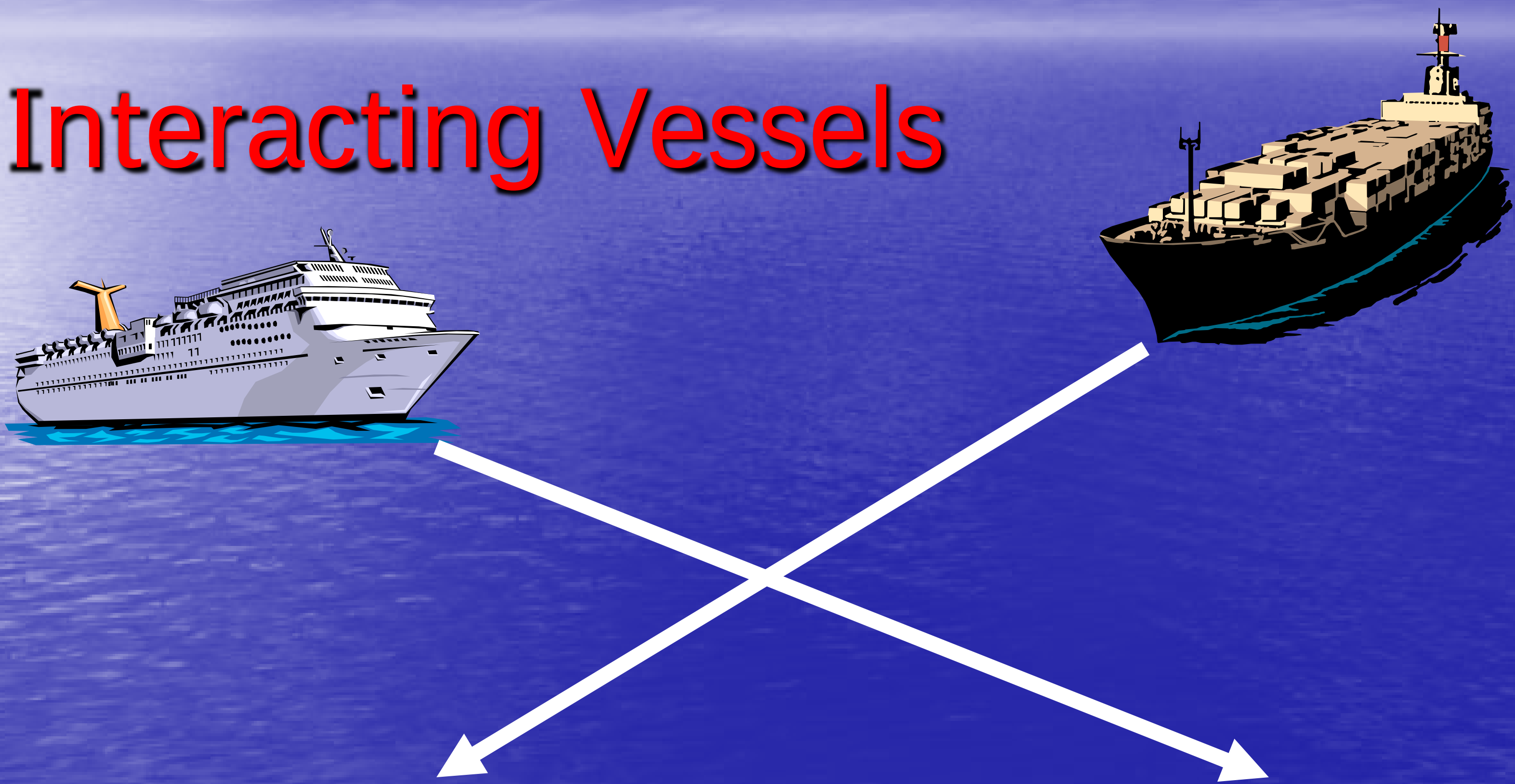
Using The Maritime System Simulation Model



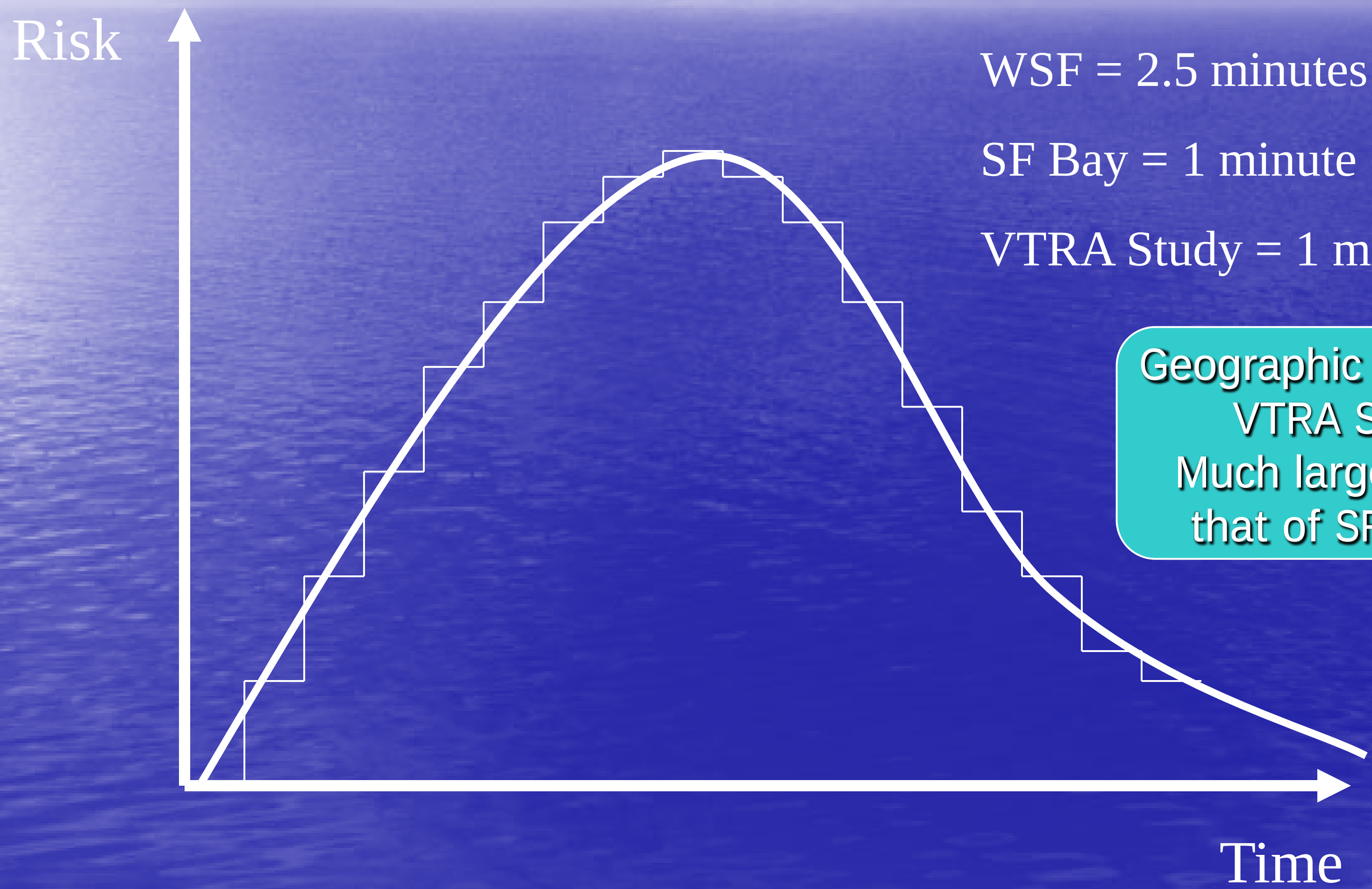
Required close cooperation with the USCG VTS and Puget Sound Harbor Safety Committee for data + validation

Count Accident Scenarios

Interacting Vessels



Risk During Interactions



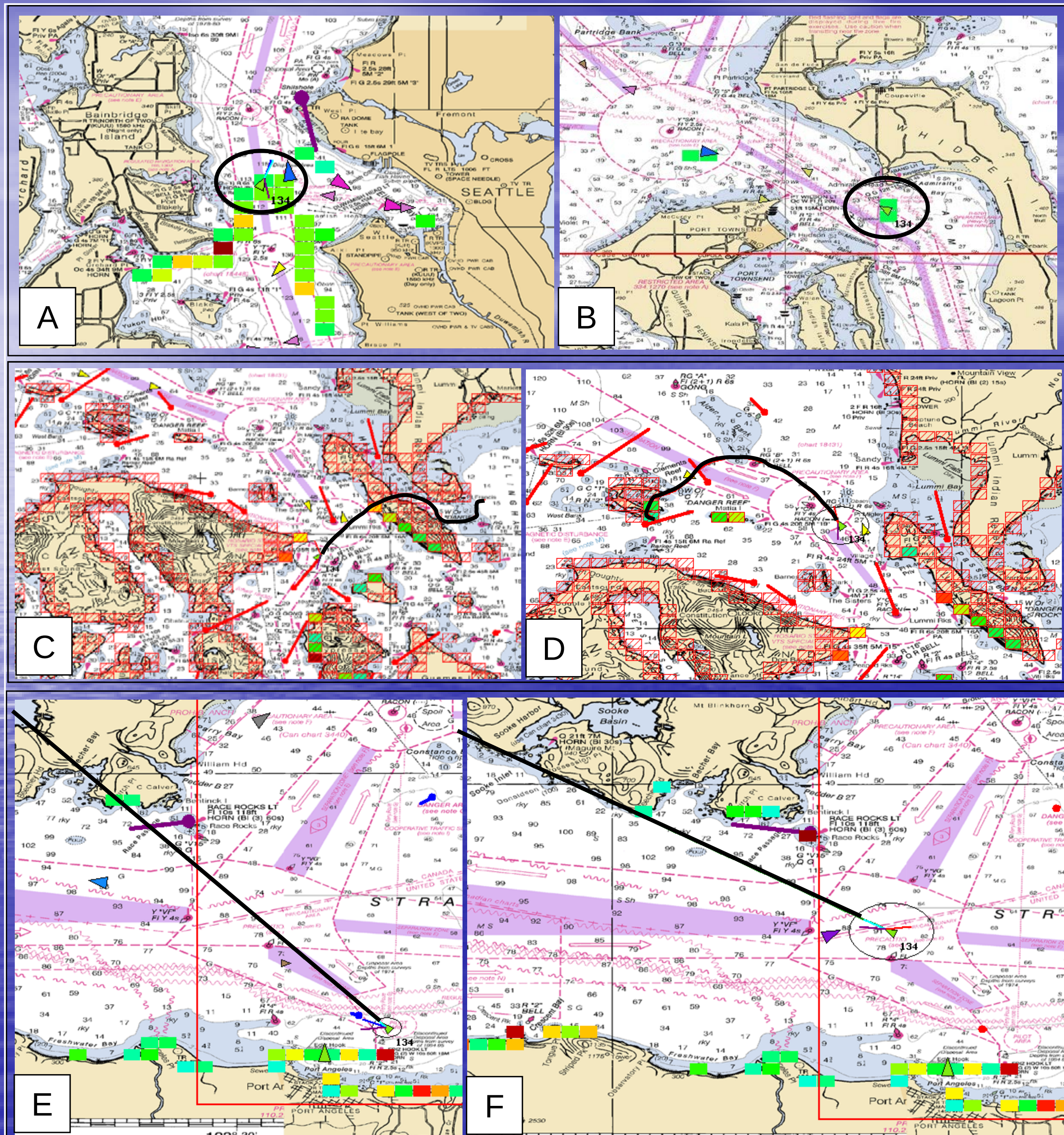
PWS = 5 minutes

WSF = 2.5 minutes

SF Bay = 1 minute

VTRA Study = 1 minute

Geographic Scope of VTRA Study Much larger than that of SF Study

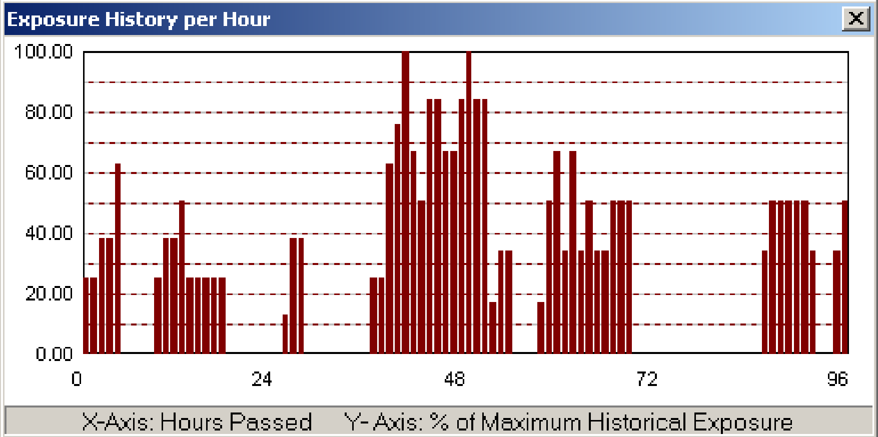


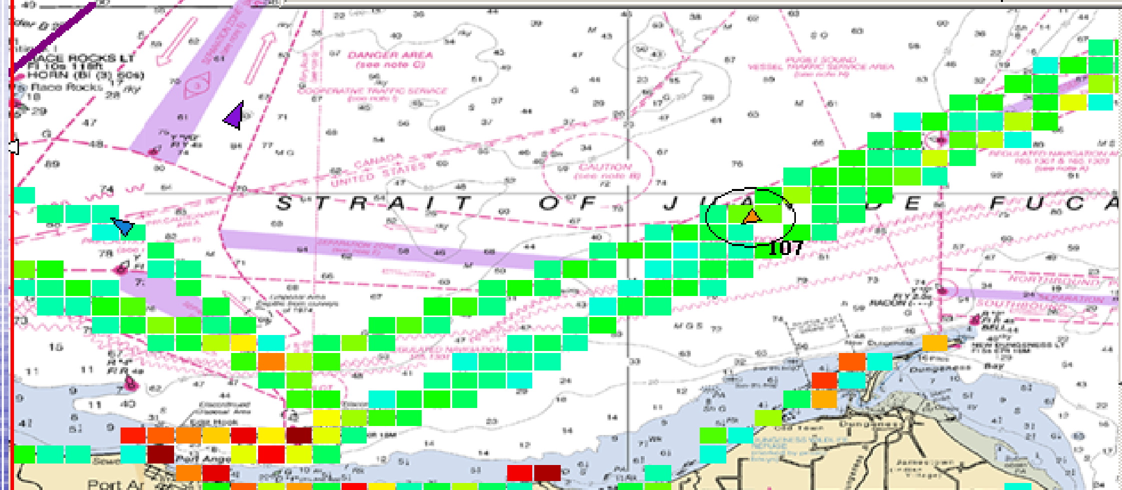
Generating Accident Scenarios:

Counting Collision Accident Scenario's

Counting Drift Grounding Accident Scenario's

Counting Powered Grounding Accident Scenario's





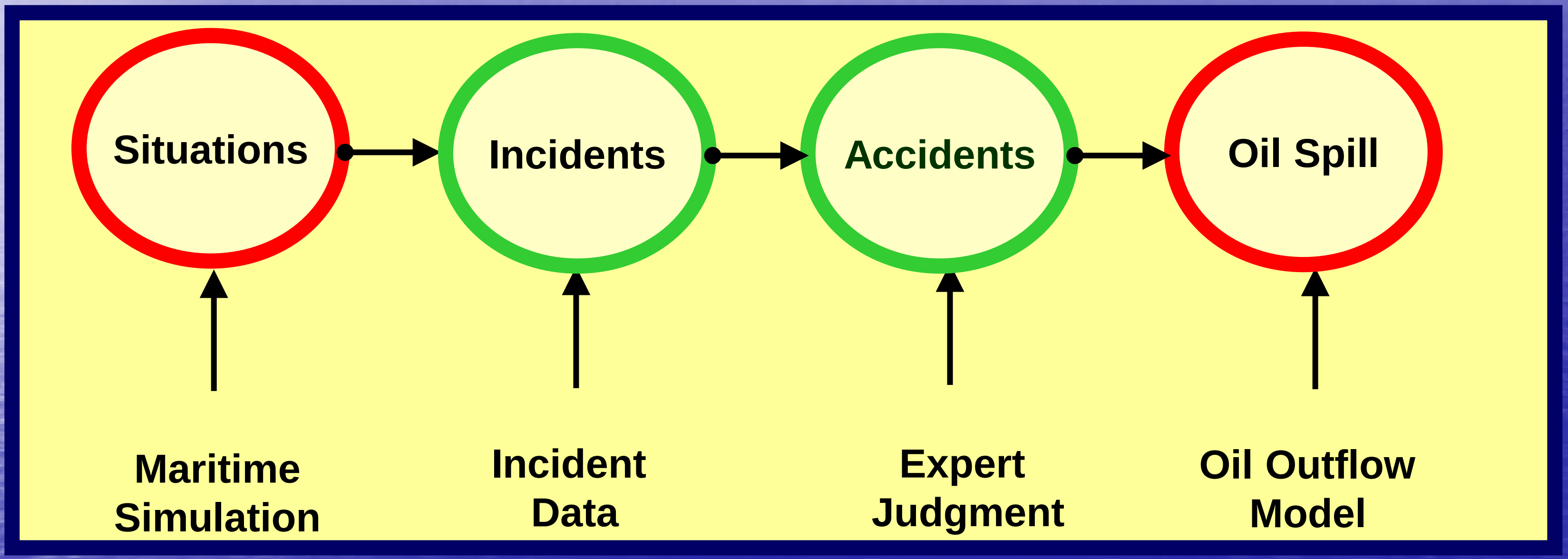
A

Data base - Vessel Interactions

Index 1	Index 2	Index 3	Index 4	Index 5	Index 6	Index 7	No of Occurrences
425120095	410901300	110222107	111122130	628013199	121094074	301132018	2
425121095	410901300	110222107	111122130	626009190	126094032	223021000	1
425121095	410901300	110222107	111122130	628013199	122094074	301132018	1
425121095	410901300	110222107	111122230	626009190	126094032	223021000	1
425121095	410901300	110222107	111122230	628013199	122094074	301132018	1
425126095	410901300	110222107	112122130	626009190	127094032	223022018	3
425127095	410901300	110222107	112122130	626009190	127094032	223022018	4
425128095	410901300	110222107	112122130	626009190	127094032	223022018	2
425174081	321004200	120262107	111112130	626009190	176082032	223032000	1

```
type INTERACTION = record
       lex_number_1          :longint;
       lex_number_2          :longint;
       lex_number_3          :longint;
       lex_number_4          :longint;
       lex_number_5          :longint;
       lex_number_6          :longint;
       lex_number_7          :longint;

       {Index 1 - VOI Location Info}
       Interaction_Type        :longint; {400000000}
       VOI                     :longint; { 26000000}
       VOI_X                   :Longint; {   500000}
       VOI_Y                   :Longint; {      500}

       {Index 2 - VOI Attributes}
       VOI_Location            :Longint; {900000000}
       VOI_Inbound_Outbound:Longint; { 20000000}
       VOI_Speed               :Longint; {  3000000}
       VOI_DP                  :longint; {    12500}
       IV_Cargo                :Longint; {       20}
       IV_Barge_Type           :Longint; {        5}

       {Index 3 - VOI Attributes}
       VOI_Cargo               :Longint; {20000000}
       VOI_Tethered_State      :Longint; {  200000}
       VOI_Barge_Type          :Longint; {   50000}
       VOI_Hook_Up             :Longint; {    4000}
       VOI_ID                  :longint; {     999}

       {Index 4 - Environment Info}
       Visibility              :longint; {20000000}
       Wind_Direction          :longint; { 2000000}
       Wind_Speed              :longint; {  400000}
       Current                 :Longint; {   30000}
       Current_Direction       :Longint; {    3000}
       N_Vessels               :Longint; {     300}
       Escort_State            :Longint; {      20}

       {Index 5 - Shore Interaction Location}
       Shore_X                 :Longint; {500000000}
       Shore_Y                 :Longint; {   500000}
       Time_to_Shore           :Longint; {      300}

       {Index 6 - Interacting Vessel Location}
       IV_X                    :Longint; {500000000}
       IV_Y                    :Longint; {   500000}
       IV_DP                   :Longint; {      125}

       {Index 7 - Interacting Vessel Info}
       IV_TrafficScenario      :Longint; {400000000}
       IV_TrafficType          :longint; { 25000000}
       IV_Speed                :Longint; {   300000}
       IV_ProxVessel           :Longint; {     2000}
       IV_InterAngle           :Longint; {      180}
   end;
```

Step 2: Evaluate Accident Likelihood per Accident Scenario



Joint work with:

VCU Personnel:
Dr. Jason R. W. Merrick, and Team

VCU

RPI Personnel:
Dr. M. Grabowsku, and Team

Rensselaer

Gather Relevant Incident and Accident Data

- Accidents: Collisions, Powered Grounding, Drift Grounding and Allisions of Tank Ships and Tug\Tow Barges.

- Incidents: Vessel Propulsion Failure, Steering Failure, Navigational Aid Failure and Human Error.

This step involves pulling together data from multiple data sources ensuring no double counting and avoiding occurrence of missing data

Summary Incident Data

- Tankers calling at BP
  - 11 years of data
  - Propulsion failures: 31
  - Steering failures: 11
  - Nav. aid failures: 10
- ATBs and ITBs calling at BP
  - 7.5 years of data
  - Propulsion failures: 3
  - Steering failures: 2
  - Nav. aid failures: 2
- Human error incidents are rarely recorded
  - 4 accidents have occurred in data collection period
  - 3 of these were caused by human error and 1 by mechanical failure
  - Use 1 to 3 multiplier on mechanical failure rates

Joint work with:

Rensselaer

RPI Personnel: Dr. Martha Grabowski, Zhi Zhou, Michael Steward, Brittany Steward, Huawei Song, Zhuyu You

Summary Accident Data

- 11 years of data, 4 accidents
- 1 collision
  - The tanker Allegiance and its escort tug Sea King collided in Straits of Juan de Fuca east
- 1 grounding
  - ITB New York dragged anchor and grounded in 55 knots winds off March Point
- 2 allisions
  - Tanker Leyte Spirit allides with dock when trying to leave dock in high winds and seas
  - Tanker Overseas Arctic allides with piling bracket when docking at Tacoma

Joint work with:

Rensselaer

RPI Personnel: Dr. Martha Grabowski, Zhi Zhou, Michael Steward, Brittany Steward, Huawei Song, Zhuyu You

Calibration to Accident Data

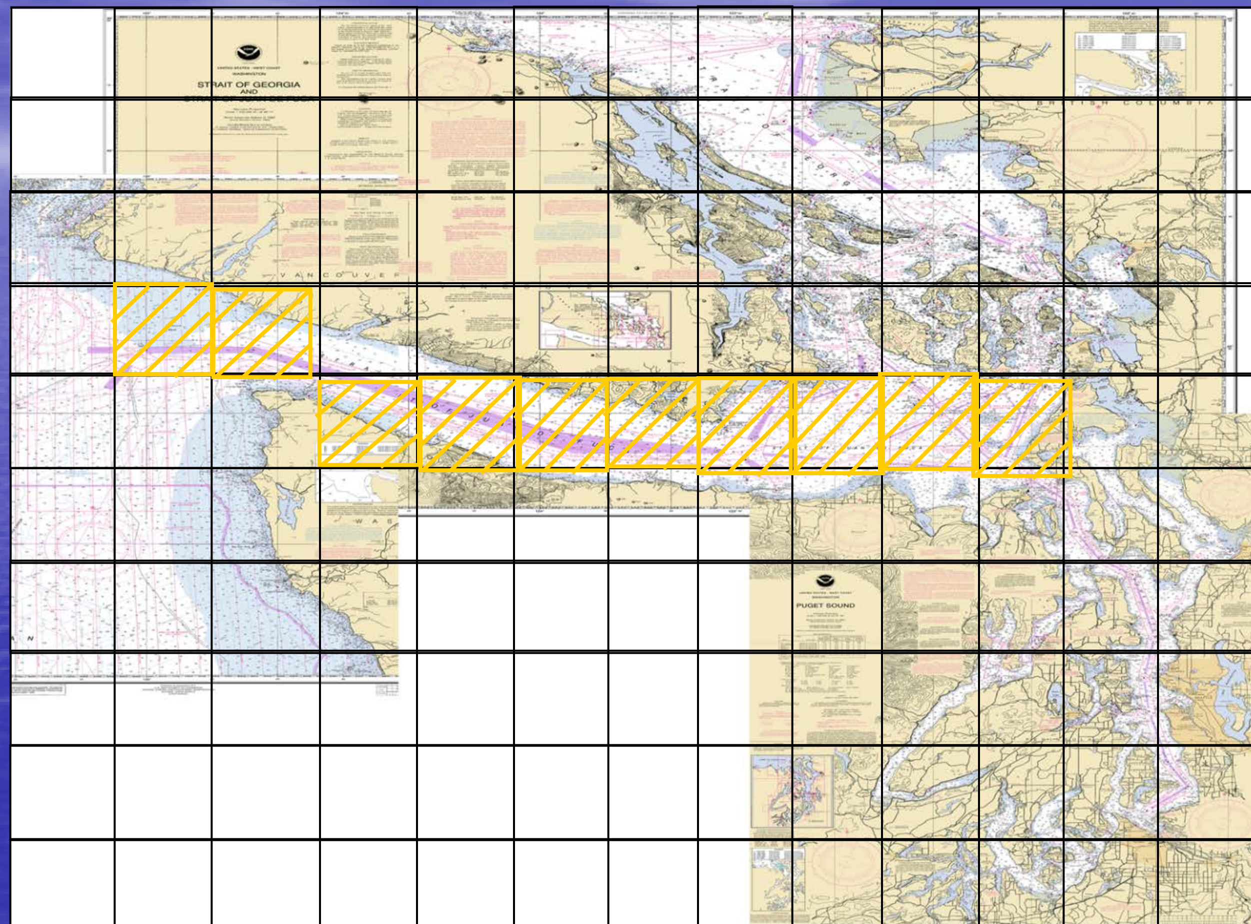
- Counting Grid: 130 Grid Cells

- Suppose we have a we a total of 130 Vessel Interactions evenly in 10 Grid Cells over the area.

