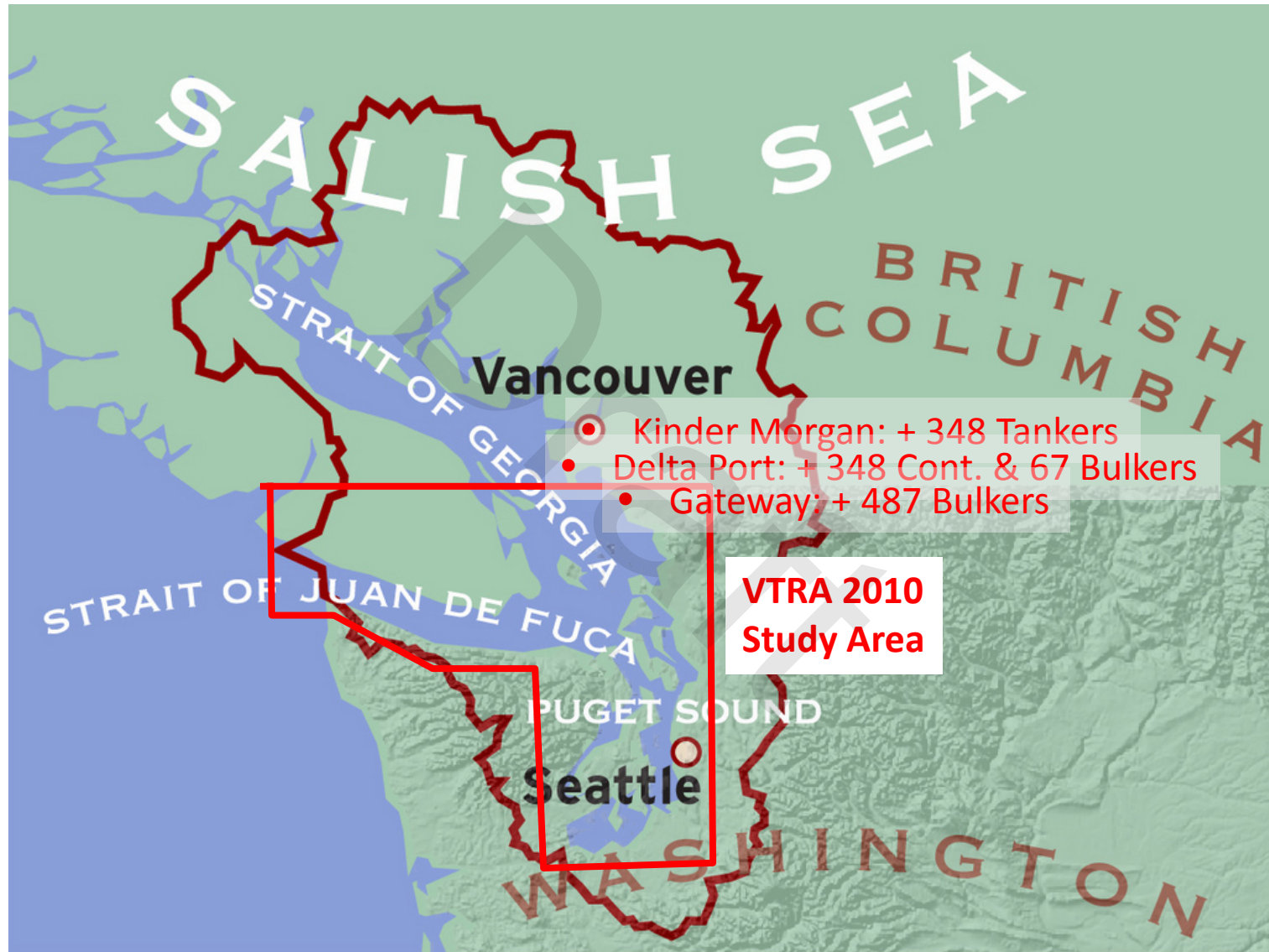


What do **Coin Tosses**, **Decision Making under Uncertainty**,
The VTRA 2010 and **Average Return Time Uncertainty**
have in common?



Jason R.W. Merrick (VCU) and Rene van Dorp (GW)
Review of VTRA 2010 Analysis Approach + Results
Presented by: J. Rene van Dorp

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2010



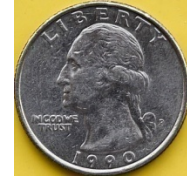
VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2010



OUTLINE

1. **Coin Tosses**
2. Decision Making under Uncertainty
3. VTRA 2010
 - Base Case Traffic Description
 - What-If and Benchmark Cases

1. Imagine we have a coin and we flip it repeatedly



2. When heads turns up you “win” when tails turns up you “lose”

Suppose we flip the coin **four times**,
how many times do you expect to win?

2 times

Suppose we flip the coin **ten times**,
how many times do you expect to win?

5 times

WHAT ASSUMPTION(S) DID YOU MAKE?

Conclusion: you made **reasonable assumptions** –

1. The coin has two different sides
2. When flipping it, each side turns up 50% of the time “on average”.

Would it have made sense to assume
the coin had only one face
i.e. both sides show heads (or tails)?

No

Assuming both sides show heads or tails
is equivalent to making
a **worst case** or **best case** assumption.

Suppose you actually flip the “fair” coin ten times
How many times will “heads” turn up?