- Suppose we have a we have a total of 1 Collision in our Data.

- Suppose all interactions are the same

$$\text{Pr(Collision per Interaction)} = \frac{1}{130}$$



Calibration Step means that in Base Case Simulation the accident rate per year is the same as the historically observed accident Rate

Calibration to Accident Data

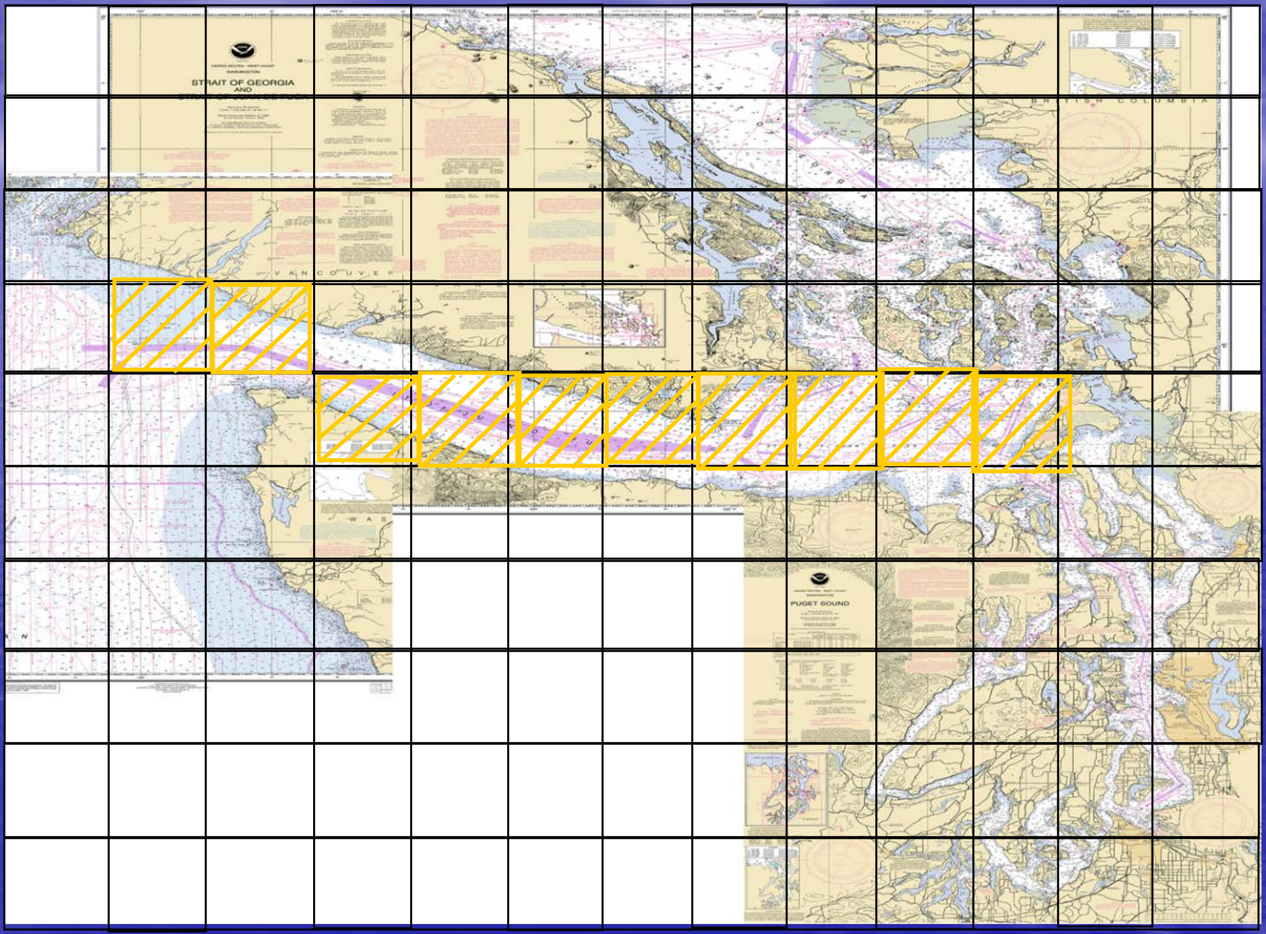
- Counting Grid: 130 Grid Cells

- Suppose we have a we a total of 130 Vessel Interactions evenly in 10 Grid Cells over the area.

- Suppose we have a we have a total of 1 Collision in our Data.

- Suppose all interactions are the same

$$\Pr(\text{Collision per Interaction}) = \frac{1}{130}$$



DOES NOT MAKE SENSE BECAUSE LIKELIHOOD OF A COLLISION IS NOT THE SAME FOR EVERY INTERACTION

Calibration to Accident Data

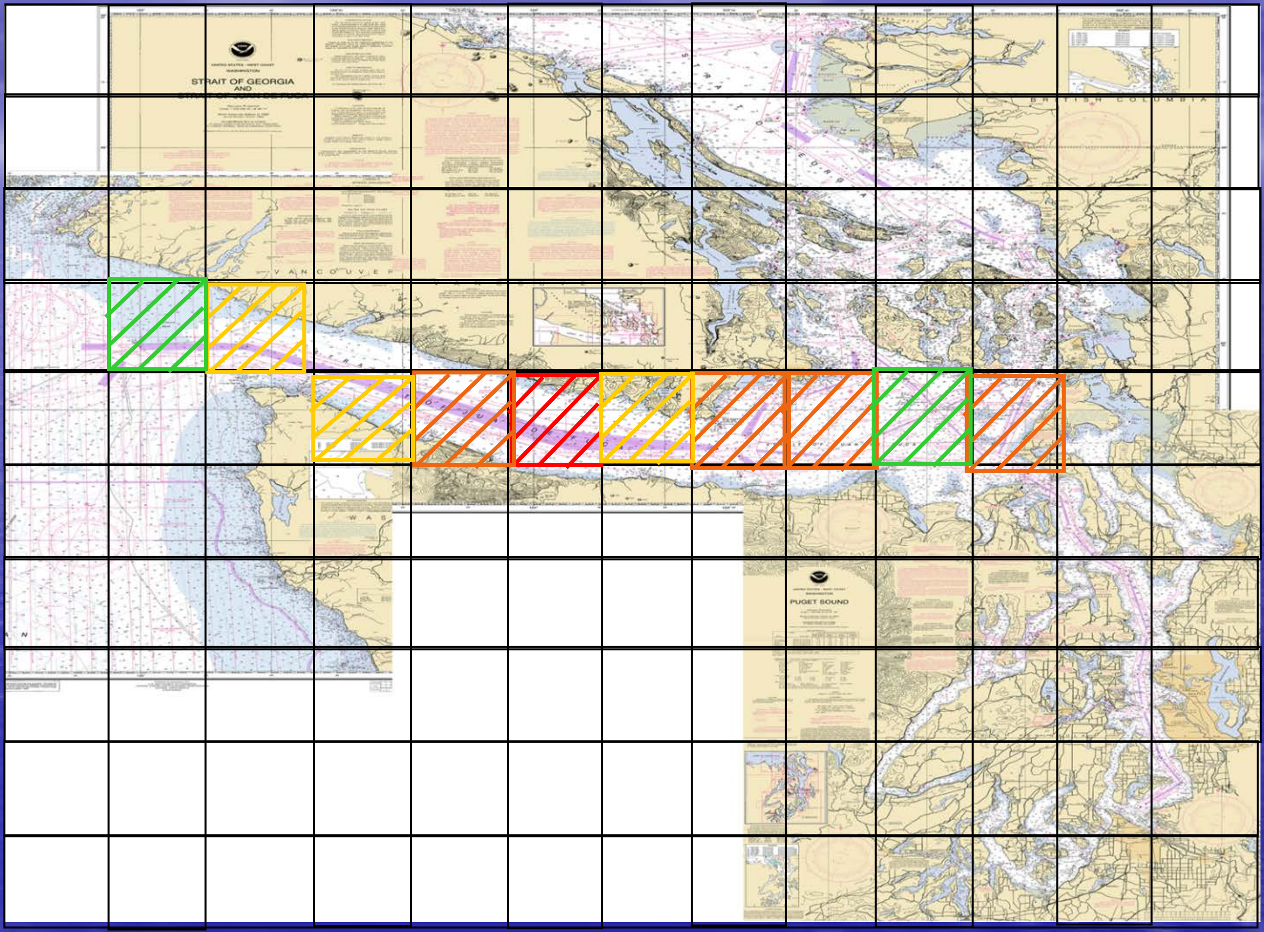
- Counting Grid: 130 Grid Cells

- Suppose we have a we a total of 130 Vessel Interactions evenly in 10 Grid Cells over the area.

- Suppose we have a we have a total of 1 Collision in our Data.

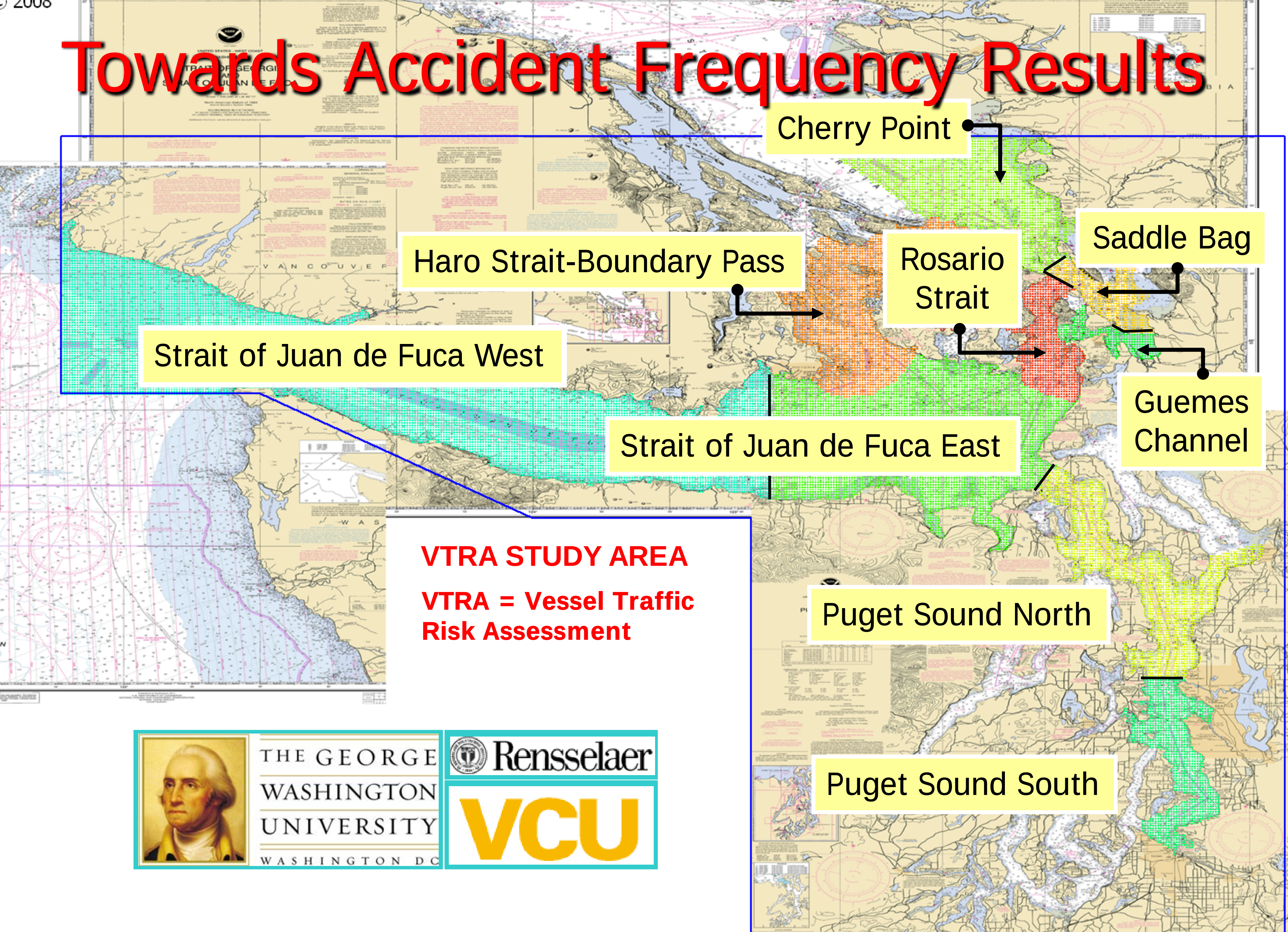
- Suppose all interactions are the same

$$Pr(\text{Collision per Interaction}) = \frac{1}{130}$$



CALLIBRATE SO OVERALL ACCIDENT RATE REMAINS THE SAME, BUT ACCOUNT FOR RELATIVE LIKELIHOOD OF ACCIDENTS IN DIFFERENT INTERACTIONS

Towards Accident Frequency Results



VTRA STUDY AREA

VTRA = Vessel Traffic Risk Assessment

THE GEORGE WASHINGTON UNIVERSITY WASHINGTON DC

Rensselaer

VCU

Accident Attributes Tanker Model

LOCATION	DIRECTION	CARGO	ESCORTS	TETHERED
Cherry Point Area	Inbound	Unladen	2 Escorts	tethered
Puget Sound South	Outbound	Laden	1 Escort	untethered
Strait of Juan de Fuca East			No Escorts	
Strait of Juan de Fuca West				
Puget Sound North				
Saddle Bag Area				
Rosario Strait				
Haro Strait\Boundary Pass				
Guemes Channel				

VESSEL TYPE	TRAFFIC PROXIMITY	TRAFFIC SCENARIO
Tug without Barge	1 to 5 miles	Crossing Astern
Tug ATB's or ITB's	Less than 1 mile	Meeting
Tug Pushing Ahead		Overtaking
Container		Crossing the Bow
Tanker		
Bulk carrier		
Freighter		
Passenger vessel		
Service vessel		
Public vessel		
Fishing Vessel		
Tug Towing Astern		
Recreational Vessel		

VISIBILITY	WD	WIND SPEED	CURRENT	CUR_DIR
More than 0.5 mile	Along Vessel	Less than 10 knots	Almost Slack	Along Vessel - Opposite
Less than 0.5 mile	Abeam Vessel	20 knots	Max Eb or Max Flood	Along Vessel - Same Dir.
		30 knots		Abeam Vessel
		More than 40 knots		

Accident Attributes Tug Model

LOCATION	DIRECTION	CARGO	HOOKUP
Cherry Point Area	Inbound	No Barge	No Barge
Puget Sound South	Outbound	Unladen Barge	ATB or ITB
Strait of Juan de Fuca East		Laden Container Barge	Pushing Ahead
Strait of Juan de Fuca West		Laden Bulk Cargo Barge	Towing Astern
Puget Sound North		Laden Derrick/Crane Barge	
Saddle Bag Area		Laden Oil Barge	
Rosario Strait		Log Tow	
Haro Strait\Boundary Pass			
Guemes Channel			

VESSEL TYPE	TRAFFIC PROXIMITY	TRAFFIC SCENARIO
Tug without Barge	1 to 5 miles	Crossing Astern
Tug ATB's or ITB's	Less than 1 mile	Meeting
Tug Pushing Ahead		Overtaking
Container		Crossing the Bow
Tanker		
Bulk carrier		
Freighter		
Passenger vessel		
Service vessel		
Public vessel		
Fishing Vessel		
Tug Towing Astern		
Recreational Vessel		

VISIBILITY	WD	WIND SPEED	CURRENT	CUR_DIR
More than 0.5 mile	Along Vessel	Less than 10 knots	Almost Slack	Along Vessel - Opposite
Less than 0.5 mile	Abeam Vessel	20 knots	Max Eb or Max Flood	Along Vessel - Same Dir.
		30 knots		Abeam Vessel
		More than 40 knots		

Conduct Expert Judgment Elicitations via Questionnaires

Q30

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**	Less than 0.5 mile Visibility
Along Vessel	**Wind Direction**	-
Less than 10 knots	**Wind Speed**	-
Almost Slack	**Current**	-
Along Vessel - Opposite Direction	**Current Direction**	-
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**

Example of potential experts: USCG VTS Operators, Puget Sound Pilots, Tanker Captains and First Mates, Tug Captains and First Mates, etc.

Collision Probability Model:

$$Pr(Collision|Incident, \underline{X}) = P_0 exp\left\{\underline{\beta}^T \underline{X}\right\},$$

Collision Question j, j=1,..., n:

$$\frac{Pr(Collision|Incident, \underline{X}_1^j)}{Pr(Collision|Incident, \underline{X}_2^j)} = exp\left\{\underline{\beta}^T [\underline{X}_1^j - \underline{X}_2^j]\right\}$$

$$\ln\left[\frac{Pr(Collision|Incident, \underline{X}_j^1)}{Pr(Collision|Incident, \underline{X}_j^2)}\right] = \underline{\beta}^T q_j,\ q_j = [\underline{X}_j^1 - \underline{X}_j^2]$$

Expert Responds to Question j:

$$\frac{Pr(Collision|Incident, \underline{X}_1^j)}{Pr(Collision|Incident, \underline{X}_2^j)} = y_j \Rightarrow \ln(y_j) = \underline{\beta}^T q_j$$

Accident Probability Model + Data

$$Pr(Accident|Incident, \underline{X}) = P_0 Exp(\underline{\beta}^T \underline{X}).$$

Expert response vector $Z = (z_1, \ldots, z_n)$ to questions organized in questionnaire matrix $Q = [q_1, \ldots, q_n]$

$$z_j = \ln(y_j) = \underline{\beta}^T q_j,\ (Z_j|\mu_j, r) \sim N(\mu_j, r),\ \mu_j = \underline{\beta}^T q_j,\ r = 1/\sigma^2$$

BAYESIAN INFERENCE

Likelihood

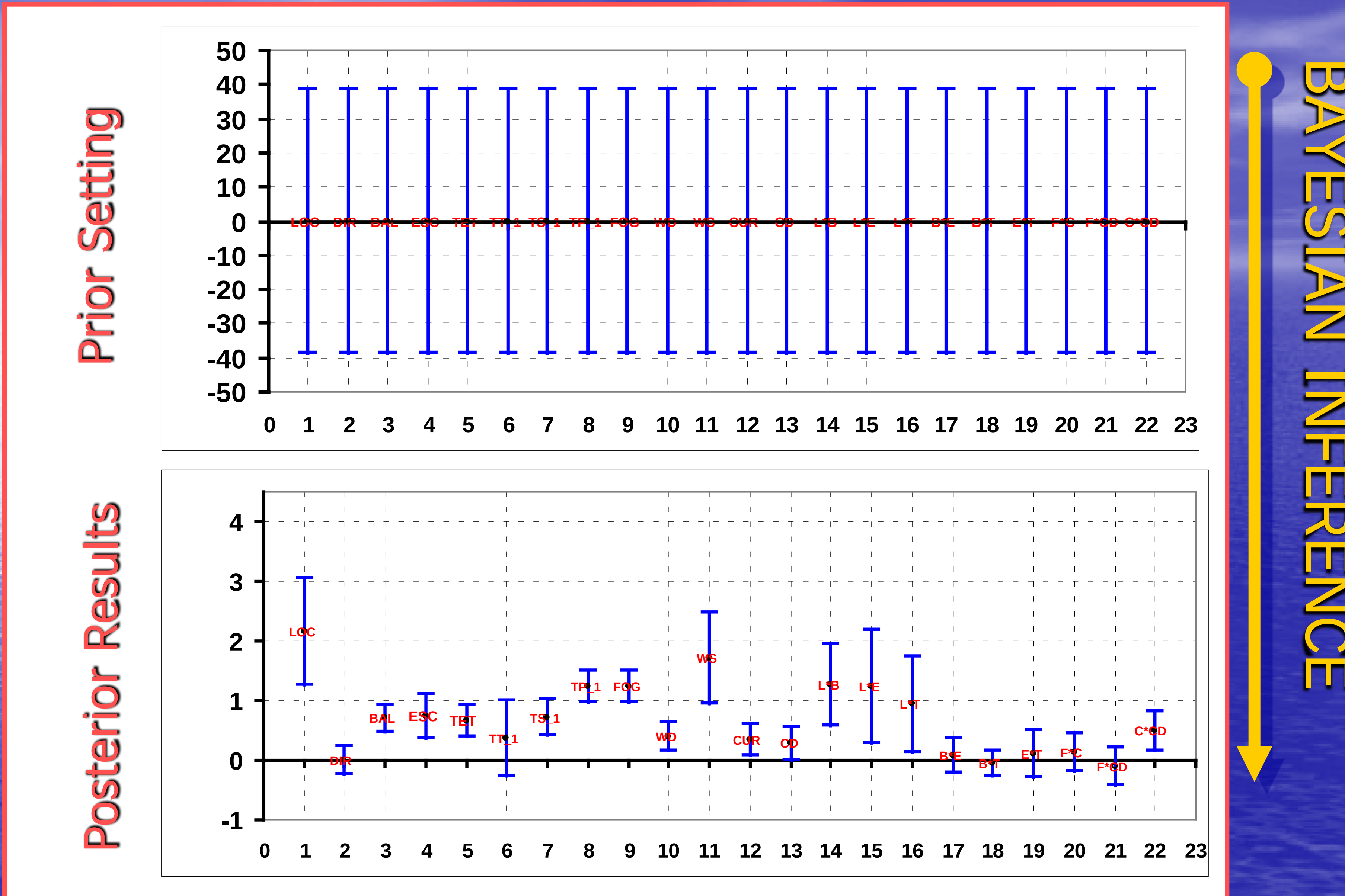
$$\mathcal{L}(Z|\,\underline{\beta}, r, Q) \propto r^{\frac{n}{2}} exp\left\{-\frac{r}{2}(c - 2\,\underline{b}^T\,\underline{\beta} + \underline{\beta}^T A\,\underline{\beta})\right\}$$

$$A = \sum_{j=1}^{n} q_j q_j^T;\ \underline{b} = \sum_{j=1}^{n} z_j q_j;\ c = \sum_{j=1}^{n} z_j^2$$

Prior distribution

$$\prod(\,\underline{\beta}\,,\ r\,) \propto r^{\frac{a}{2}-1} exp(-\frac{r}{2}\nu) \times r^{\frac{p}{2}} exp\left\{-\frac{r}{2}(\underline{\beta} - \underline{m})^T \Delta(\underline{\beta} - \underline{m})\right\}.$$

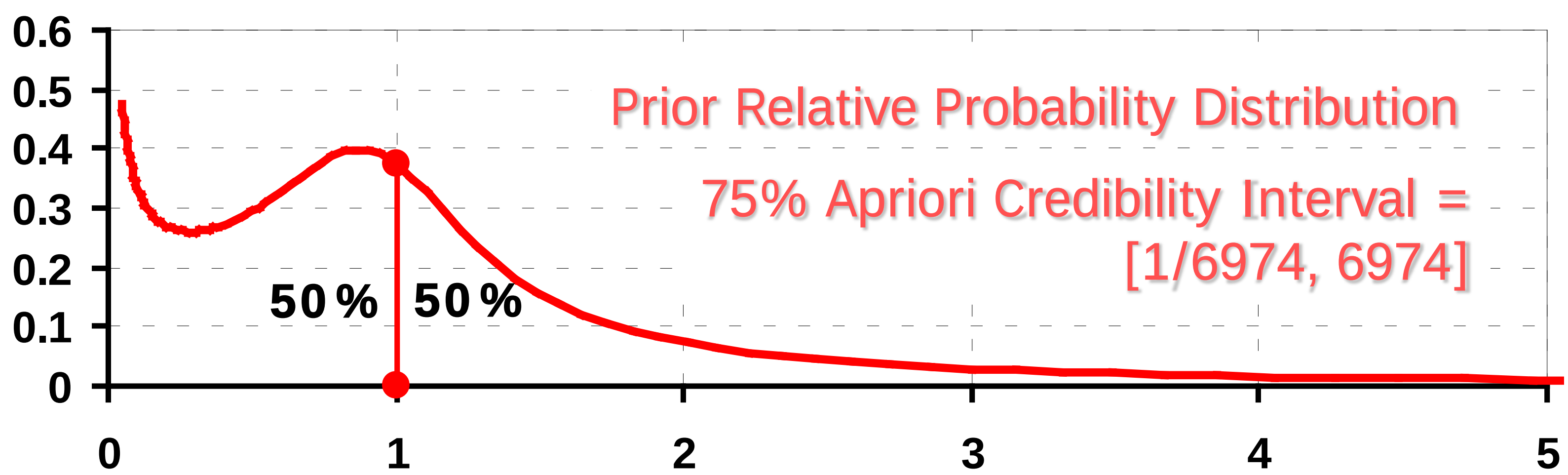
In: P. Szwed, J. Rene van Dorp, J.R.W.Merrick, T.A. Mazzuchi and A. Singh (2006). "A Bayesian Paired Comparison Approach for Relative Accident Probability Assessment with Covariate Information", European Journal of Operations Research, Vol. 169 (1), pp. 157-177.



In: P. Szwed, J. Rene 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.

Q30

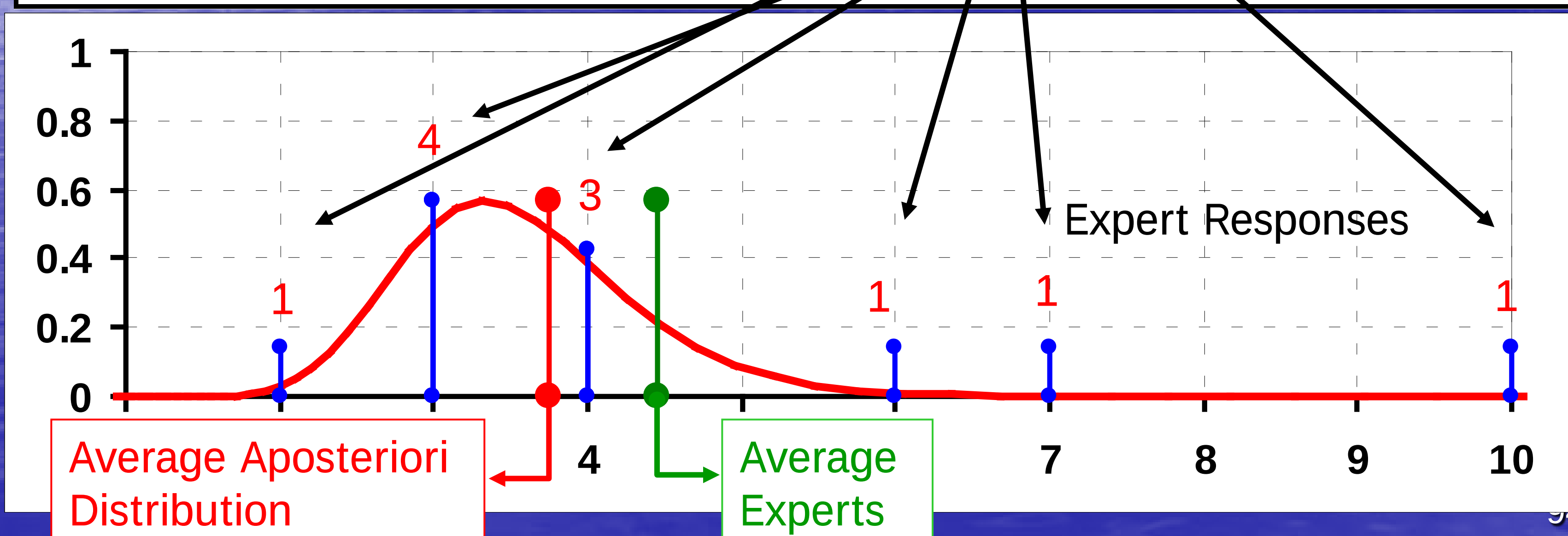
Situation 1	TANKER DESCRIPTION	Situation 2
Strait of Juan de Fuca East	**Location**	-
Inbound	**Direction**	-
Laden	**Cargo**	-
1 Escort	**Escorts**	-
Untethered	**Tethering**	-
	INTERACTING VESSEL	
Shallow Draft Pass. Vessel	**Vessel Type**	-
Crossing the Bow	**Traffic Scenario**	-
Less than 1 mile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



Q30

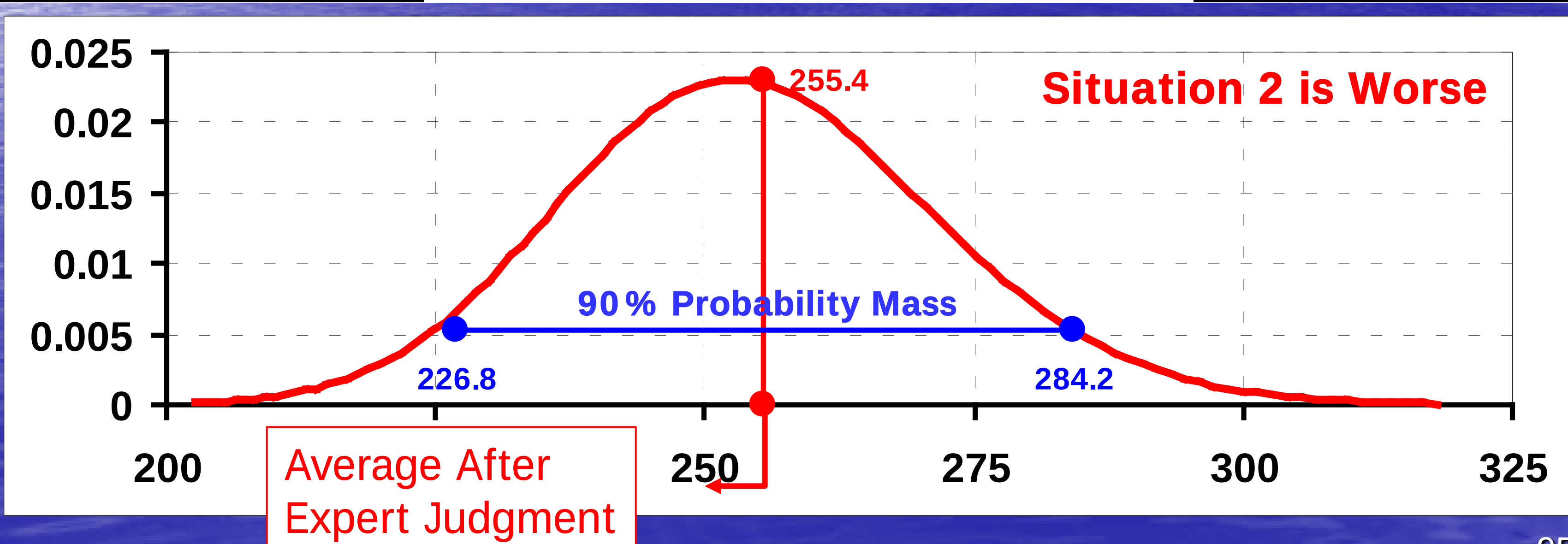
Average of **A posteriori distribution** is different than the **Average of the expert responses** since we combine in this average also the information of the expert responses to all the other 43 questions

Situation 1 is worse	<=====================X=====================>	Situation 2 is worse



Situation 1	TANKER DESCRIPTION	Situation 2
Rosario Strait	**Location**	Guemes Channel
Inbound		-
Laden		
1 Escor		orts
One Tethe		ered
Shallow Draft Pa		
Crossing the		
Less than 1		
More than 0.5 mile Visibility	**Visibility**	-
Along Vessel	**Wind Direction**	-
Less than 10 knots	**Wind Speed**	-
Almost Slack	**Current**	-
Along Vessel - Same Direction	**Current Direction**	-

While Expert questions vary only
One attribute at a time we may
Now vary multiple attributes



Organizations Participating in Expert Judgment Elicitations

- 1. Puget Sound Pilots
- 2. ATC
- 3. US and Canadian Tug Companies operating in the VTRA study area:

  US-Based: Foss, Crowley, Olympic Tug and Barge (US), K-Sea, Sea Coast, Sause Bros.

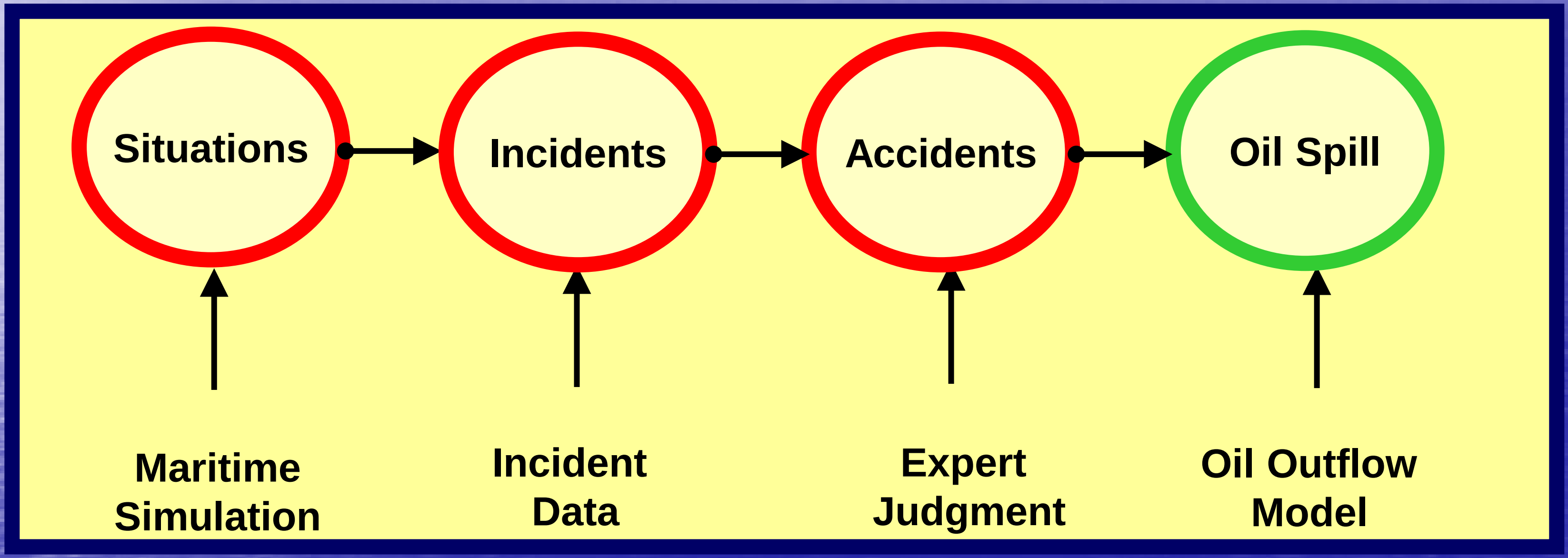
  Canadian Based: Seaspan, Island Tug and Barge
- 4. The Washington State Ferries
- 5. Seattle sector US Coast guard VTS.

Summary of Expert Judgment Data Source

- A total of 9 questionnaires
- 38 experts over 7 separate elicitation sessions dispersed over a 1 year period.
- Combined numbers of years sailing experience exceeds 922 years.

9 QUESTIONNAIRES	38 EXPERTS - Numbers indicate years sailing experience in VTRA Study area	CUMULATIVE EXPERIENCE (YRS)	7 SESSIONS
Bradley-Terry Pair Wise Comparison Location Questionnaire	7 PILOTS (42,34,32,25,16,16) 6 TUG OPERATORS (39, 30, 30, 30, 15, 12) 4 FERRY OPERATORS (31, 30, 25, 8) 2 PORT CAPTAINS (27, 25) 1 VTS WATCH (25)	186 156 94 52 25	Dec-06 Feb-07
Bradley-Terry Pair Wise Comparison Traffic Sc	7 PILOTS (42,34,32,25,16,16)	186	Dec-06 eb-07
Brac 1st			)6)7
Brac 2nd			)7)7)7
Brac Tug			)7)7)7
Tan Acc Give			)7)7
Tan Acc Give Given Given Hu Given Near By Vessel Failure			)7)7
Tug Pair Wise Situation Accident Probability Questionnaires Given Propulsion Failure	7 TUG OPERATORS (53, 21, 20, 32 30, 28, 18) 2 PORT CAPTAINS (32, 30)	202 52	Aug-07 Sep-07 Dec-07
Tug Pair Wise Situation Collision Accident Probability Questionnaires Given Steering Failure, Given Navigational Aid Failure Given Human Error Given Near By Vessel Failure	7 TUG OPERATORS (53, 21, 20, 32 30, 28, 18) 2 PORT CAPTAINS (32, 30)	202 52	Aug-07 Sep-07 Dec-07

Step 3: Evaluate Consequence per Accident Scenario



Joint work with:

TU Delft
Delft University of Technology

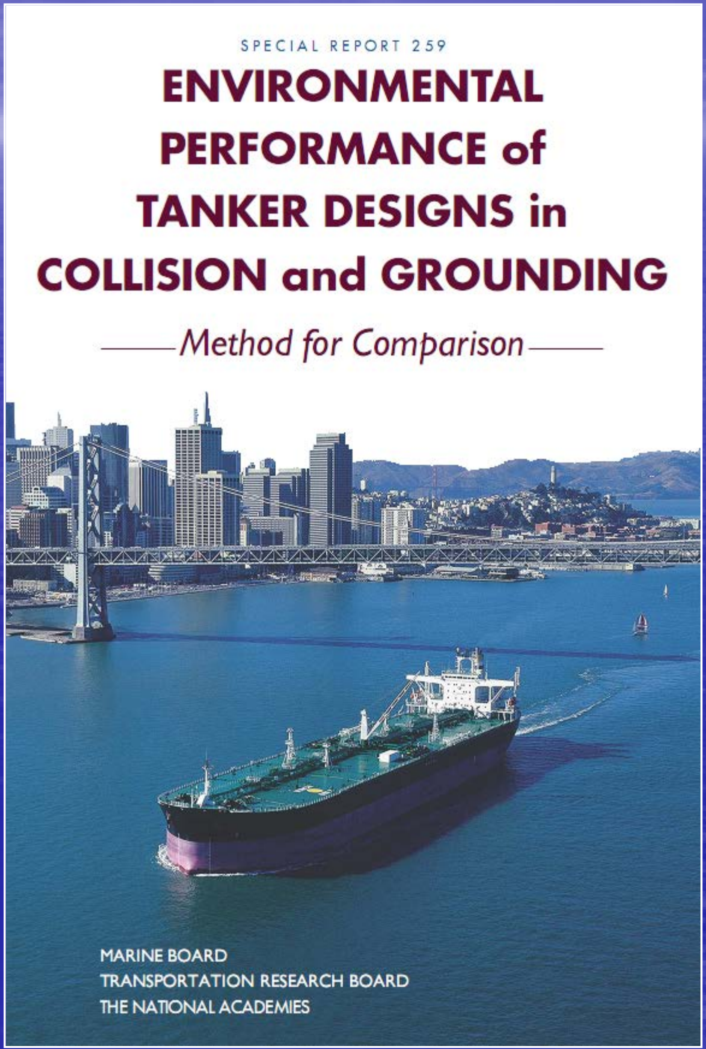
TU Delft Personnel:
Giel van de Wiel

NATIONAL RESEACH COUNCIL SPECIAL REPORT 259

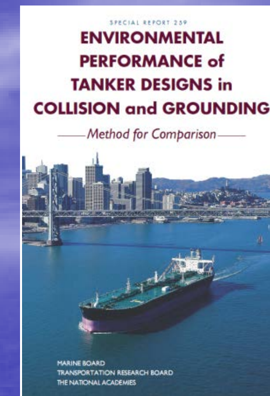
"Given the status of previous efforts to establish a methodology for comparing the environmental performance of alternative tanker designs, **the committee concluded that the development of a new approach was warranted**."

"The committee ran a total of 80,000 accident scenarios: 10,000 collision and 10,000 grounding events for each of two designs (single-hull and double-hull) of the two different sizes (150,000 and 40,000 DWT)."

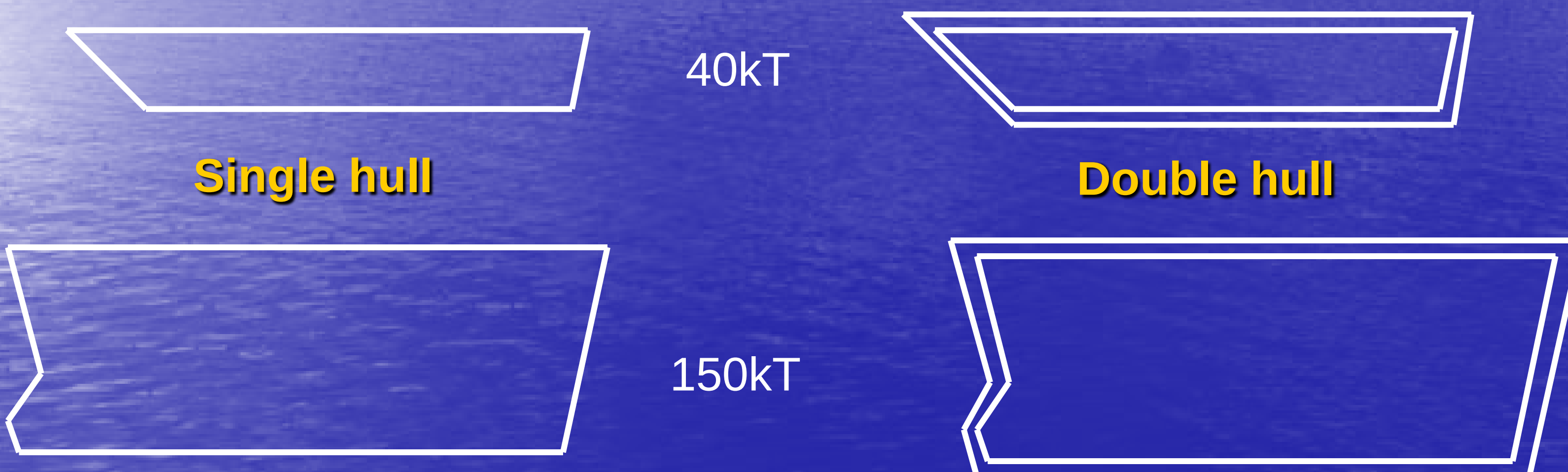
Quoted from: NRC Special Report 259



NATIONAL RESEACH COUNCIL SPECIAL REPORT 250



- **10,000 collision +**
- **10,000 grounding scenarios**
  - Applied to 4 tanker designs:



- **Use physical damage simulation software SIMCOL and DAMAGE to generate oil outflows (Computationally extensive)**

For our Oil Outflow model development computational efficiency is a requirement

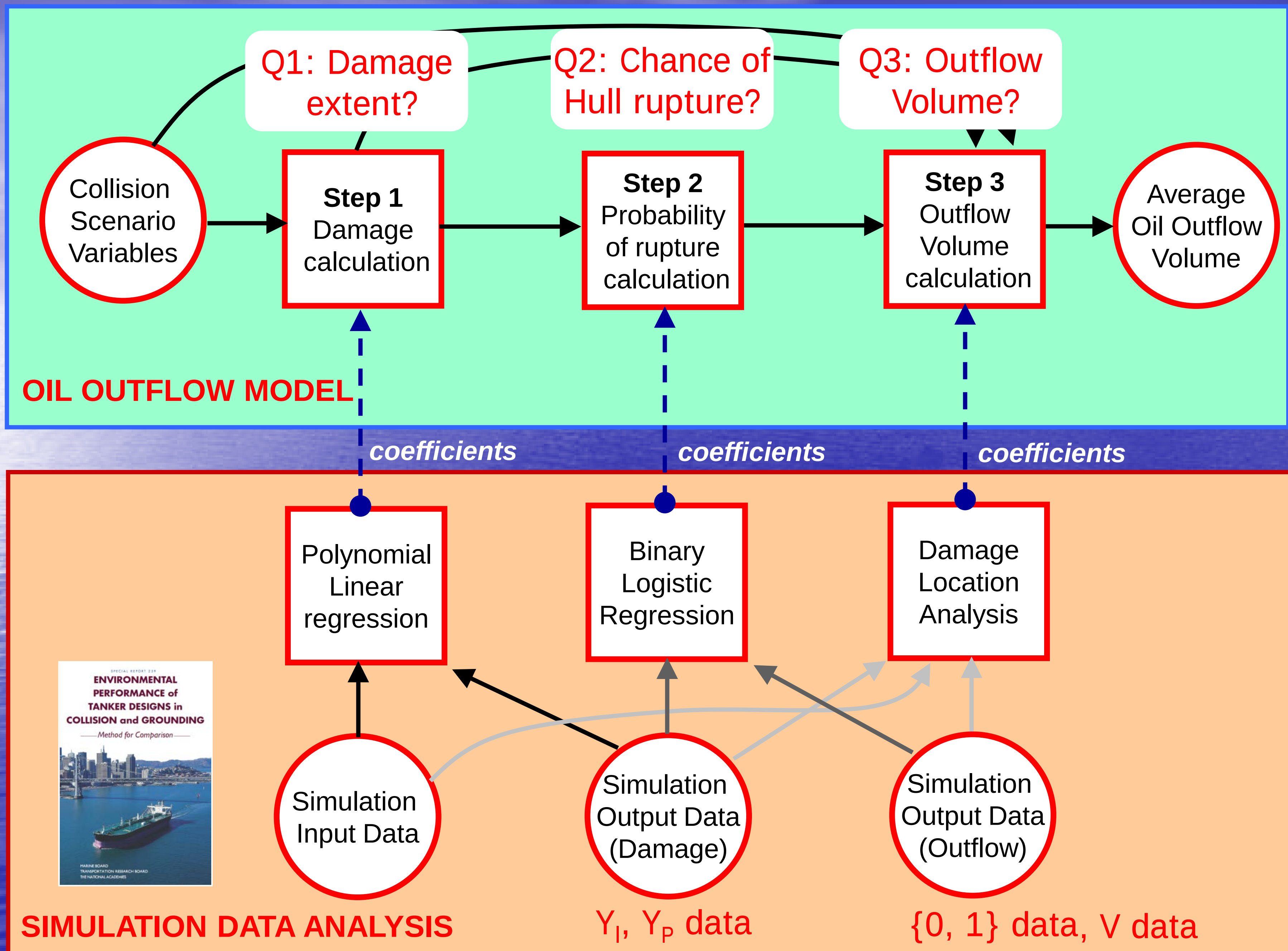
A baseline system risk analysis using our maritime risk simulation generated:

157,670 collision and 1,236,603 grounding scenarios

Scope: collision and grounding scenarios

Answers 3 questions:

1. Given accident scenario what is the damage extent?
2. What is the probability of outflow given the damage extent?
3. Which compartments are affected, i.e. what is the total outflow volume?


Q1: Damage extent?
Q2: Chance of Hull rupture?
Q3: Outflow Volume?
Collision Scenario Variables
Step 1 Damage calculation
Step 2 Probability of rupture calculation
Step 3 Outflow Volume calculation
Average Oil Outflow Volume
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coefficients
coefficients
coefficients
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Method for Comparison
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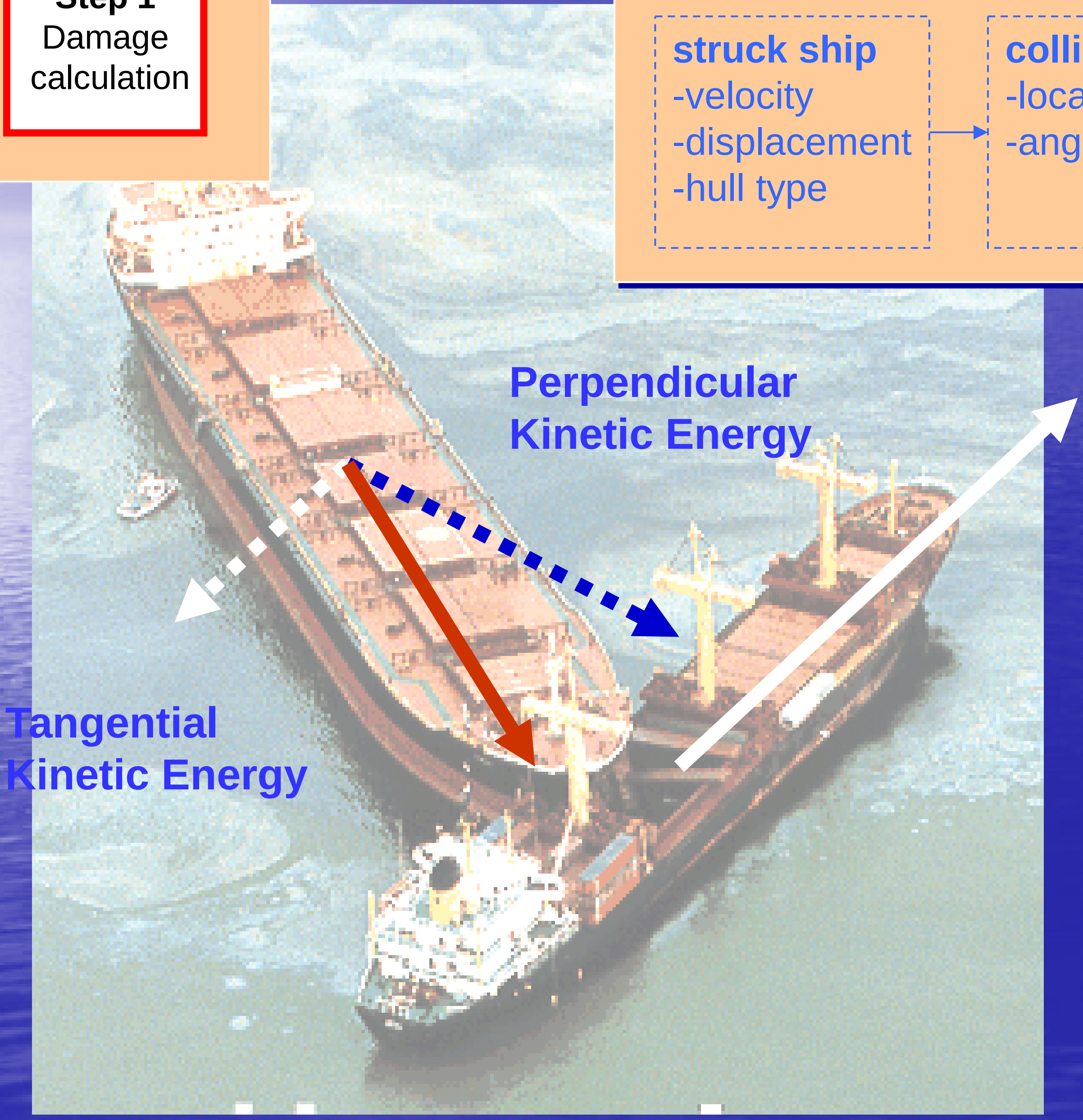
Simulation Output Data (Outflow)
SIMULATION DATA ANALYSIS
Y_I, Y_P data
{0, 1} data, V data

Step 1
Damage calculation

A SR 259 Collision Scenario

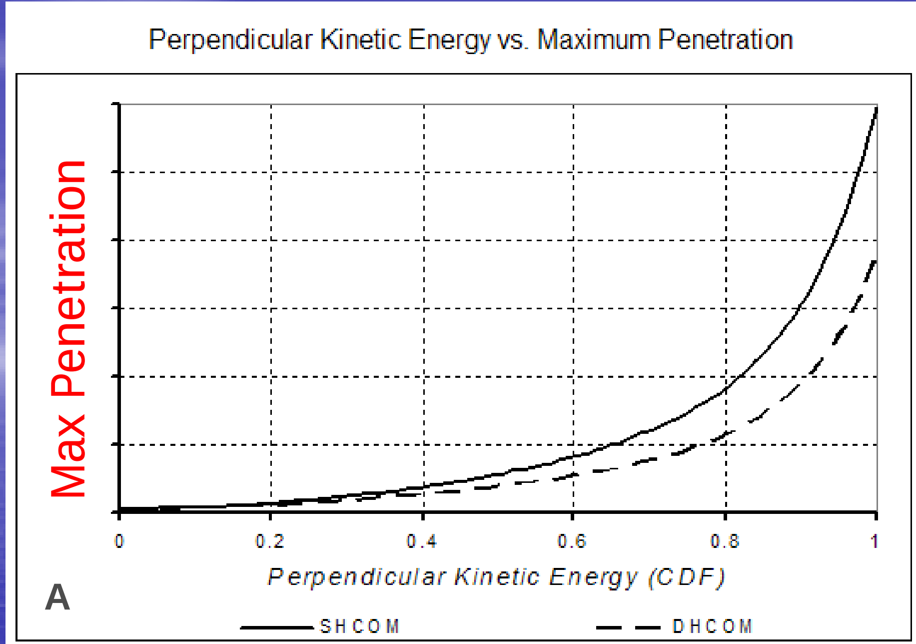
struck ship	**collision**	**striking ship**
-velocity -displacement -hull type	-location -angle	-velocity -displacement -bow angle

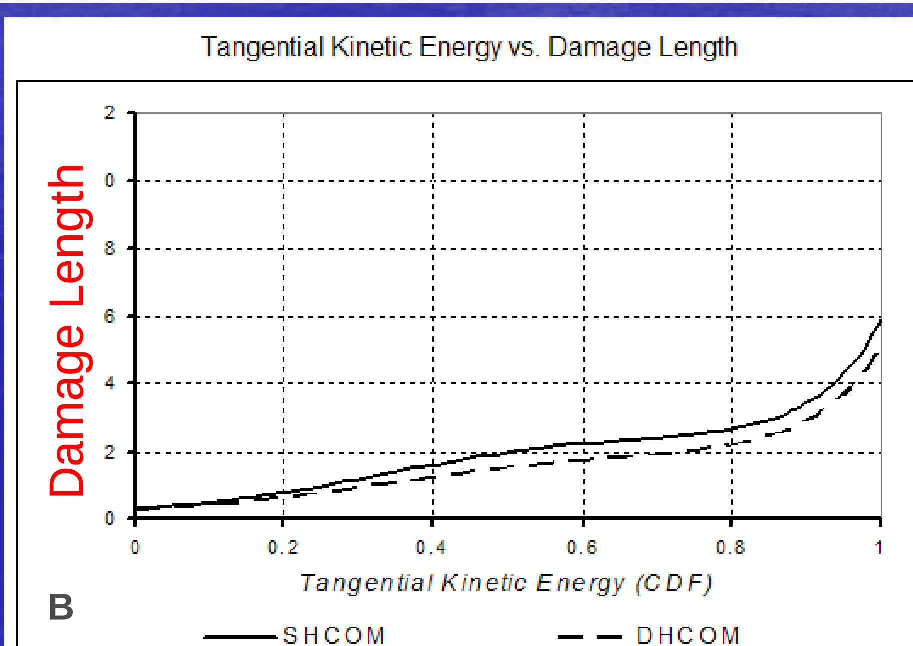


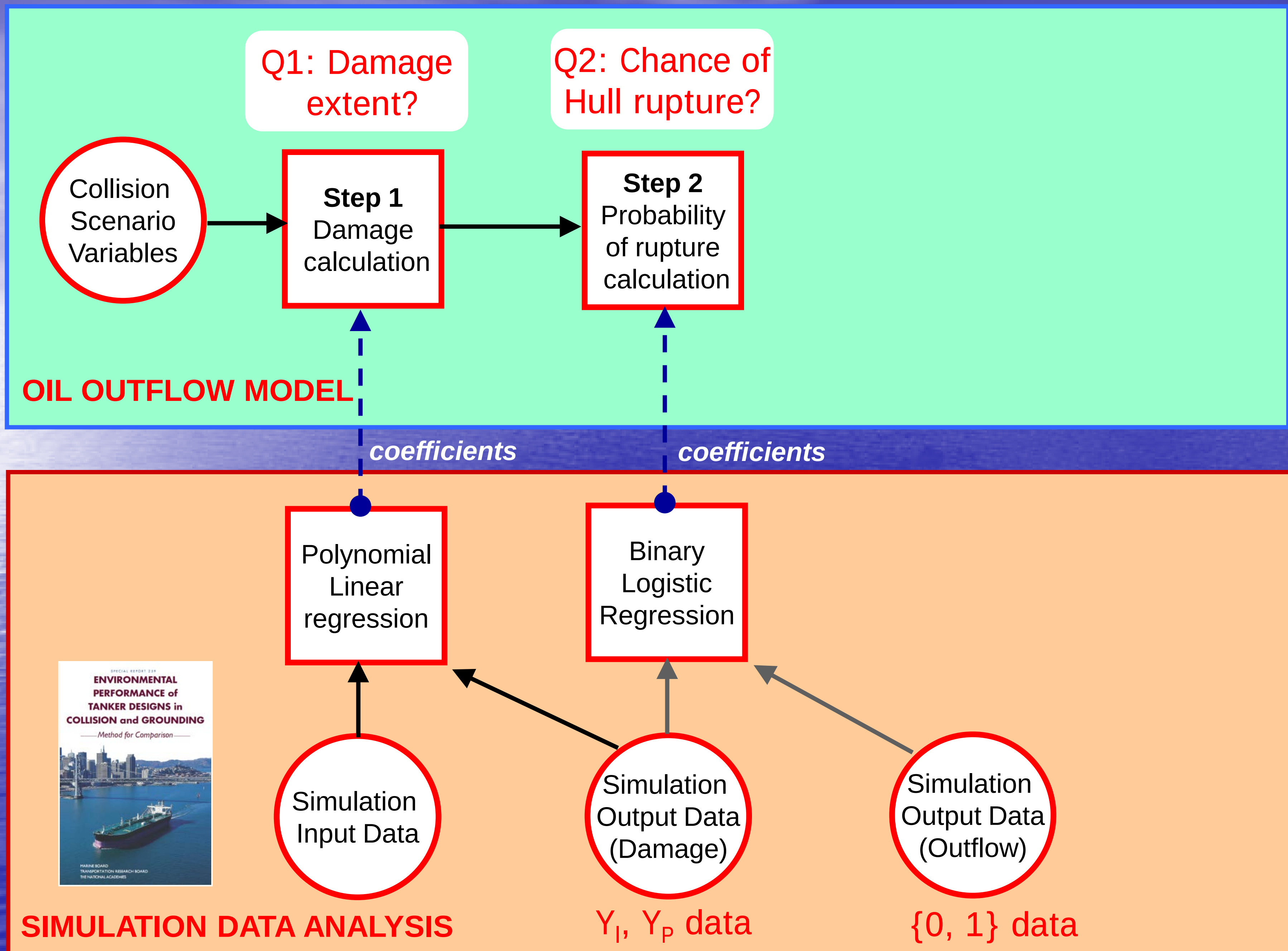
Step 1
Damage calculation

R^2 approx 70%

	SH40	SH150	SHCOM	DH40	DH150	DHCOM
number of data points	7467	7473	14940	7454	7466	14920
R^2-value	70.9%	68.1%	68.9%	71.5%	69.9%	70.6%
Mallows C_p-value	19.0	19.8	13.1	14.2	24.0	16.0
Coefficients						
β_0	-2.914	-2.661	-2.982	-2.931	-2.786	-2.632
$\beta_{1,1}$	3.078	-1.215	2.246	2.128	2.047	-0.117
$\beta_{2,1}$	5.550	5.303	5.231	6.180	4.692	4.670
$\beta_{3,1}$	0.031	-2.493	-3.369	0.708	-3.224	-1.973
$\beta_{4,1}$	0.546	1.613	1.188	0.655	1.429	1.155
$\beta_{5,1}$	-	-	0.223	-	-	0.052
$\beta_{1,2}$	-	10.181	0.687	0.598	-	5.792
$\beta_{2,2}$	-	-	-	-5.563	-	-
$\beta_{3,2}$	-	20.261	25.010	-	24.187	16.819
$\beta_{4,2}$	-	-0.931	-0.560	-	-0.784	-0.566
$\beta_{5,2}$	-	-	-	-	-	-
$\beta_{1,3}$	-	-8.145	-	-	-	-
$\beta_{2,3}$	-11.982	-6.405	-6.750	-	-5.410	-5.756
$\beta_{3,3}$	-	-68.750	-75.742	-13.309	-69.908	-53.668
$\beta_{4,3}$	-	-	-	-0.158	-	-
$\beta_{5,3}$	-	-	-	-	-	-
$\beta_{1,4}$	-2.924	-	-	-	-	-10.900
$\beta_{2,4}$	9.403	-	-	-	-	-
$\beta_{3,4}$	-	94.811	96.400	27.442	85.081	69.372
$\beta_{4,4}$	-	-	-	-	-	-
$\beta_{5,4}$	-	-	-	-	-	-
$\beta_{1,5}$	2.823	2.008	-	-	0.542	7.798
$\beta_{2,5}$	-	4.134	4.529	2.291	3.724	4.031
$\beta_{3,5}$	-0.480	-44.783	-43.224	-15.354	-36.872	-31.216
$\beta_{4,5}$	-	-	-	-	-	-
$\beta_{5,5}$	-	-	-	-	-	-



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Simulation Output Data (Outflow)
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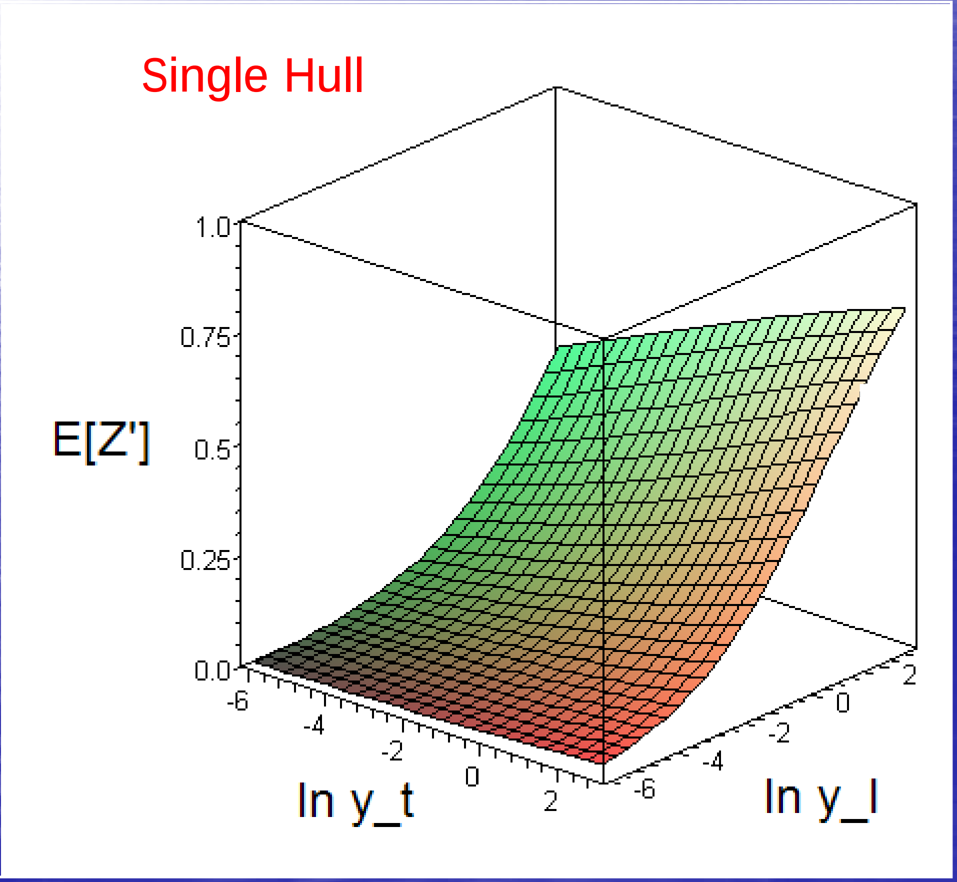
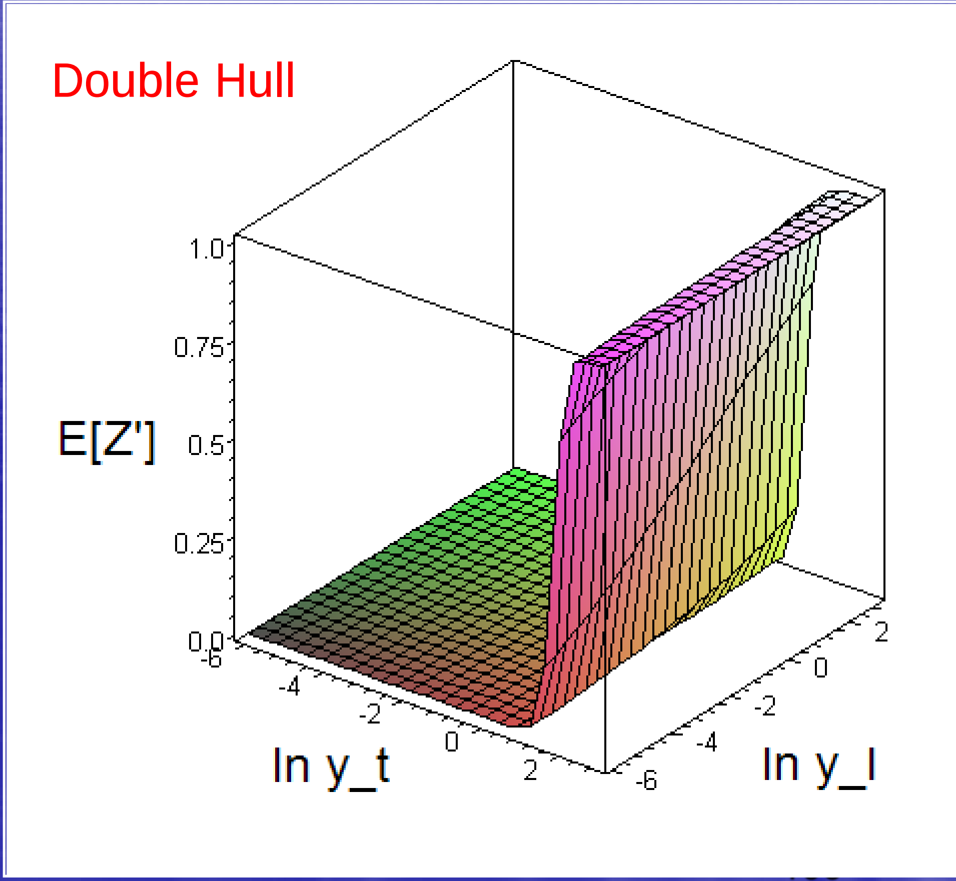
Y_I, Y_P data
{0, 1} data

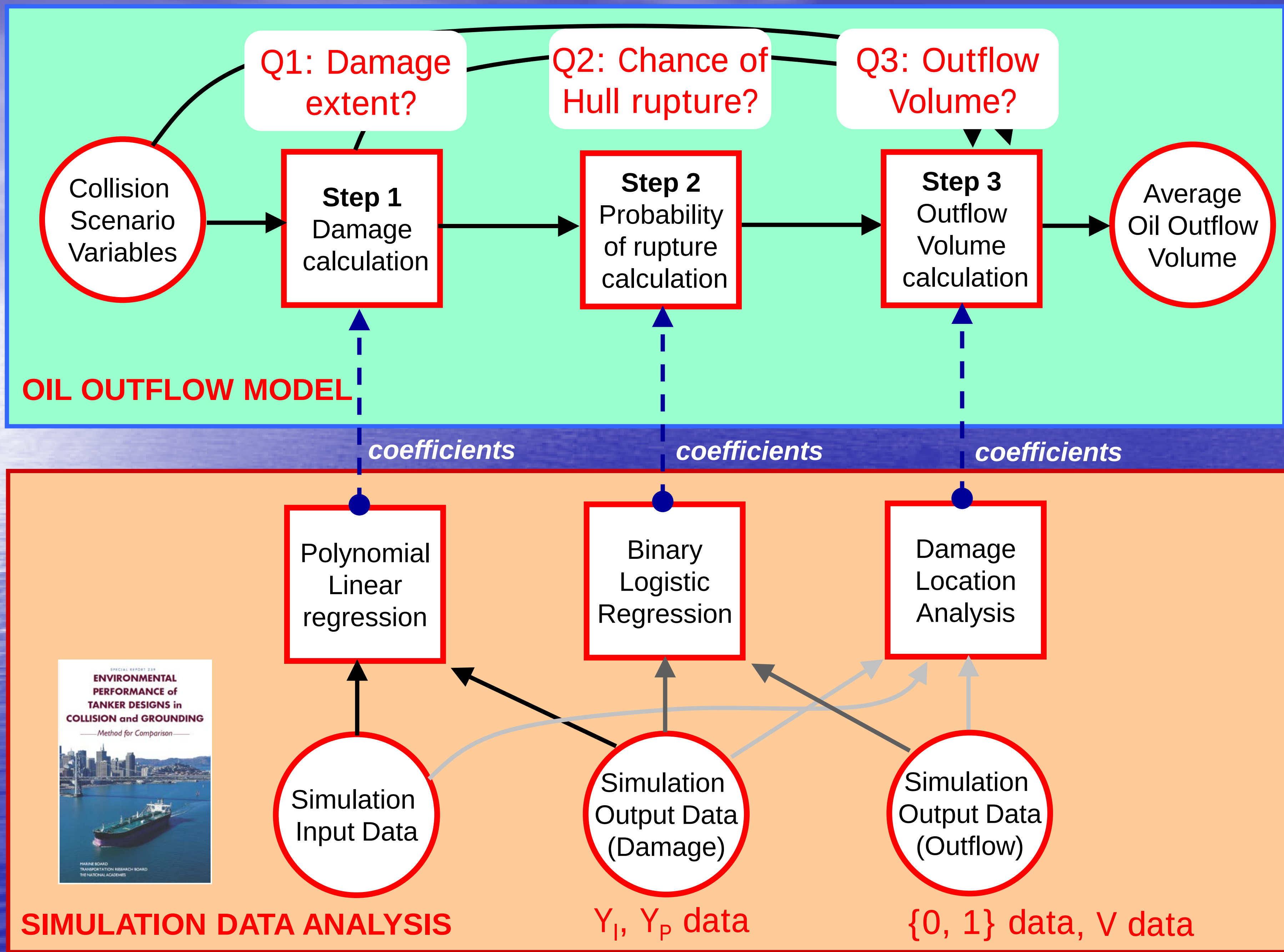
Step 2
Probability of rupture calculation

Gradual Function of both Longitudinal and Transversal Damage

Almost a Step Function in Transversal Damage only



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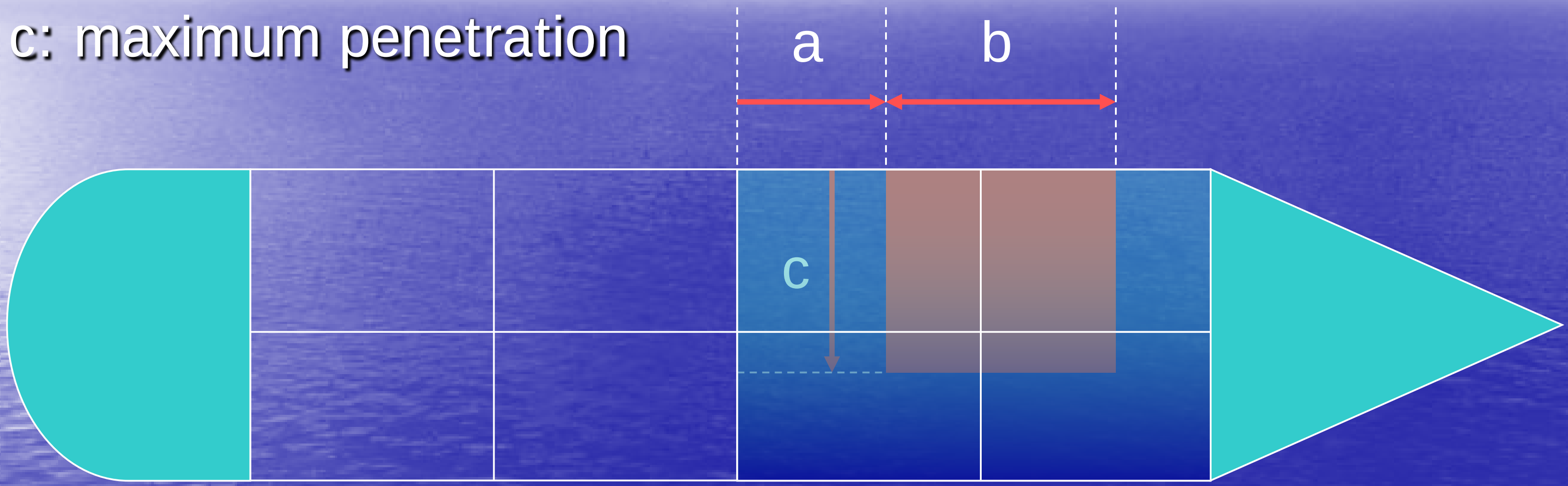
Y_I, Y_P data
{0, 1} data, V data

Outflow Volume (Collisions)

a: location from mid ship

b: damage length

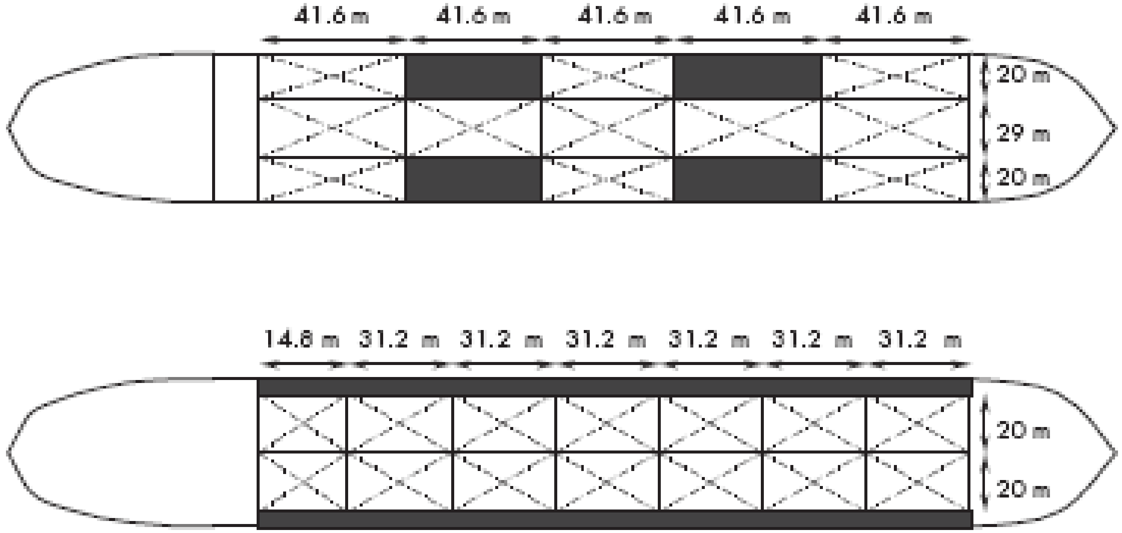
c: maximum penetration



Assumption 1: **worst case scenario:** damage area is a square

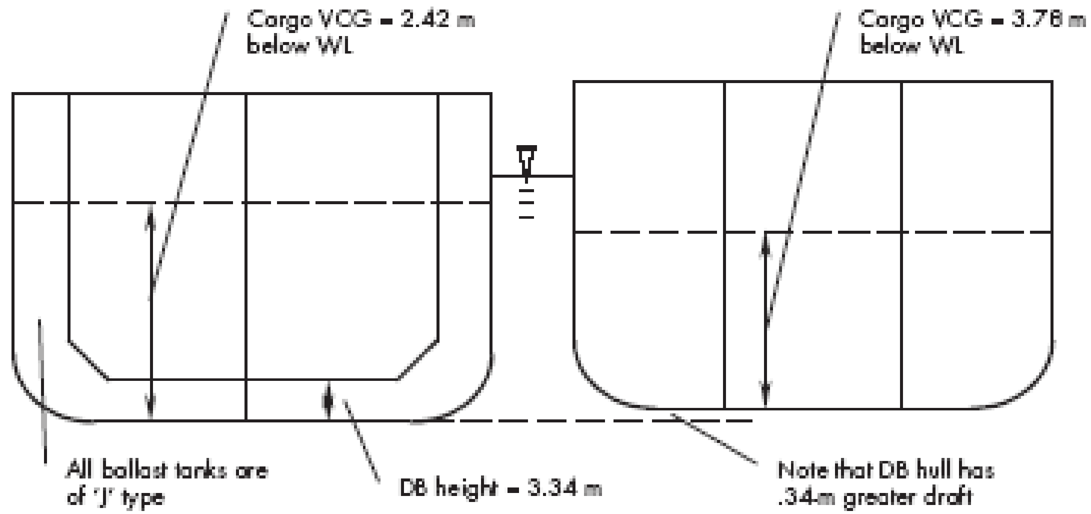
Assumption 2: **worst case assumption:** all oil from a penetrated compartment is lost

Tanker Configurations 150 kT



Single Hull

Double Hull

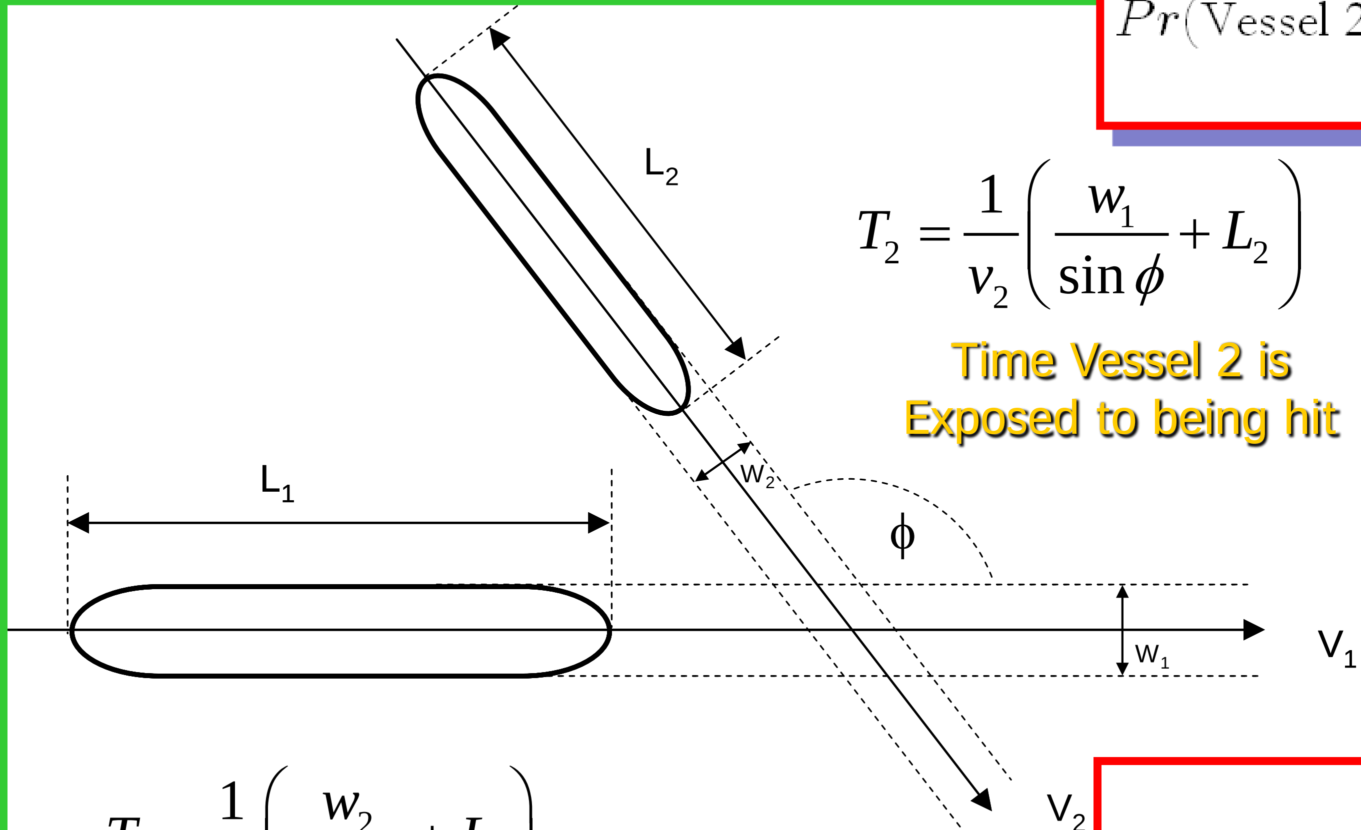


Taken From NRC 259 Report

Other Aspects of Oil Outflow model

Struck Probability Model

$$Pr(\text{Vessel 2 is struck}) = \frac{T_2}{T_1 + T_2}.$$



$$T_2 = \frac{1}{v_2}\left(\frac{w_1}{\sin\phi} + L_2\right)$$

Time Vessel 2 is Exposed to being hit

Vessel Size ↑

Struck Prob. ↑

Vessel Speed ↑

Struck Prob. ↓

$$T_1 = \frac{1}{v_1}\left(\frac{w_2}{\sin\phi} + L_1\right)$$

Time Vessel 1 is Exposed to being hit

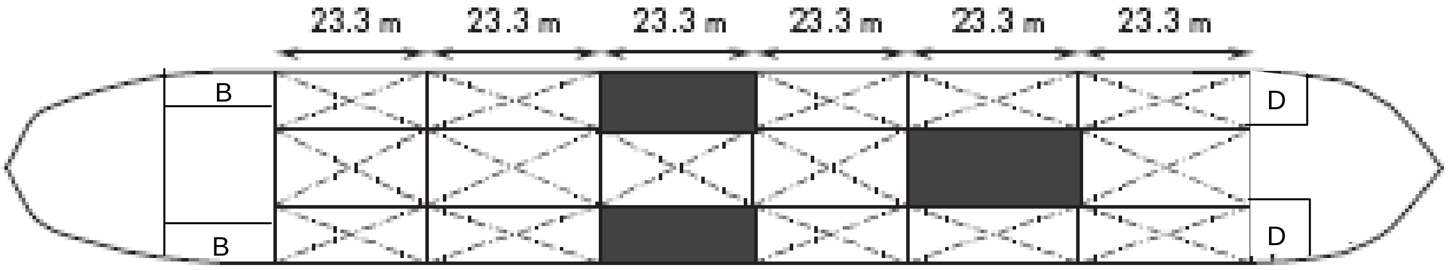
$$Pr(\text{Vessel 1 is struck}) = \frac{T_1}{T_1 + T_2}$$

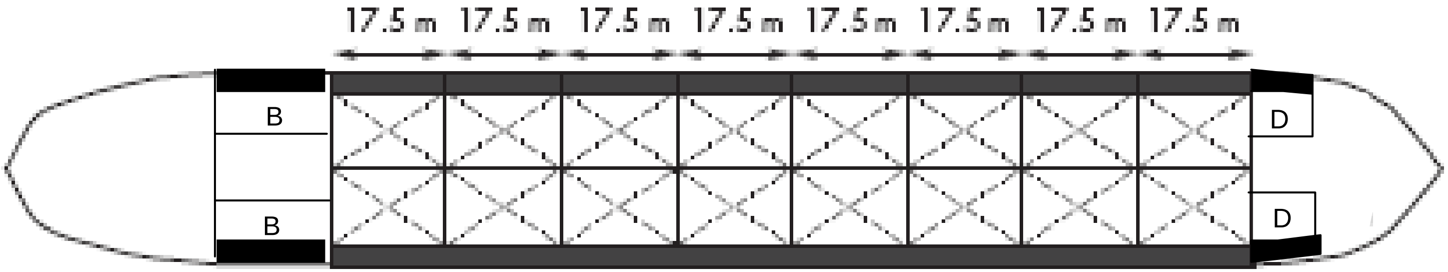
Other Aspects of Oil Outflow model

Fuel Losses of Tankers and other Deep Draft Vessels

Worst Case assumptions for locations of Bunker Fuel and Diesel Fuel

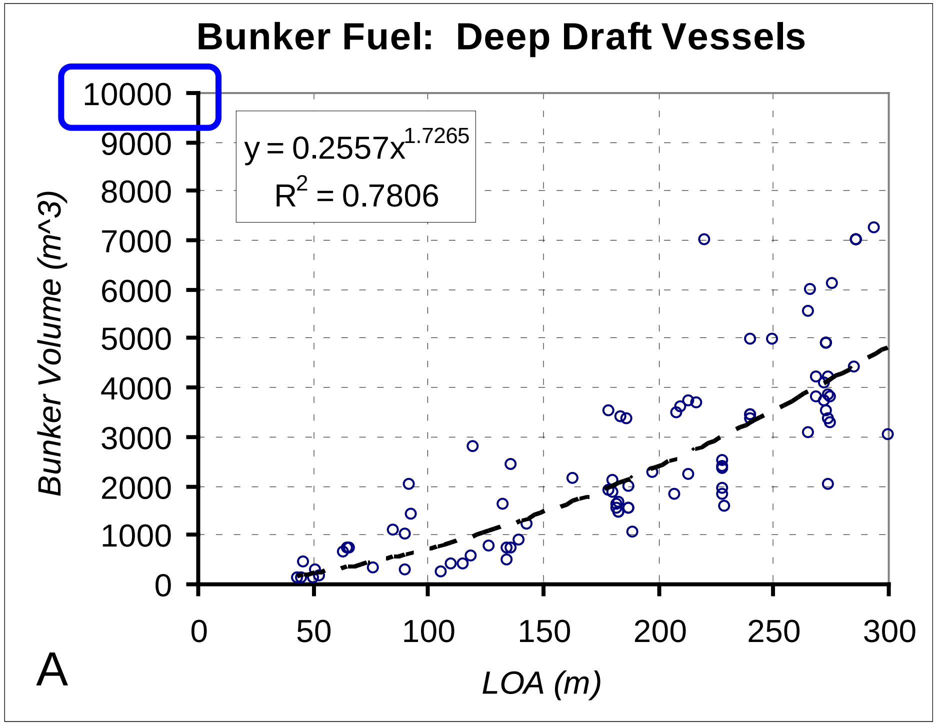
Tanker Configurations 40 kT

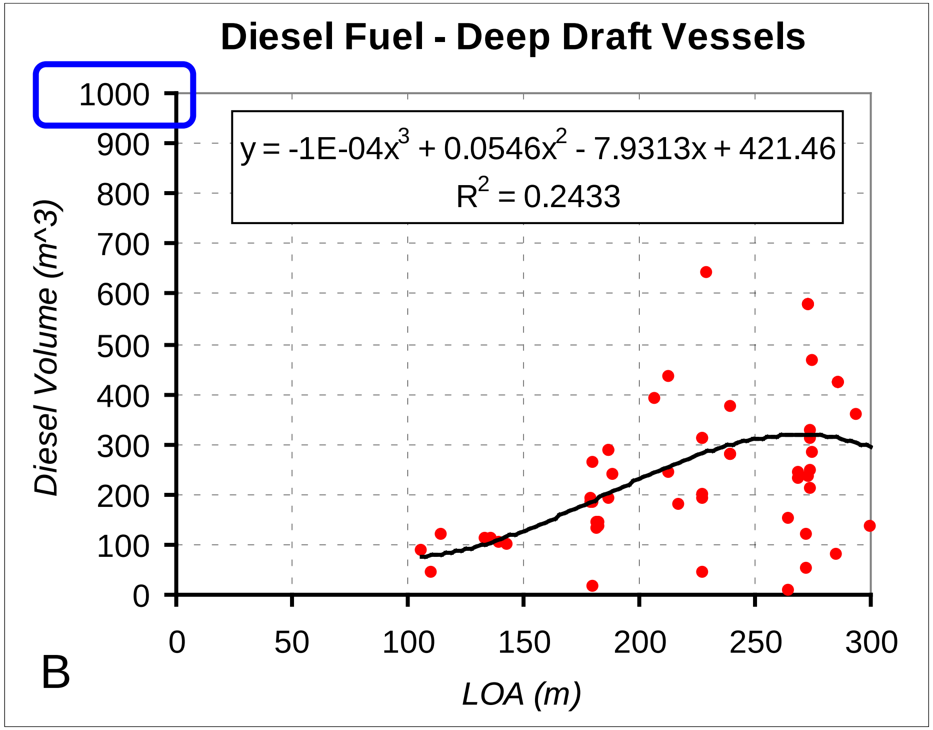




Other Aspects of Oil Outflow model

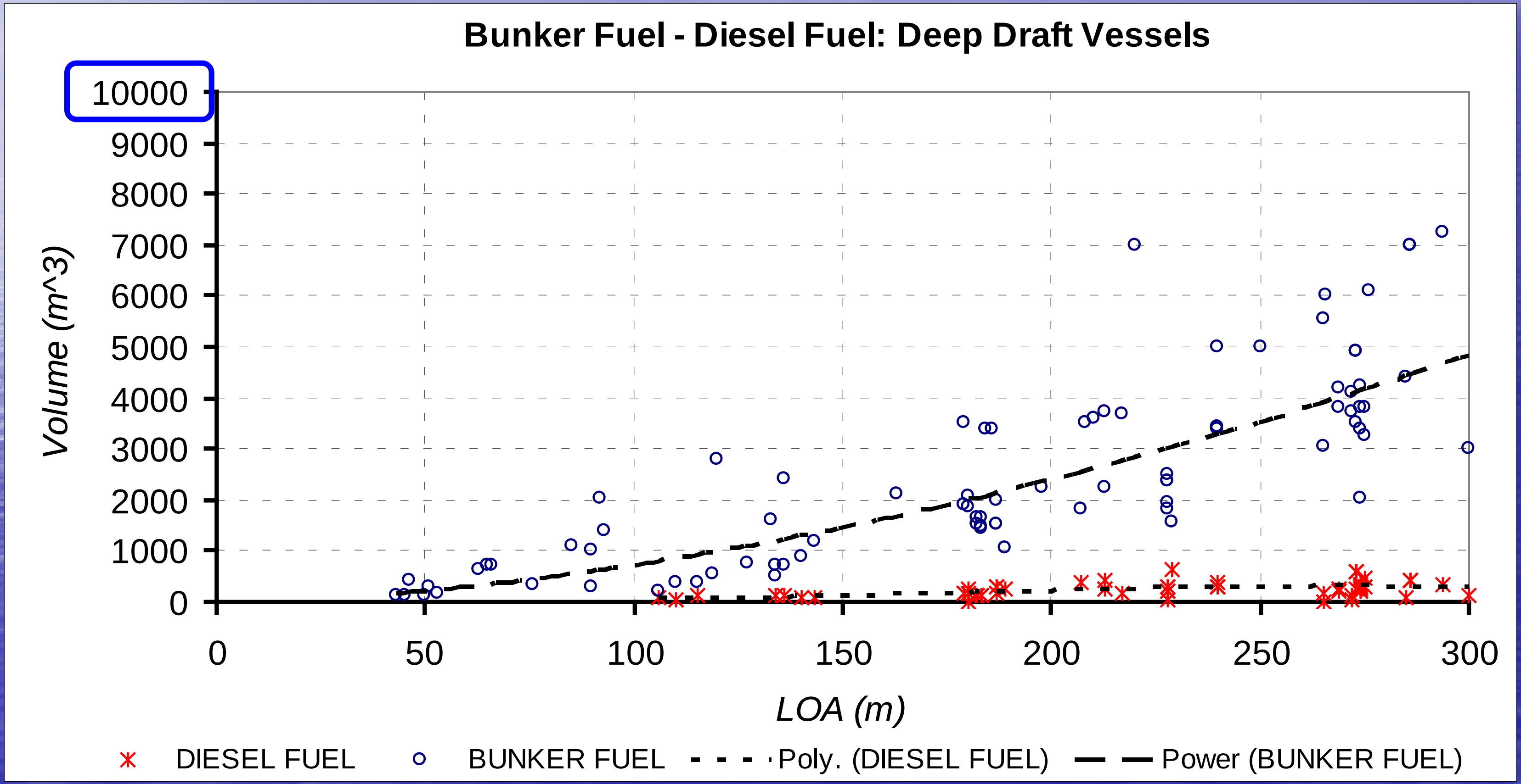
Fuel Losses of Tankers and other Deep Draft Vessels





Other Aspects of Oil Outflow model

Fuel Losses of Tankers and other Deep Draft Vessels



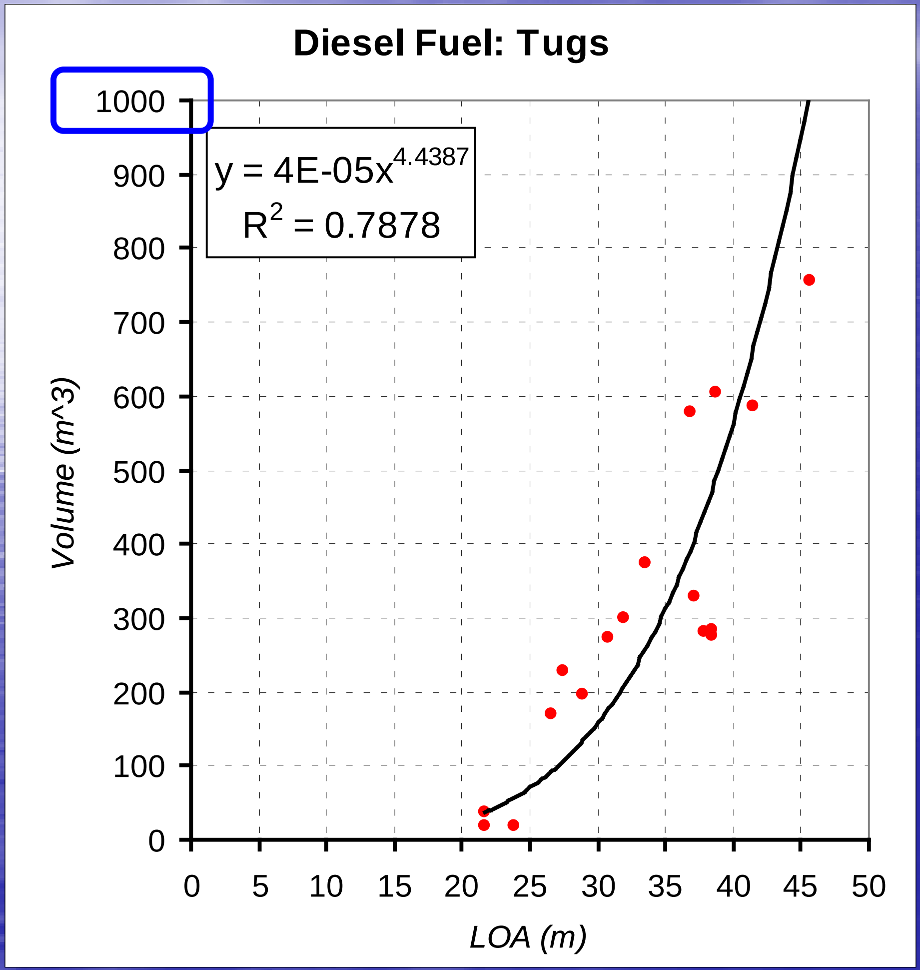
Other Aspects of Oil Outflow model

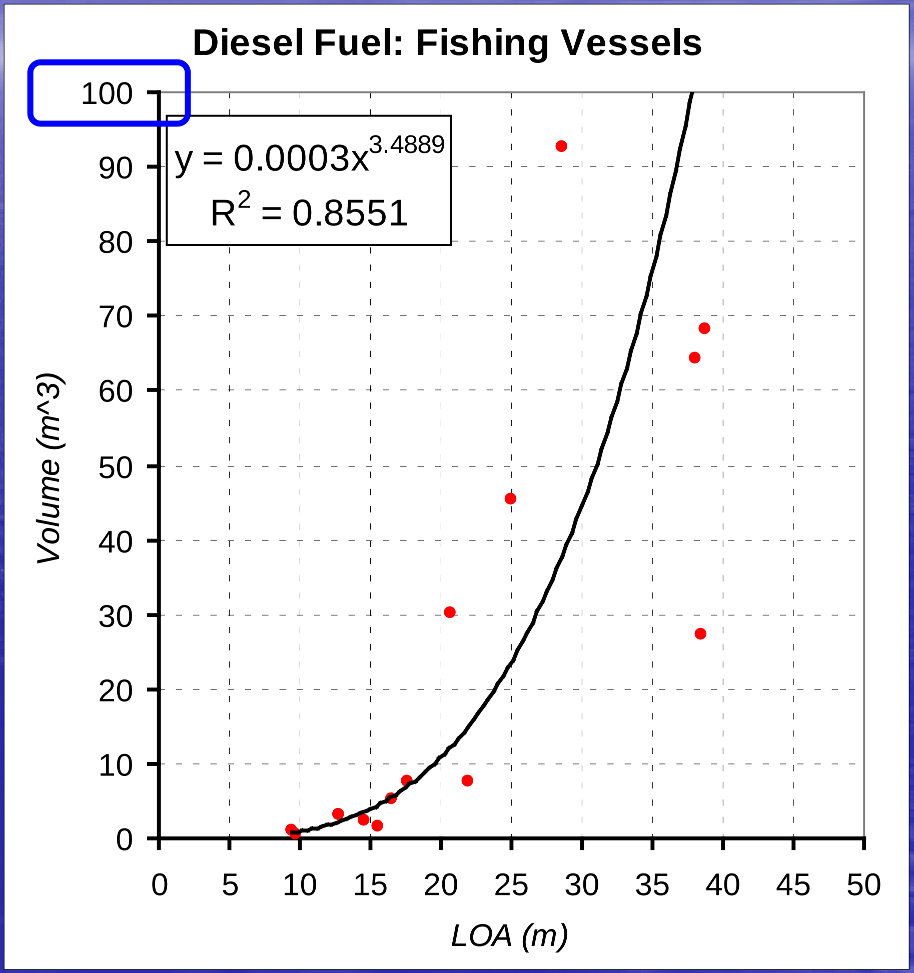
Fuel Losses of WSF Ferries and like Ferries

WSF Ferry	Class	Total Fuel Capacity (in Gallons)	Number of Fuel Tanks	Location Fuel Tank (Mid-Ship, Starboard, Port)	Approximate length Fuel Tank	Approximate width Fuel Tank
Puyallup	Jumbo Mark II	110385	2	#1 Centerline #2 Centerline	37	30
Tacome	Jumbo Mark II	110385	2	#1 Centerline #2 Centerline	37	30
Wenatchee	Jumbo Mark II	110385	2	#1 Centerline #2 Centerline	37	30
Spokane	Jumbo	125000	2	#1 Centerline #2 Centerline	40	35
Walla Walla	Jumbo	125000	2	#1 Centerline #2 Centerline	40	35
Elwha	Super	62372	3	Port Center STB (MID)	27	24
Hyak	Super	77683	3	Port Center STB (MID)	27	24
Kaleetan	Super	77683	3	Port Center STB (MID)	27	24
Yakima	Super	77683	3	Port Center STB (MID)	27	24
Cathlamet	Issaquah 130	115400	4	Wing Port, Deep Port Deep STB Wing STB (MID)	1&4 -- 13'6" 2&3 -- 27'	#2&3 fuel oil tks. 22'-6"W, 1&4 fuel oil tks.14'-0"W
Chelan	Issaquah 130	115400	4	Wing Port, Deep Port Deep STB Wing STB (MID)	1&4 -- 13'6" 2&3 -- 27'	#2&3 fuel oil tks. 22'-6"W, 1&4 fuel oil tks.14'-0"W
Issaquah	Issaquah 130	115400	4	Wing Port, Deep Port Deep STB Wing STB (MID)	1&4 -- 13'6" 2&3 -- 27'	#2&3 fuel oil tks. 22'-6"W, 1&4 fuel oil tks.14'-0"W
Kitsap	Issaquah 130	115400	4	Wing Port, Deep Port Deep STB Wing STB (MID)	1&4 -- 13'6" 2&3 -- 27'	#2&3 fuel oil tks. 22'-6"W, 1&4 fuel oil tks.14'-0"W
Kittitas	Issaquah 130	115400	4	Wing Port, Deep Port Deep STB Wing STB (MID)	1&4 -- 13'6" 2&3 -- 27'	#2&3 fuel oil tks. 22'-6"W, 1&4 fuel oil tks.14'-0"W
Sealth	Issaquah 100	115400	4	Wing Port, Deep Port Deep STB Wing STB (MID)	1&4 -- 13'6" 2&3 -- 27'	#2&3 fuel oil tks. 22'-6"W, 1&4 fuel oil tks.14'-0"W
Evergreen State	Evergreen	30600	2	Port STB (MID)	13.5	14
Klahowya	Evergreen	30600	2	Port STB (MID)	13.5	14
Tillikum	Evergreen	30600	2	Port STB (MID)	13.5	14
Illahee	Steel Electric	9000	2	Port STB (MID)	12	6' Diameter
Klickitat	Steel Electric	9000	2	Port STB (MID)	12	6' Diameter
Nisqually	Steel Electric	9000	2	Port STB (MID)	12	6' Diameter
Quinault	Steel Electric	9000	2	Port STB (MID)	12	6' Diameter
Rhodondendron	Rhodondendron	11397	2	Center Line #1 end #2 end	20	12'
Hiyu	Hiyu	10000	2	Port STB #1 end	12'	NA
Kalama	POV	6714	2	Port STB (MID)	6	6
Skagit	POV	6714	2	Port STB (MID)	6	6

Other Aspects of Oil Outflow model

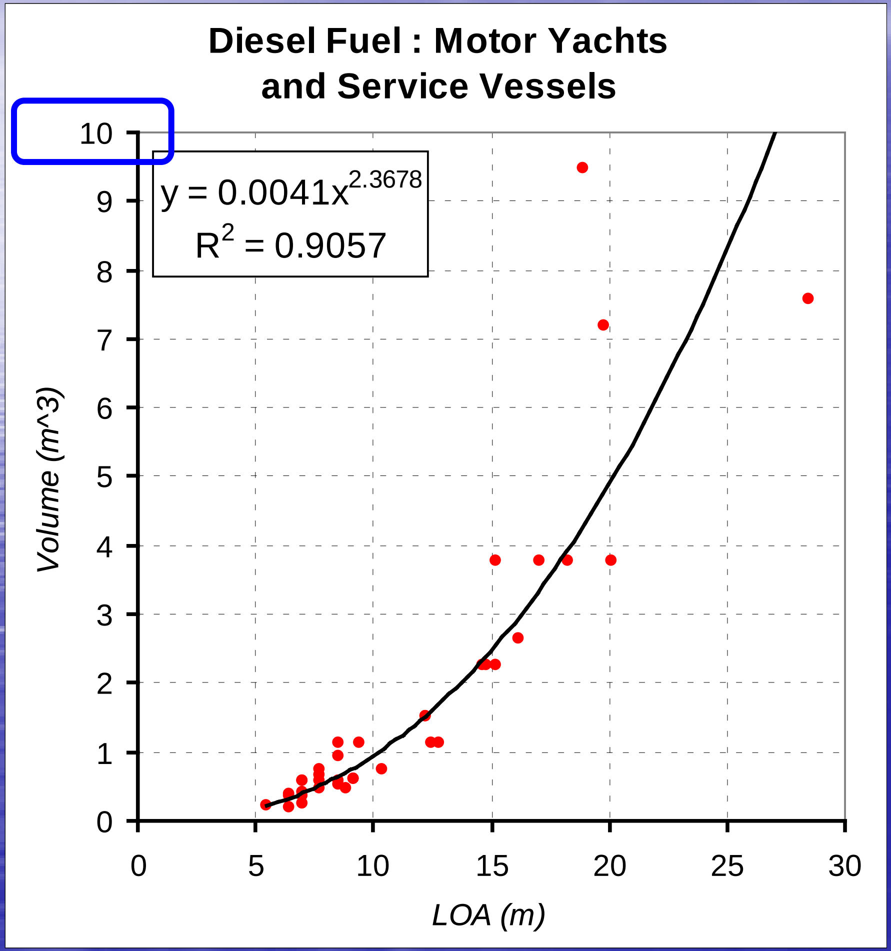
Fuel Losses of Other Interacting Vessels

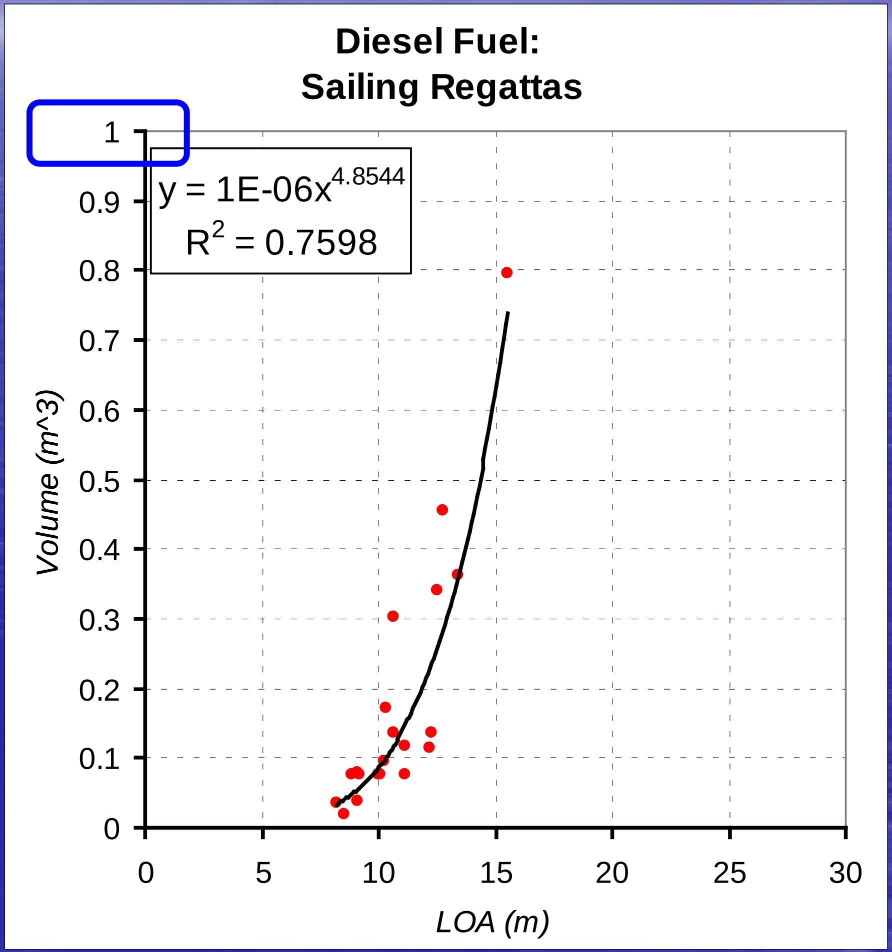




Other Aspects of Oil Outflow model

Fuel Losses of Other Interacting Vessels





Oil Outflow Categories

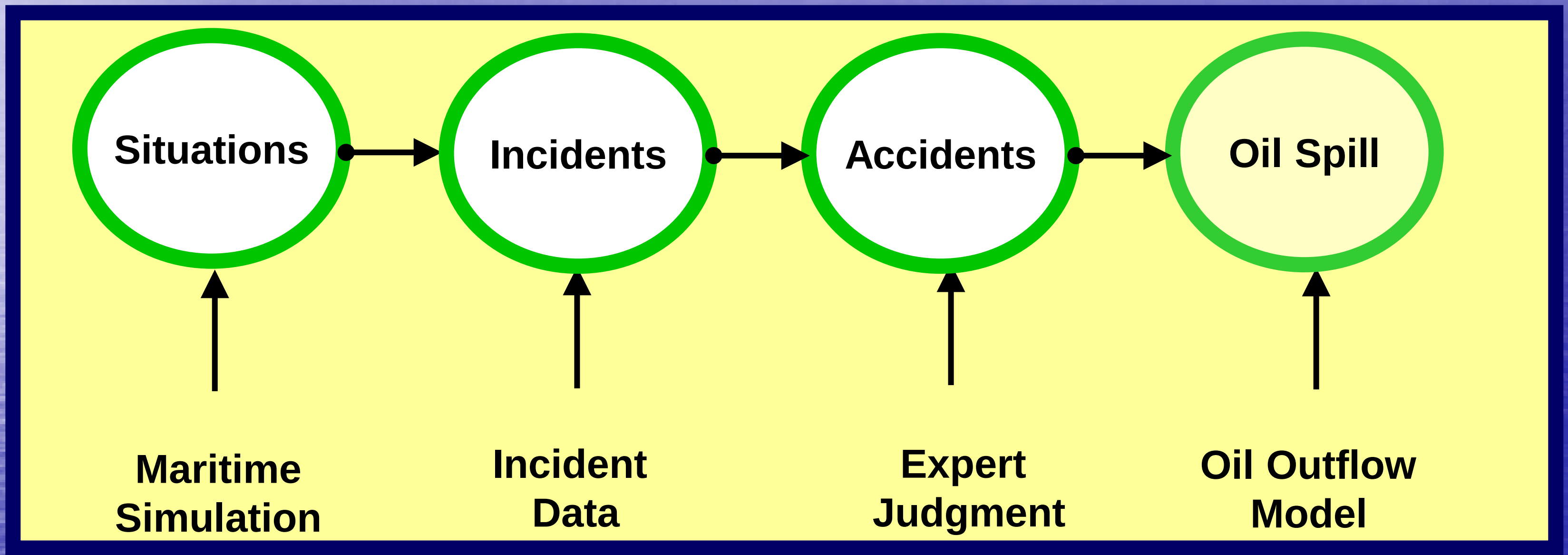
- **Vessel of Interest - Persistent Oil: VOI - PO**
  (Crude and Bunker Fuel) – Tanker, ATB, ITB

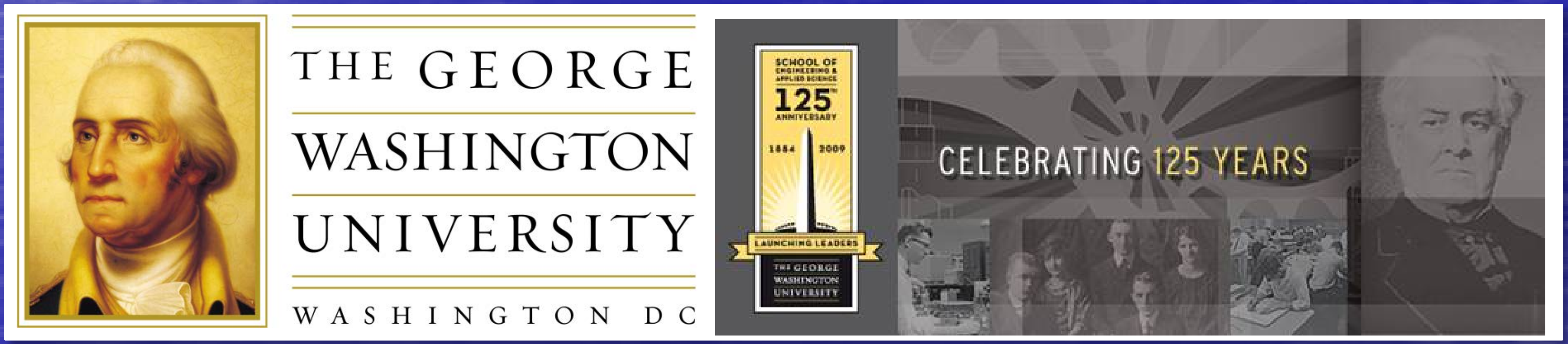
- **Vessel of Interest – Non Persistent Oil: VOI - NPO**
  (Product and Diesel Fuel) – Tanker, ATB, ITB

- **Interacting Vessel - Persistent Oil: IV - PO**
  (Crude and Bunker Fuel) – Colliding Vessels

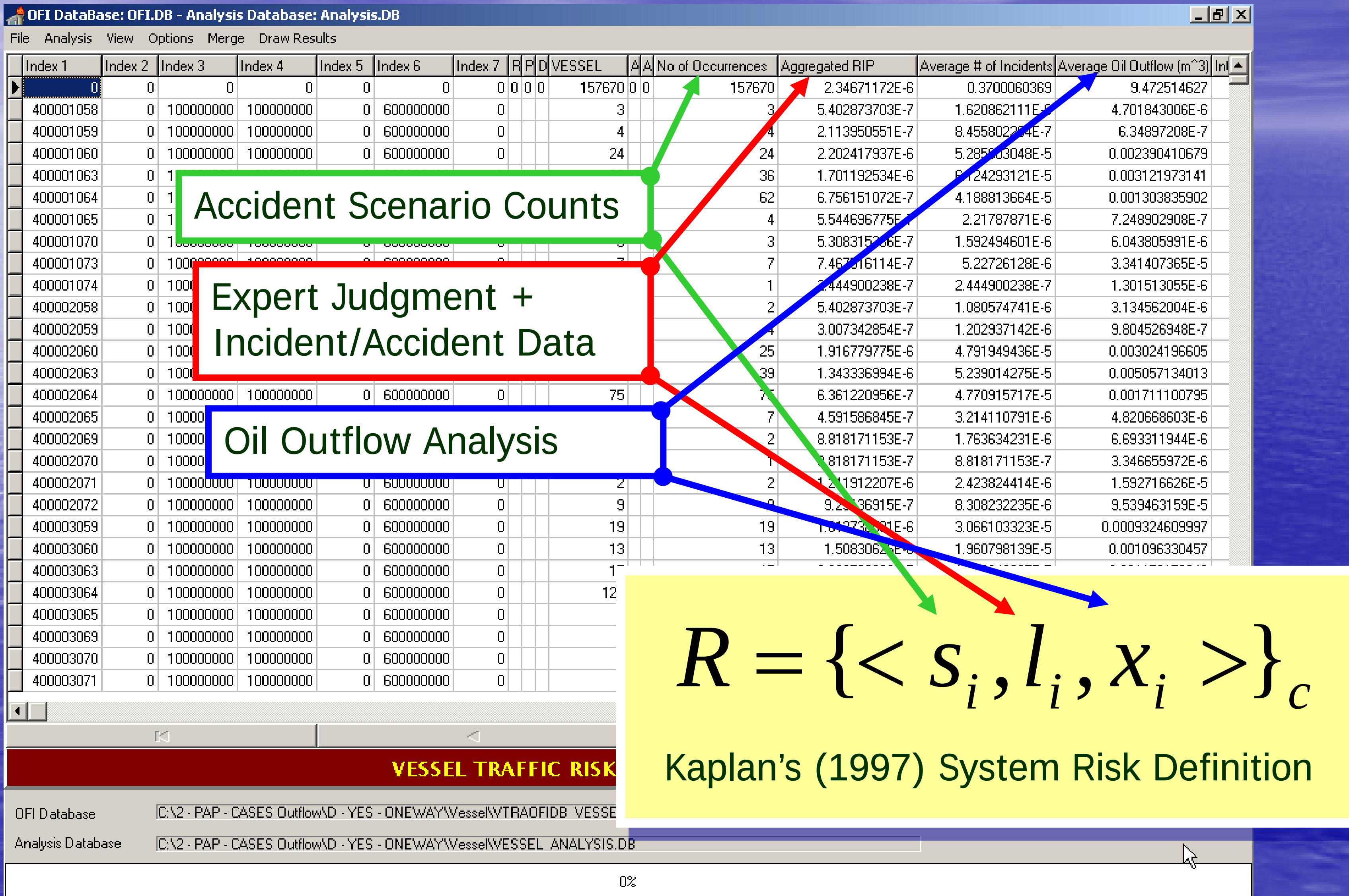
- **Interacting Vessel – Non Persistent Oil: IV - NPO**
  (Product and Diesel Fuel) – Colliding Vessels

Step 4: Integrate Previous 3 Steps





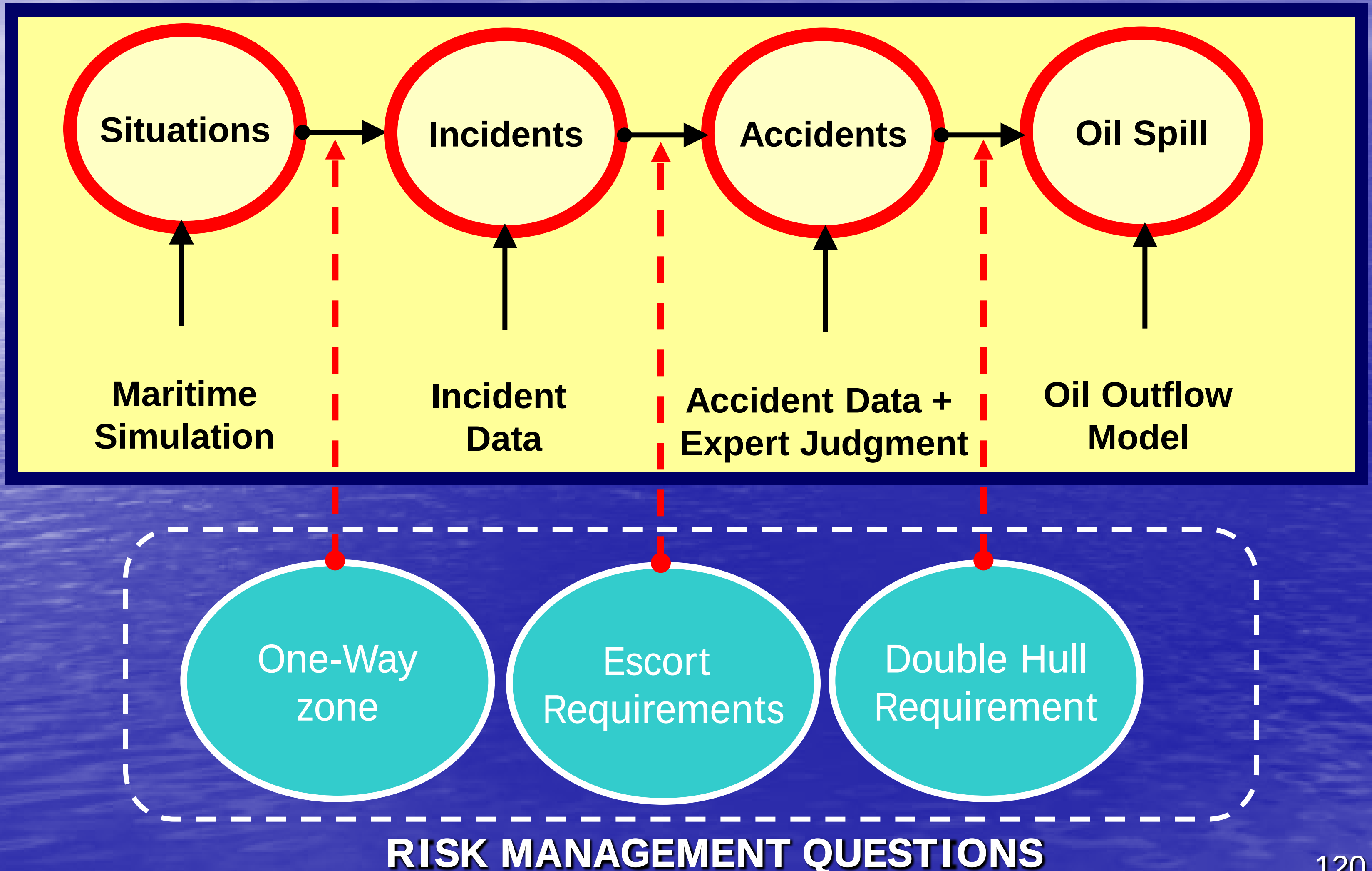
Develop Post-Processing Analysis Engine that integrates:



$$R = \{< s_i, l_i, x_i >\}_c$$

Kaplan's (1997) System Risk Definition

Example Risk Management Effectiveness Analysis



Description of Case Study

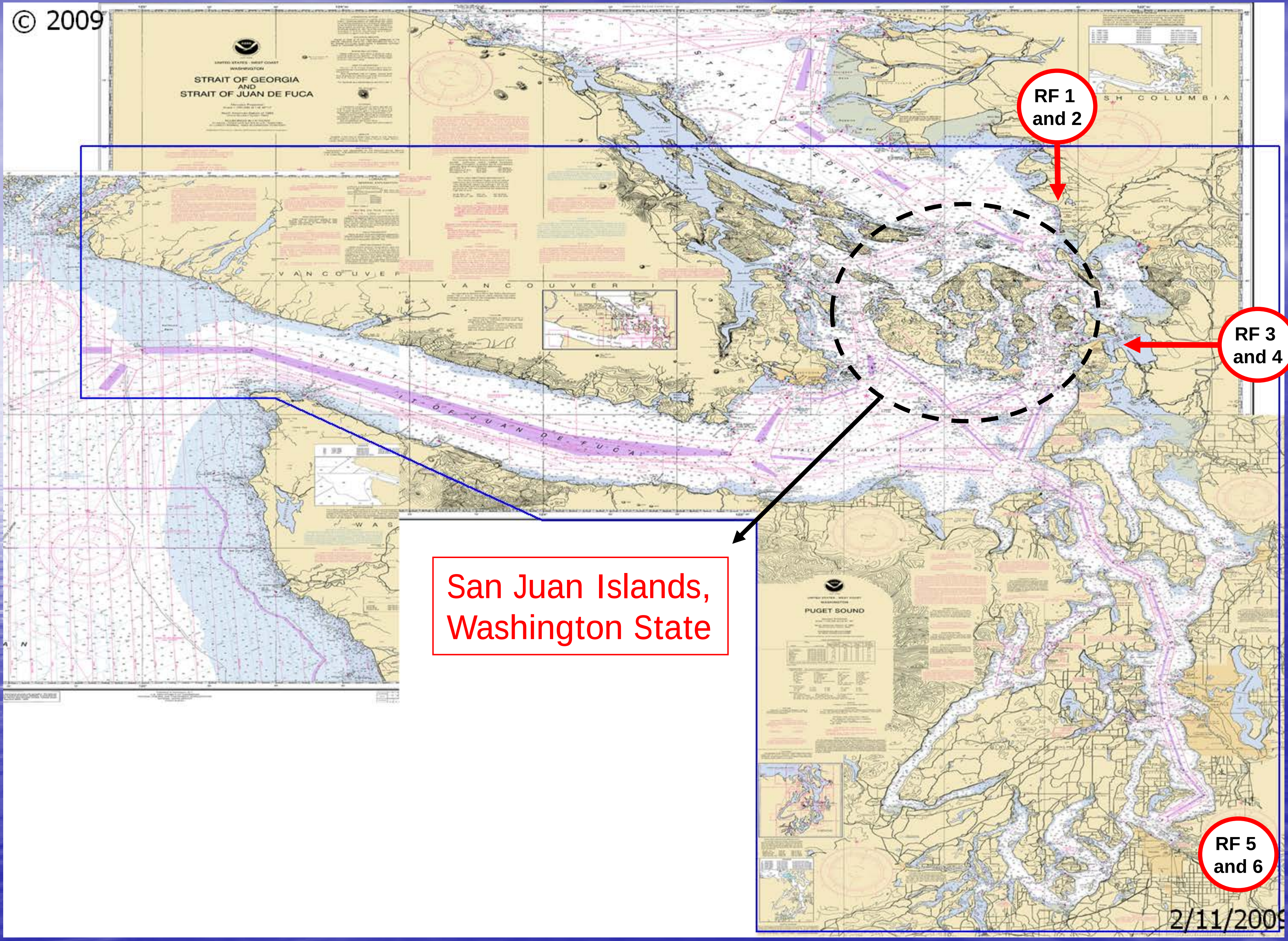
- The analysis results herein evaluate the effectiveness of the three risk intervention measures on the previous slide by considering four scenarios of an MTS simulation of the geographic area within the bleu border on the next slide.
- The vessels of interest (VOI's) are tankers, articulated tug barges and integrated tug barges serving six refineries within this geographic area. The approximate locations of these refineries are identified on the next slide. (One of them in the south operates only as a petroleum tank farm since 1998).
- The four scenarios in question are fictitious scenarios that look back in time, not into the future.

SCENARIO 1: Two-way traffic in Rosario Strait, No Escorting and all VOI's have a single hull.

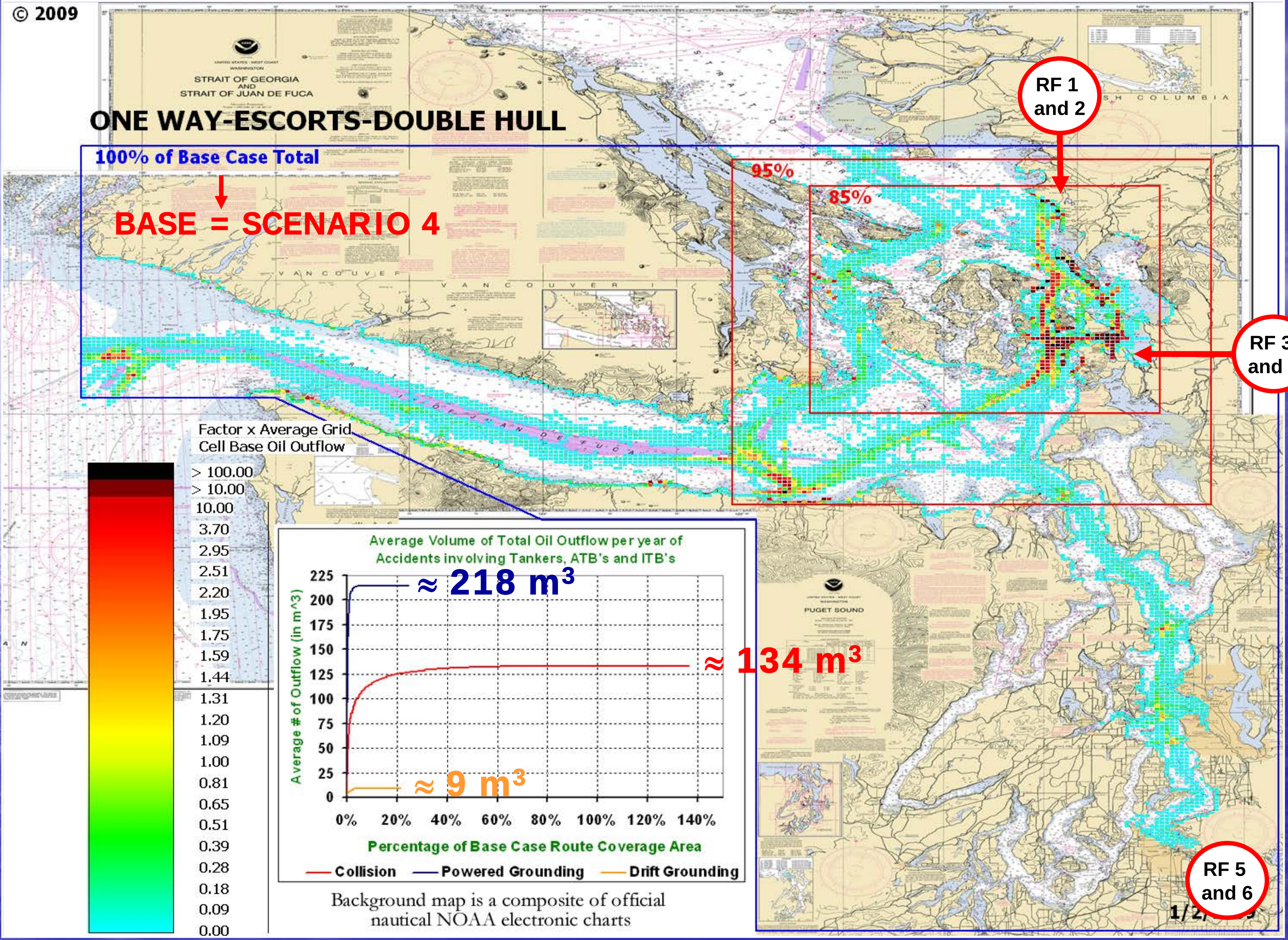
SCENARIO 2: One-way traffic in Rosario Strait, No Escorting and all VOI's have a single hull.

SCENARIO 3: One-way traffic in Rosario Strait, Escorting Scheme that mimics current regime in study area and all VOI's have a single hull.

SCENARIO 4: One-way traffic in Rosario Strait, Escorting Scheme that mimics current regime in study area and all VOI's have a double hull.



© 2009
STRAIT OF GEORGIA AND STRAIT OF JUAN DE FUCA
RF 1 and 2
RF 3 and 4
RF 5 and 6
STRAIT OF GEORGIA
STRAIT OF JUAN DE FUCA
VANCOUVER
PUGET SOUND
San Juan Islands, Washington State
2/11/2009



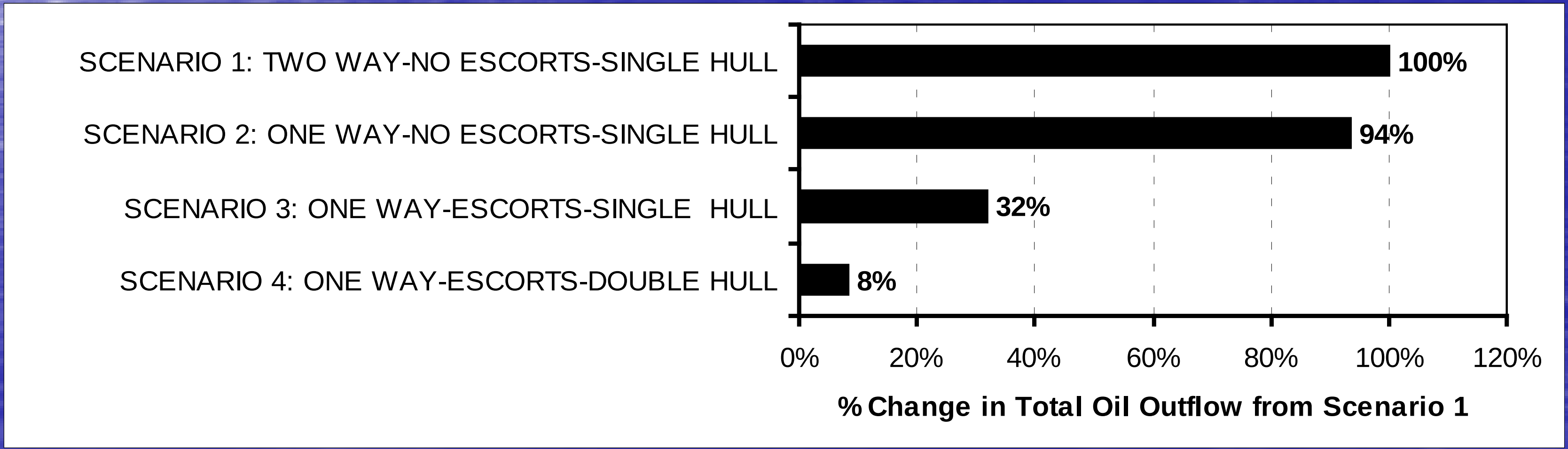
OIL OUTFLOW GEOGRAPHIC PROFILE SCENARIO 4
ALL THREE RISK INTERVENTION IN PLACE

Average Annual Oil Outflow (m^3) by Scenario	Total Outflow
SCENARIO 1: TWO WAY-NO ESCORTS-SINGLE HULL	4300.63
SCENARIO 2: ONE WAY-NO ESCORTS-SINGLE HULL	4027.72
SCENARIO 3: ONE WAY-ESCORTS-SINGLE HULL	1376.81
SCENARIO 4: ONE WAY-ESCORTS-DOUBLE HULL	360.96

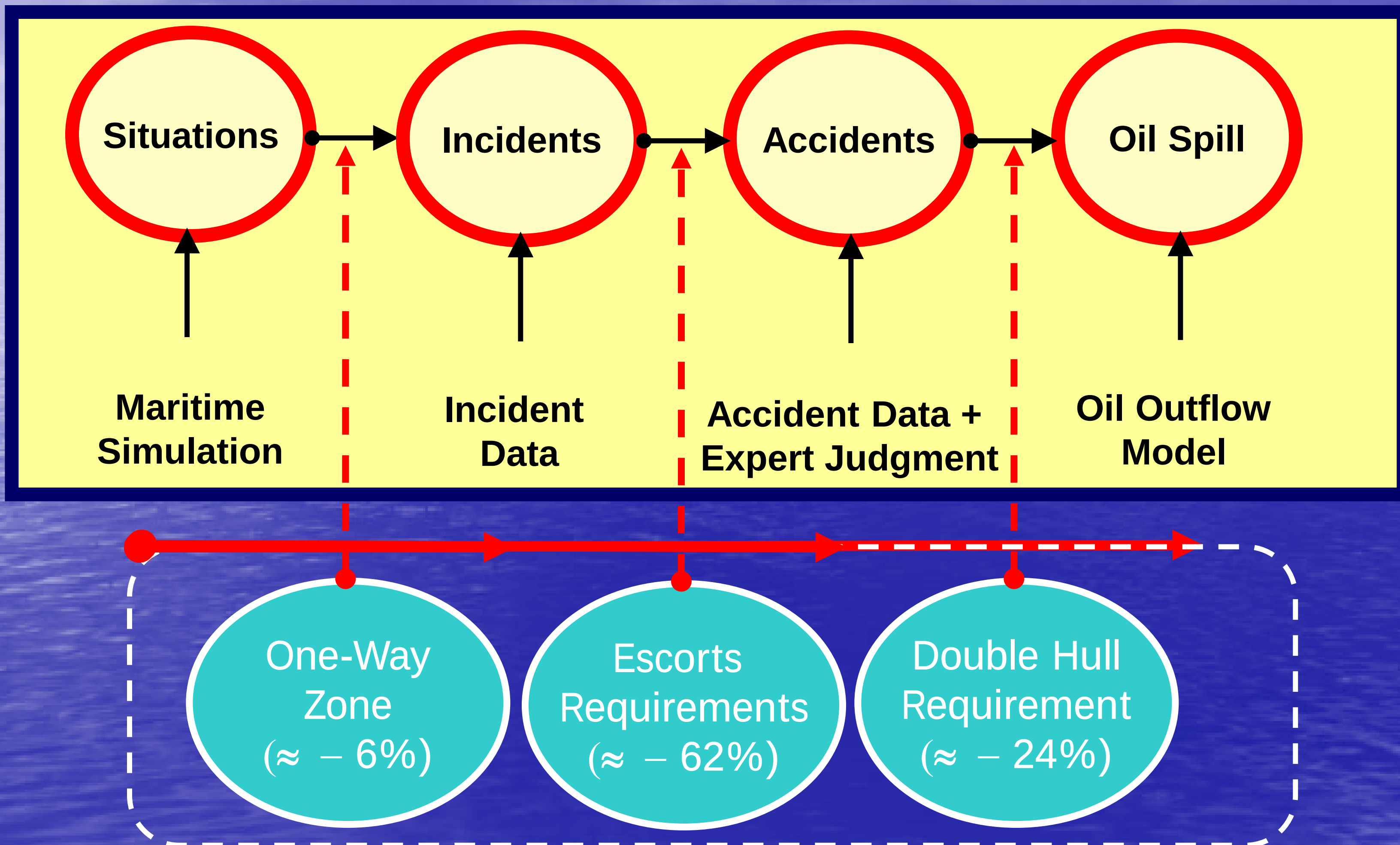
Percentage Change in Oil Outflow (m^3) from Scenario 1	Total Outflow
SCENARIO 1: TWO WAY-NO ESCORTS-SINGLE HULL	100.0%
SCENARIO 2: ONE WAY-NO ESCORTS-SINGLE HULL	93.7%
SCENARIO 3: ONE WAY-ESCORTS-SINGLE HULL	32.0%
SCENARIO 4: ONE WAY-ESCORTS-DOUBLE HULL	8.4%

≈ – 6%
≈ – 62%
≈ – 24%
≈ – 92%

Percentage Change in Oil Outflow (m^3) from Scenario 4	Total Outflow
SCENARIO 1: TWO WAY-NO ESCORTS-SINGLE HULL	1191.4%
SCENARIO 2: ONE WAY-NO ESCORTS-SINGLE HULL	1115.8%
SCENARIO 3: ONE WAY-ESCORTS-SINGLE HULL	381.4%
SCENARIO 4: ONE WAY-ESCORTS-DOUBLE HULL	100.0%



An Oil Spill is a series of cascading events referred to as a Causal Chain



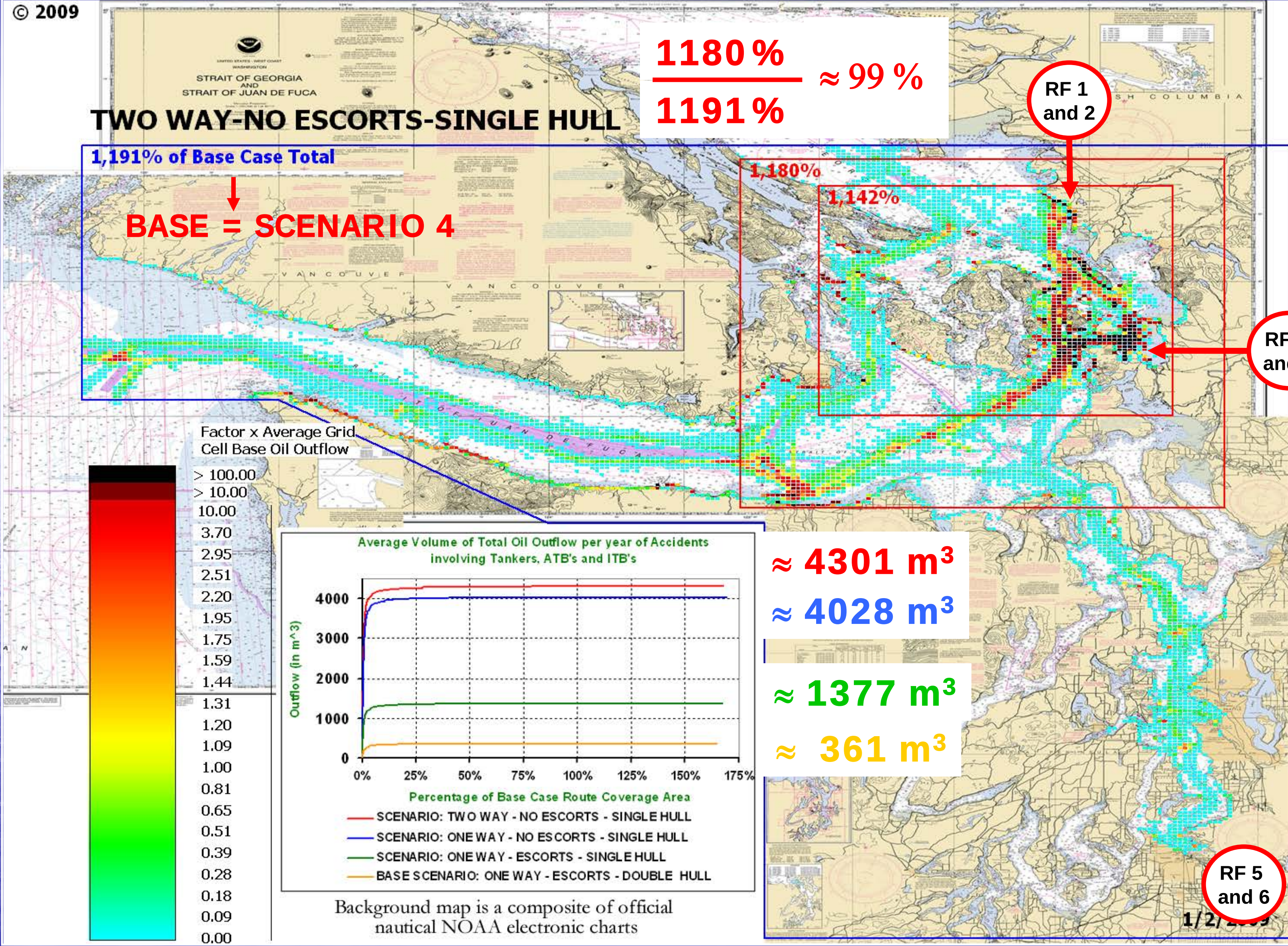
OVERALL A ≈ 92% RISK REDUCTION FROM SCENARIO 1

Oil Spill Reduction from Single Hull to Double Hull Scenario

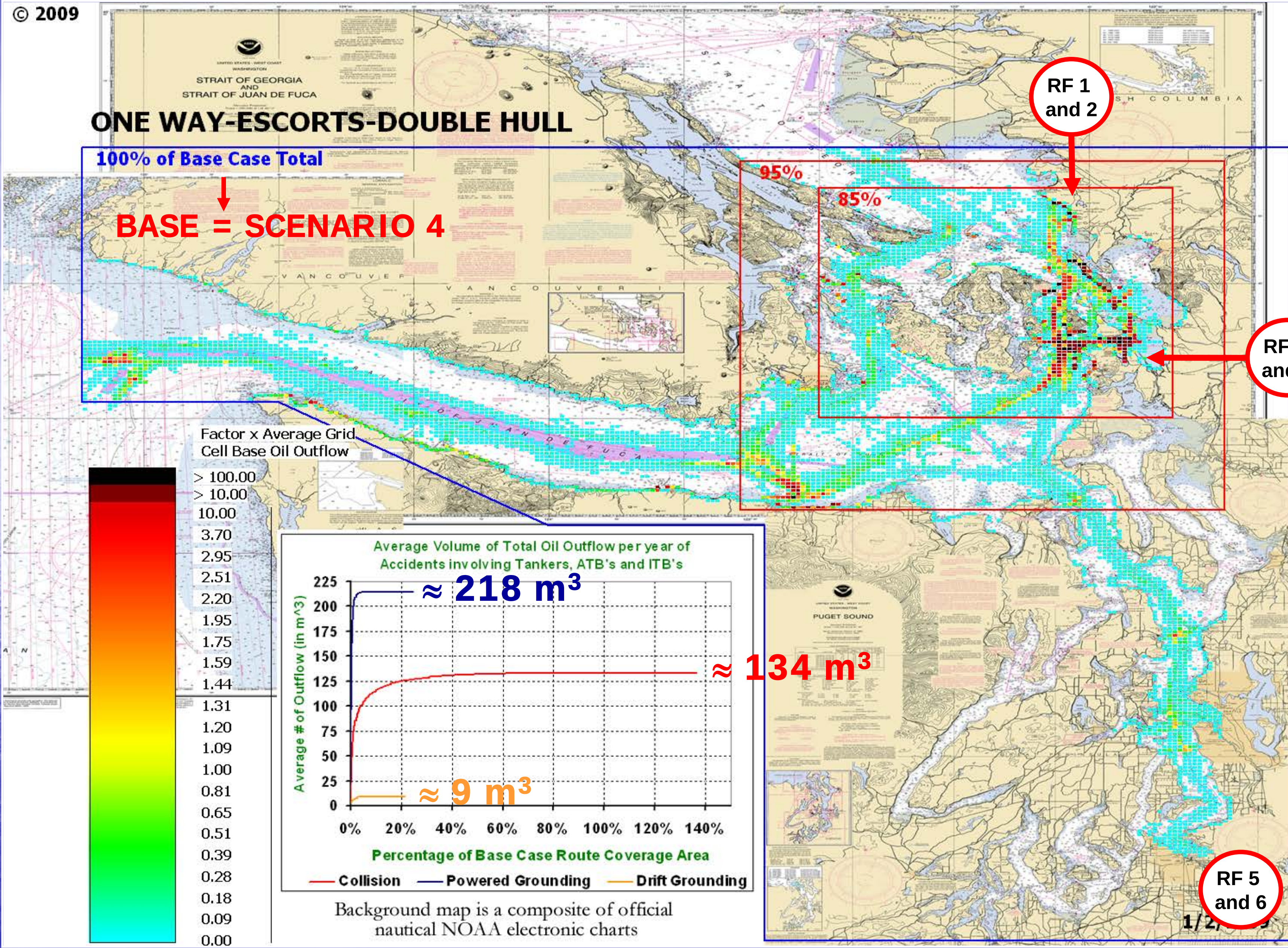
SINGLE HULL (in m^3)	VOI PO	VOI NPO	IV PO	IV NPO	Total Outflow	% Outflow
Collisions	222.7	24.8	2.1	9.5	259.0	18.8%
Groundings	1042.3	75.4			1117.8	81.2%
Total Outflow	1265.1	100.2			1376.8	100.0%
DOUBLE HULL (in m^3)	**VOI PO**	**VOI NPO**	**IV PO**	**IV NPO**	**Total Outflow**	**% Outflow**
Collisions	109.8	12.4	2.1	9.5	133.7	37.0%
Groundings	217.0	10.3			227.3	63.0%
Total Outflow	326.8	22.6			361.0	100.0%

% FROM SINGLE HULL	VOI PO	VOI NPO		Total Outflow	
Collisions	-50.7%	-50.1%	≈ – 48%	-48.4%	collisions
Groundings	-79.2%	-86.4%	≈ – 80%	-79.7%	groundings
Total Outflow	-74.2%	-77.4%	≈ – 74%	-73.8%	overall

- **In Single Hull Scenario:** about 1/5 of average out flow from collisions and 4/5 from groundings
- **In Double Hull Scenario:** about 1/3 of average out flow from collision and 2/3 from groundings



OIL OUTFLOW GEOGRAPHIC PROFILE SCENARIO 1
WITHOUT THREE RISK INTERVENTIONS IN PLACE



OIL OUTFLOW GEOGRAPHIC PROFILE SCENARIO 4
ALL THREE RISK INTERVENTION IN PLACE

Observations

- In Scenario 1 (without the three risk interventions) 99% of average oil outflow resided in the larger red rectangle of the geographic profile.
- The three risk interventions remove about 92% of total average oil outflow from Scenario 1.
- Of the remaining 8% from Scenario 1 in Scenario 4, still 95% resides in larger red rectangle.
- Hence, the larger red rectangle in Scenario 4 seems to be the natural targeted area for further risk reduction after implementation of these three risk interventions.
- However, because two of the three risk interventions specifically target this area (one-way and escorting) and the third one (double-hull) also addresses this area (double-hull) it will be progressively more difficult to further reduce risk within that area.

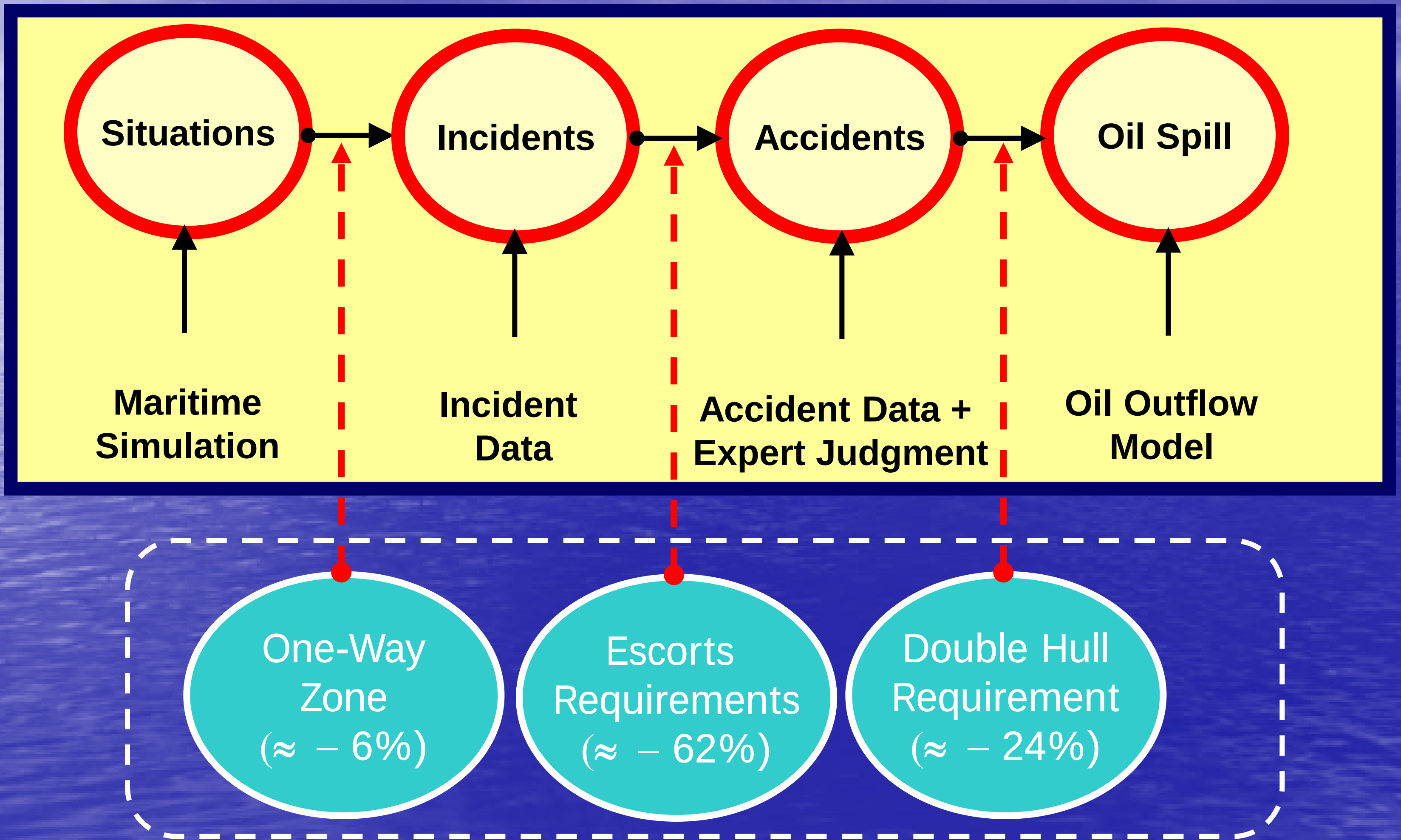
Special Thanks To:

- US Coast Guard Sector Seattle for being responsive to our countless data request during the enhancement and improvement of our MTS risk simulation methodology and recommending us to the Puget Sound Harbor Safety Committee.
- Puget Sound Harbor Safety Committee who served as a host for bimonthly meetings and provide us access to Seattle Maritime Community.
- The Seattle Maritime Community as a whole who unselfishly met with us and provided access to experts both for ship rides but also for their participation in many expert judgment elicitation sessions during which these experts donated their time for the safety improvement in their Maritime Domain.

THANK YOU!!!!

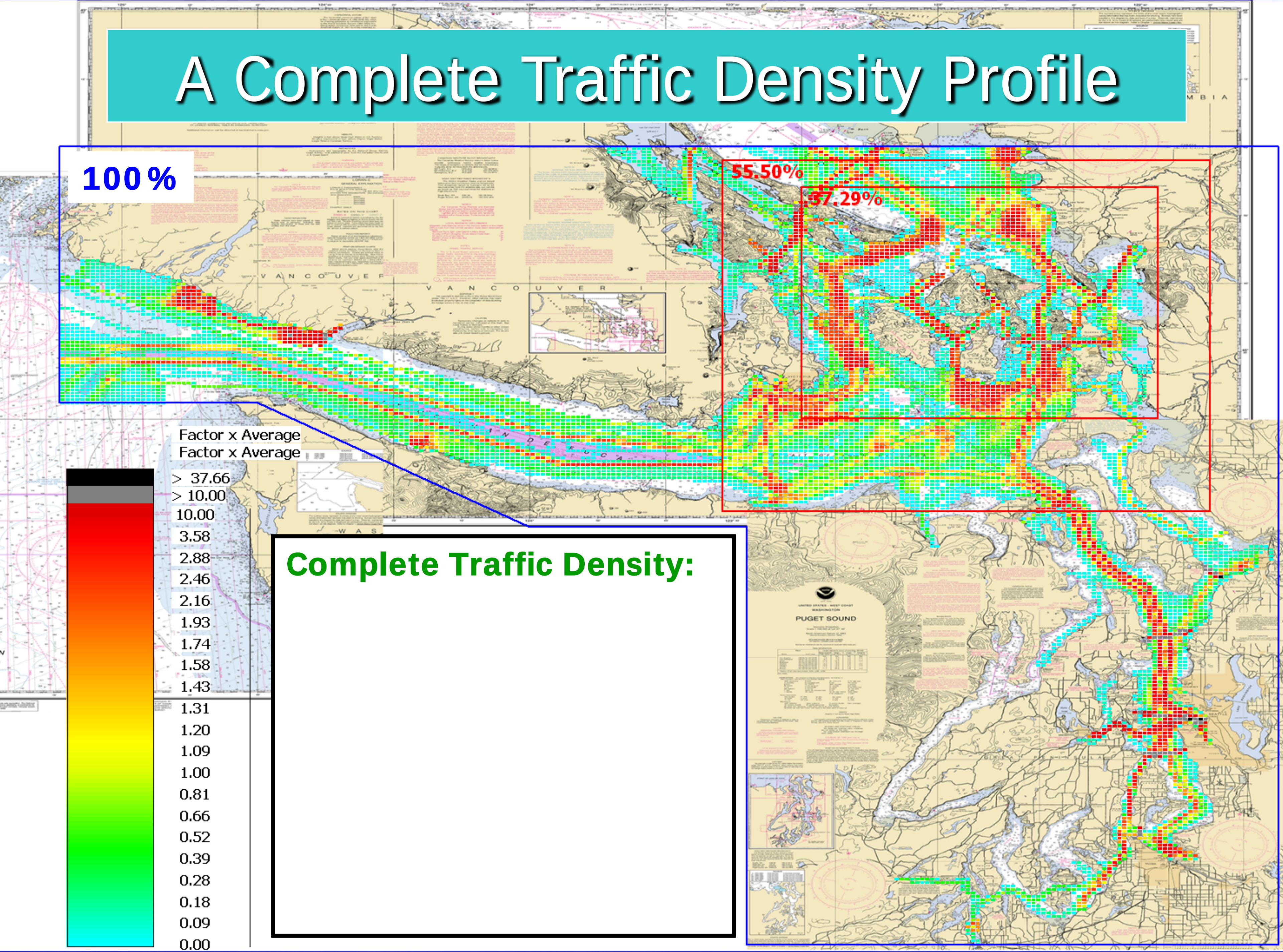
- Without their help, efficient and timely response to our repeated questions and data requests we would not have been able to further enhance and improve our MTS Risk Simulation Methodology.

A Word of Caution when making recommendations based on these results



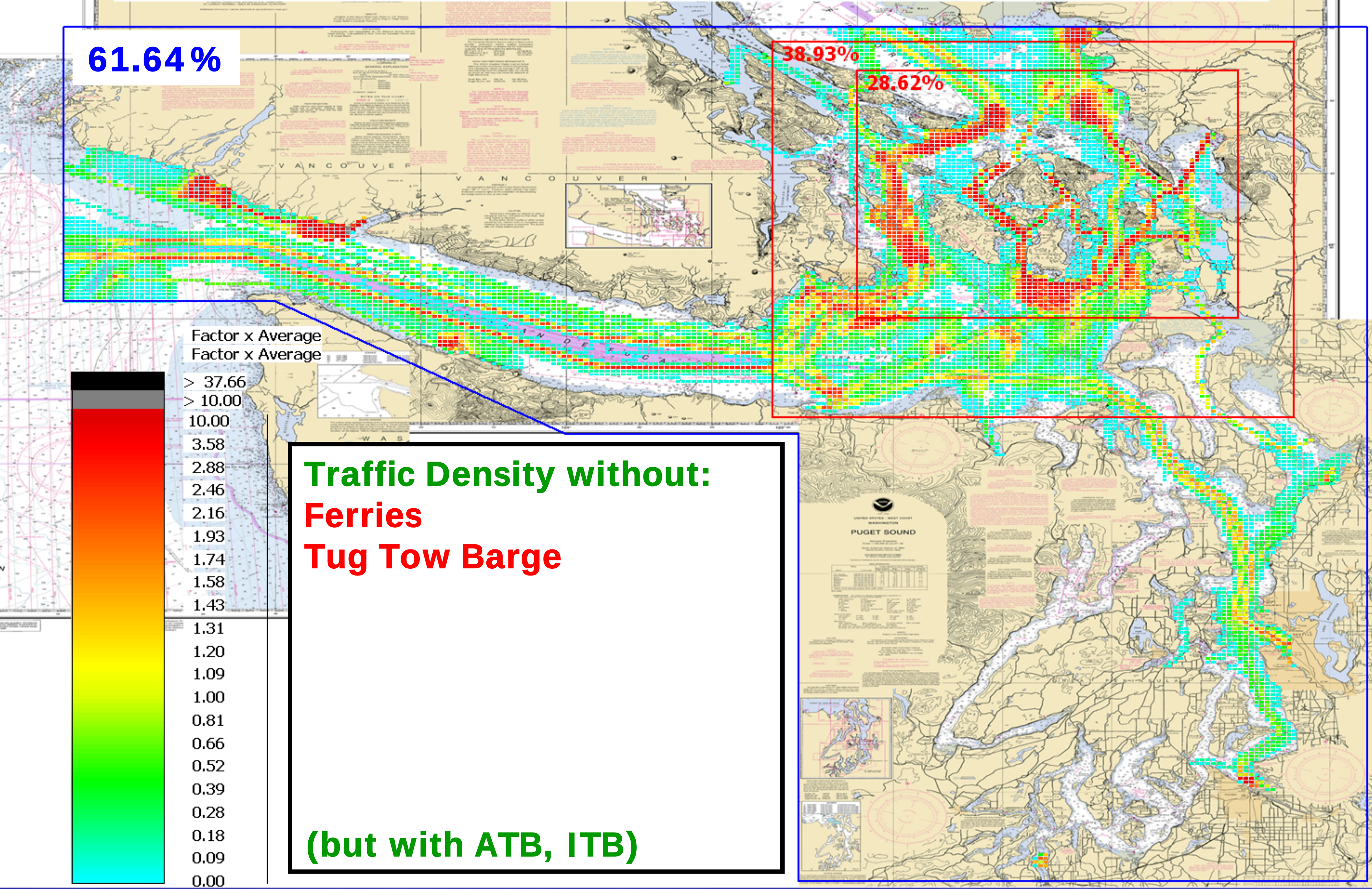
OVERALL A ≈ 92% RISK REDUCTION FROM SCENARIO 1

A Complete Traffic Density Profile

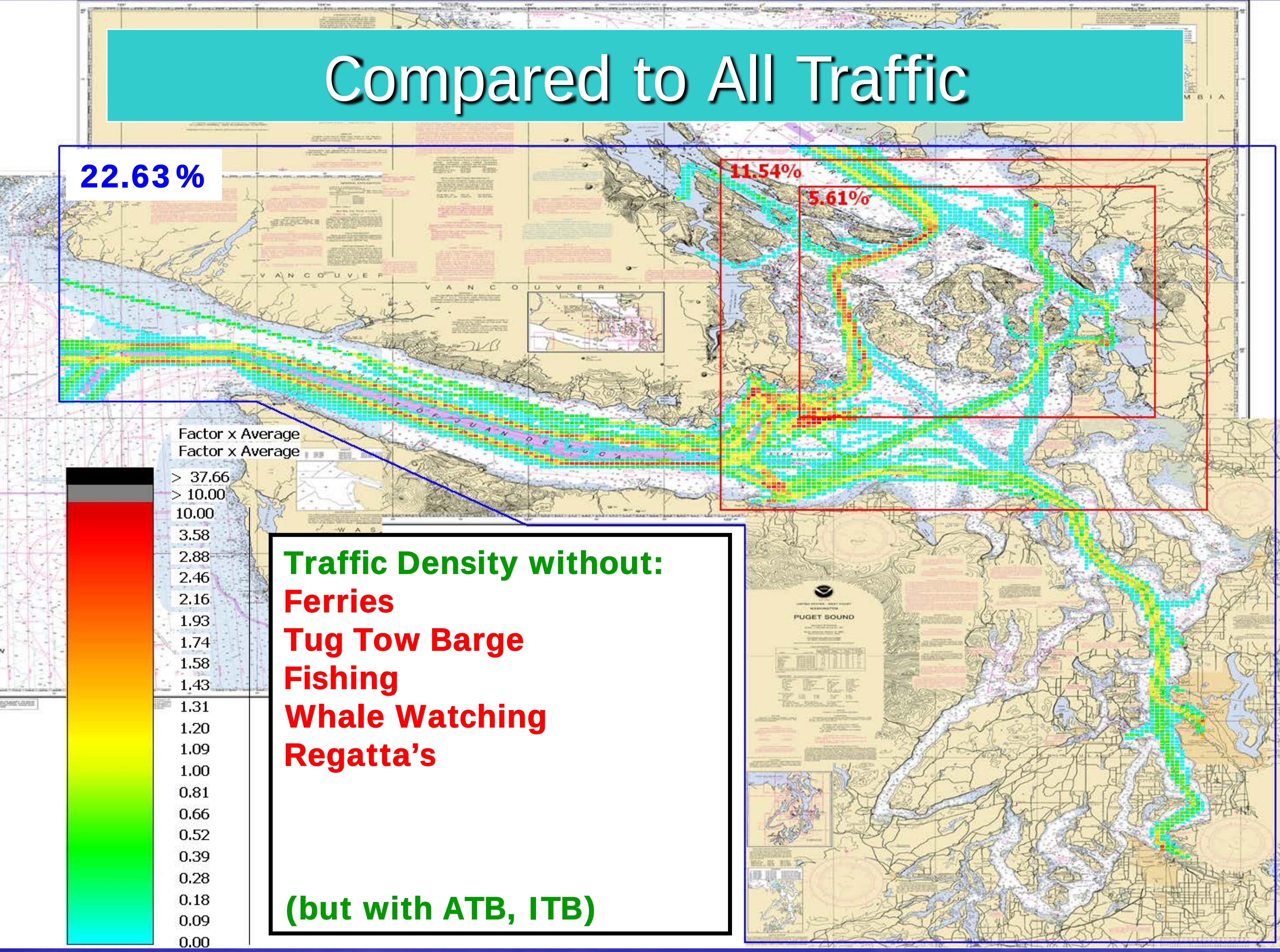


Complete Traffic Density:

Compared to All Traffic



Compared to All Traffic

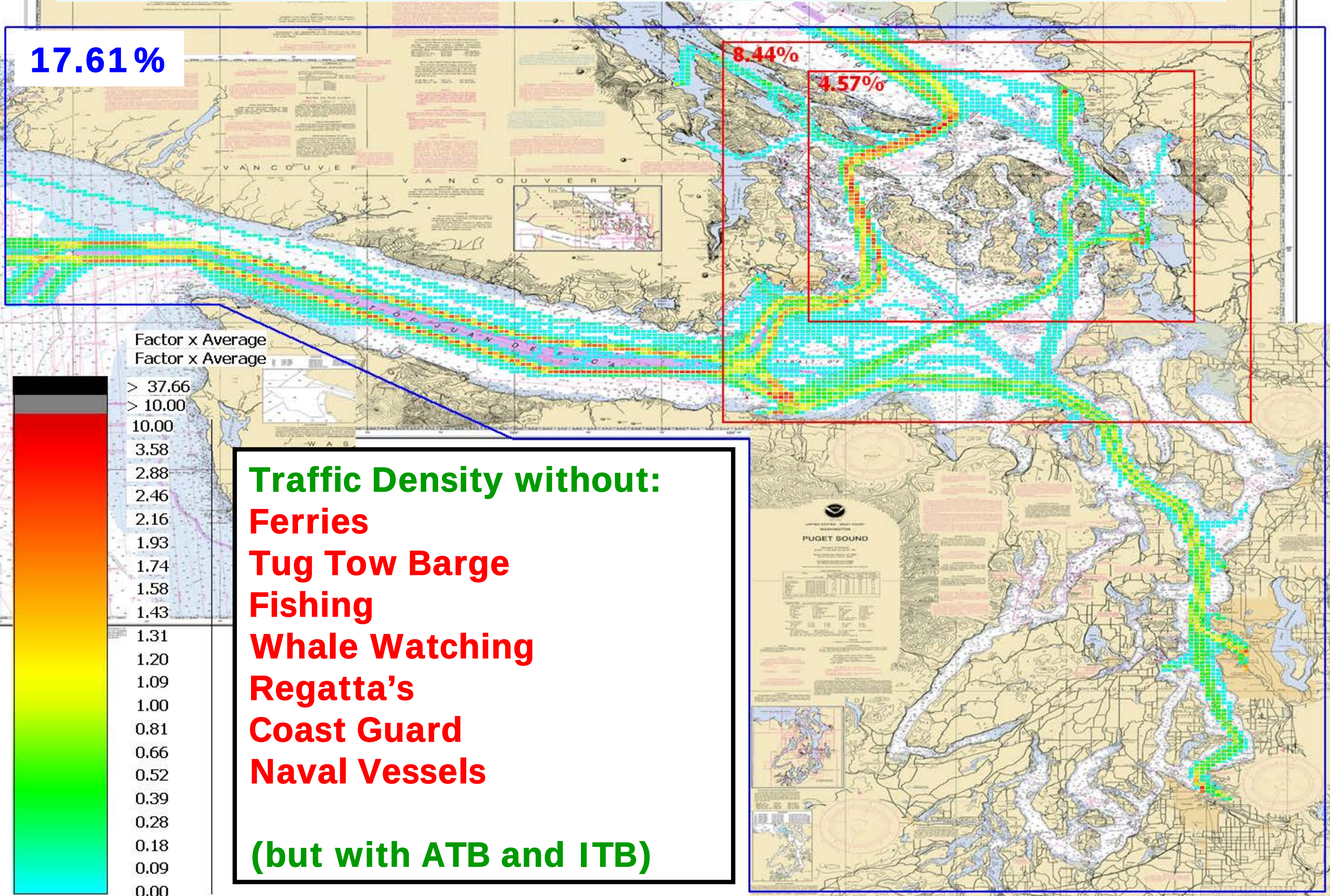


Traffic Density without:

Ferries
Tug Tow Barge
Fishing
Whale Watching
Regatta's

(but with ATB, ITB)

Compared to All Traffic

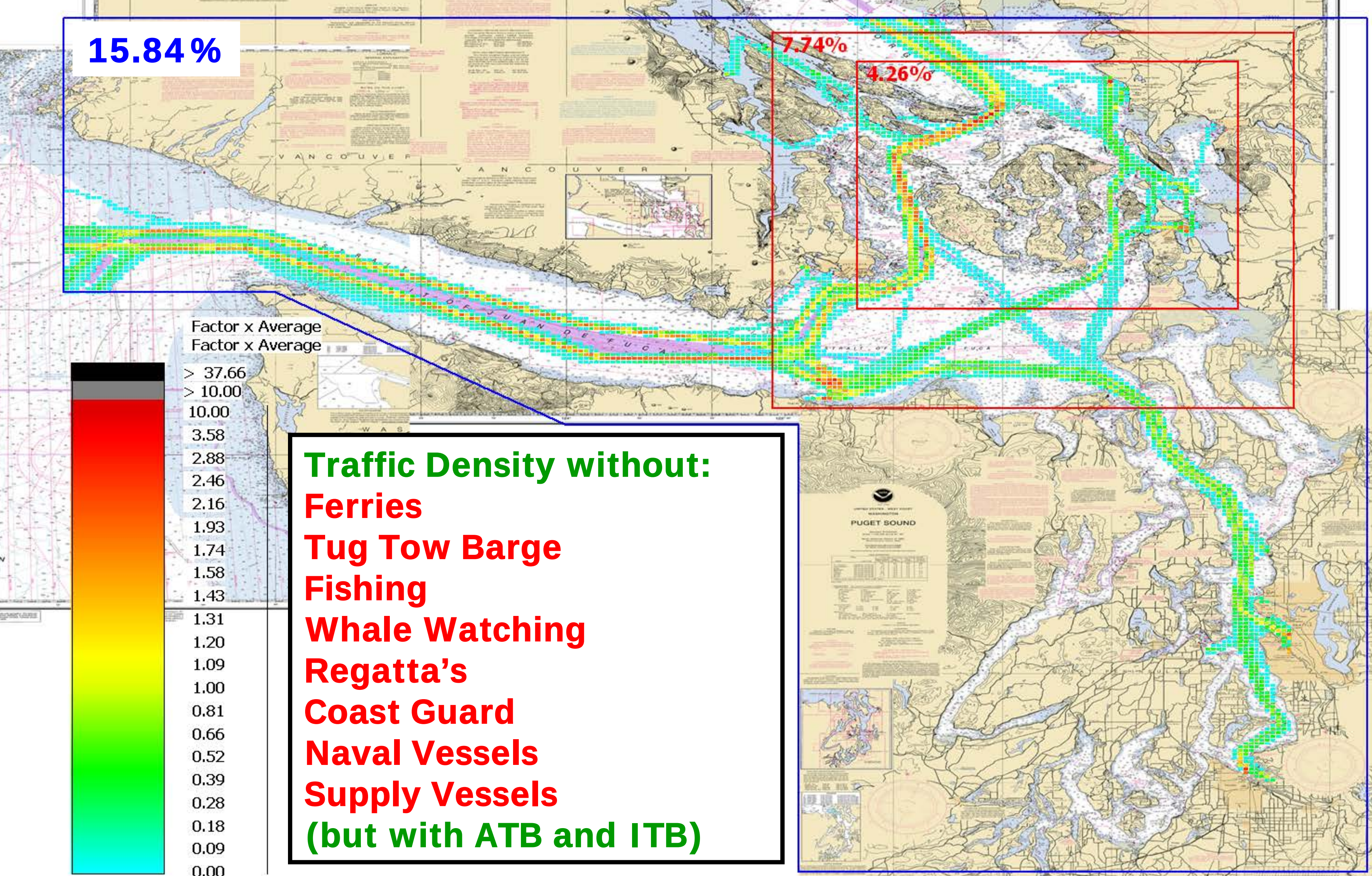


Traffic Density without:

Ferries
Tug Tow Barge
Fishing
Whale Watching
Regatta's
Coast Guard
Naval Vessels

(but with ATB and ITB)

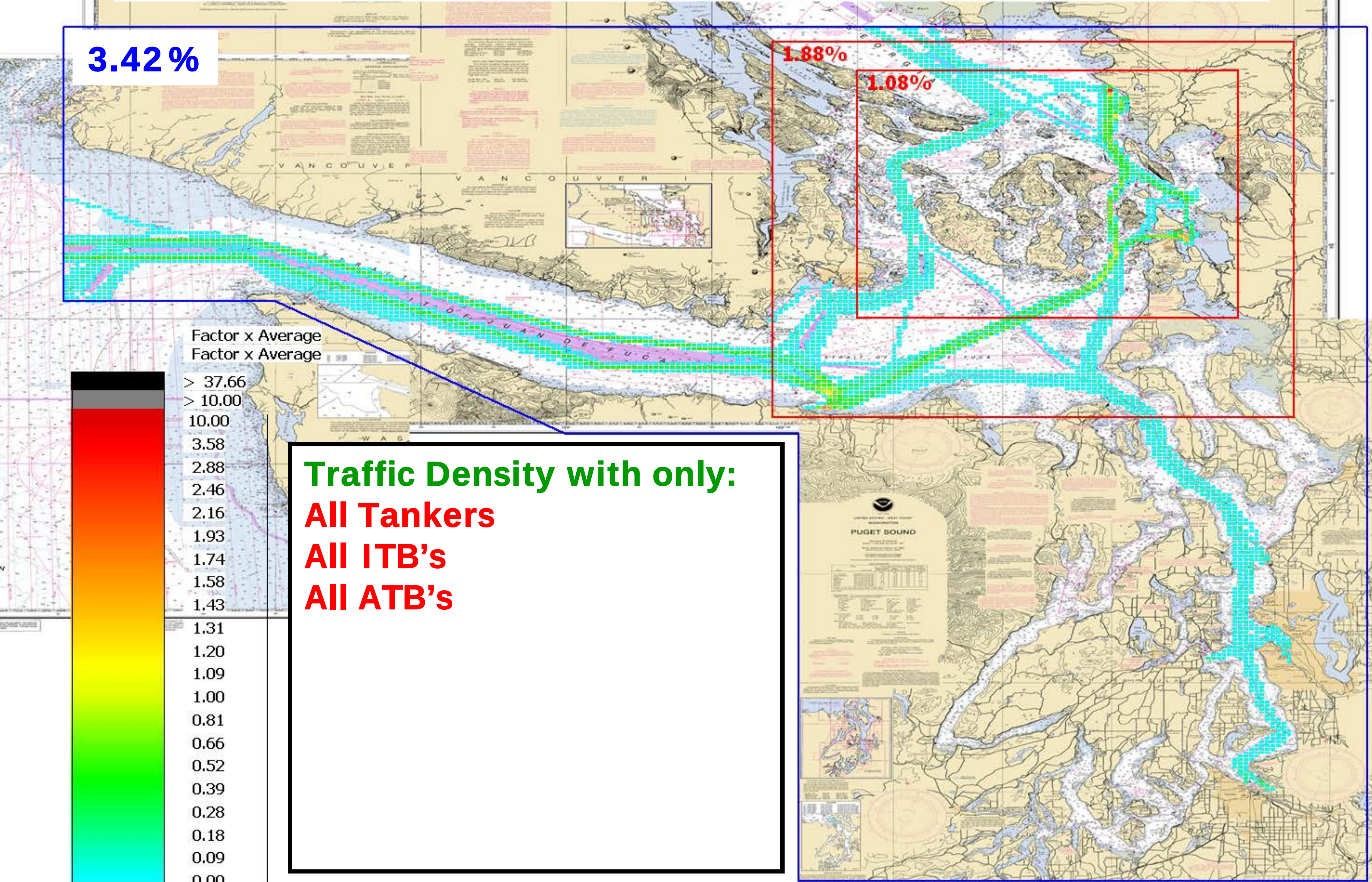
Compared to All Traffic



Traffic Density without:

Ferries
Tug Tow Barge
Fishing
Whale Watching
Regatta's
Coast Guard
Naval Vessels
Supply Vessels
(but with ATB and ITB)

Compared to All Traffic



Traffic Density with only:

All Tankers

All ITB's

All ATB's

Would like to dedicate this presentation to my friend and colleague Tayfur Altiok (1954-2012)

Tayfur passed away unexpectedly on April 14, 2012:

1. Professor Industrial and Systems Engineering at Rutgers University, the State University of New Jersey.

2. Fabulous Colleague and Mentor to his students.

3. Director of the Laboratory for Port Security at Rutgers

4. Author of numerous journal papers and two books, one on Simulation

QUESTIONS?

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