Answer could vary from 0 to 10 times, for example,

First ten times : 3 times heads turns up

Second ten times : 7 times heads turns up

Third ten times : 6 times heads turns up

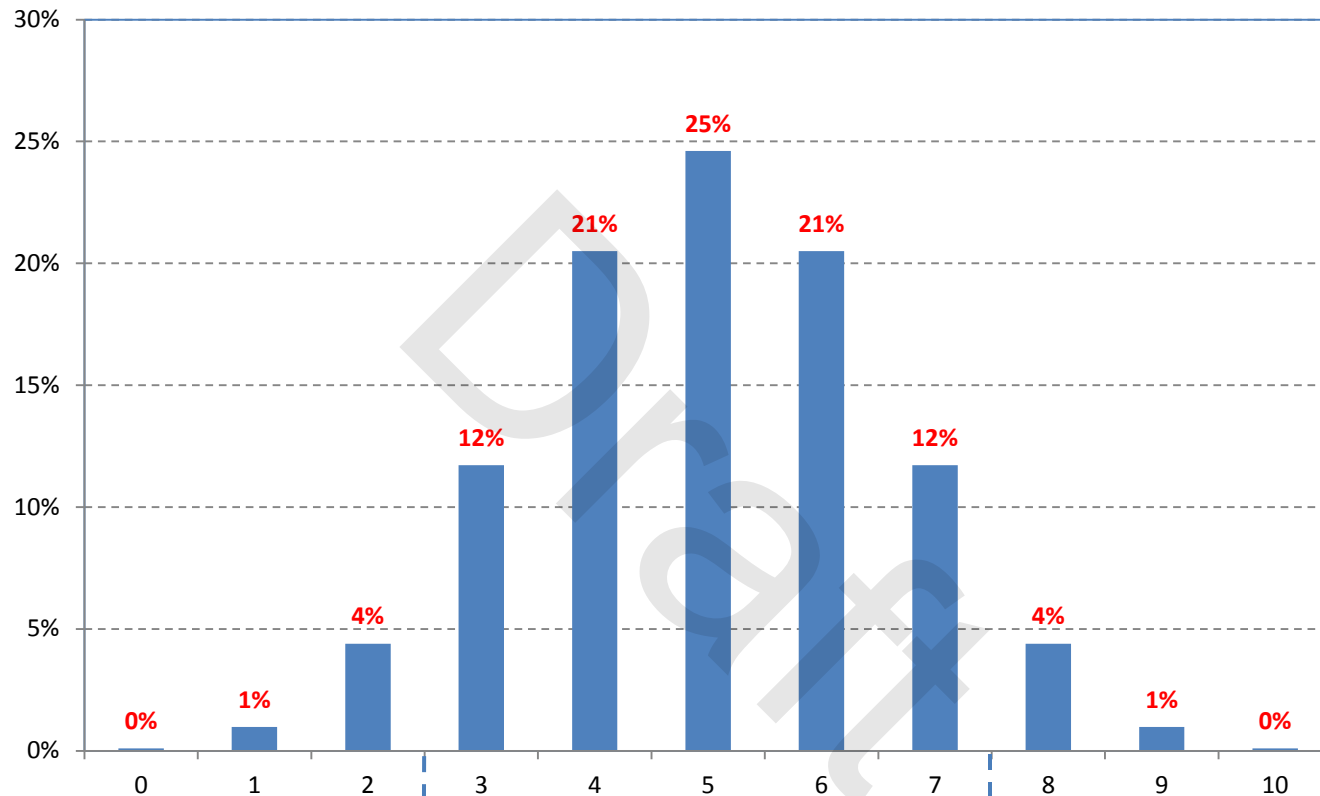
Fourth ten times : 4 times heads turns up

etc.



We say “on average” 5 out of ten times heads turns up

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2010



Approximately 90% of ten throw series will have 3, 4, 5, 6 or 7 times heads turn up

Conclusion: While we expect 5 times heads to turn up, the actual number is uncertain!

OUTLINE

1. Coin Tosses
2. **Decision Making under Uncertainty**
3. VTRA 2010
 - Base Case Traffic Description
 - What-If and Bench Mark Cases

1. Imagine we have two coins:

Coin 1 shows heads 50% of the time

Coin 2 shows heads 75% of the time

Coin 1



Coin 2



2. When heads turns up, you win a pot of money. When tails turns up, you do not get anything.

You have to choose between Coin 1 and Coin 2

Which one would you choose? **Coin 2**

WHAT ASSUMPTION DID YOU MAKE?

You assumed that the pot of money you win is the same regardless of the coin you chose!

1. Imagine we have two coins:

Coin 1 shows heads 50% of the time

Coin 2 shows heads 75% of the time

Coin 1



Coin 2



2. Each time heads turns up, you win **the same pot of money**.
When tails turns up you do not get anything, regardless of the coin you throw.

You have to choose between two alternatives

Alternative 1: Throwing **ten times** with Coin 1

Alternative 2: Throwing **five times** with Coin 2

Which alternative would you choose?

Alternative 1 you expect to win 5 times and

Alternative 2 you expect to win 3.75 times

**CHOOSE
ALTERNATIVE 1**

1. Imagine we have two coins:
Coin 1 shows heads 50% of the time
Coin 2 shows heads 75% of the time



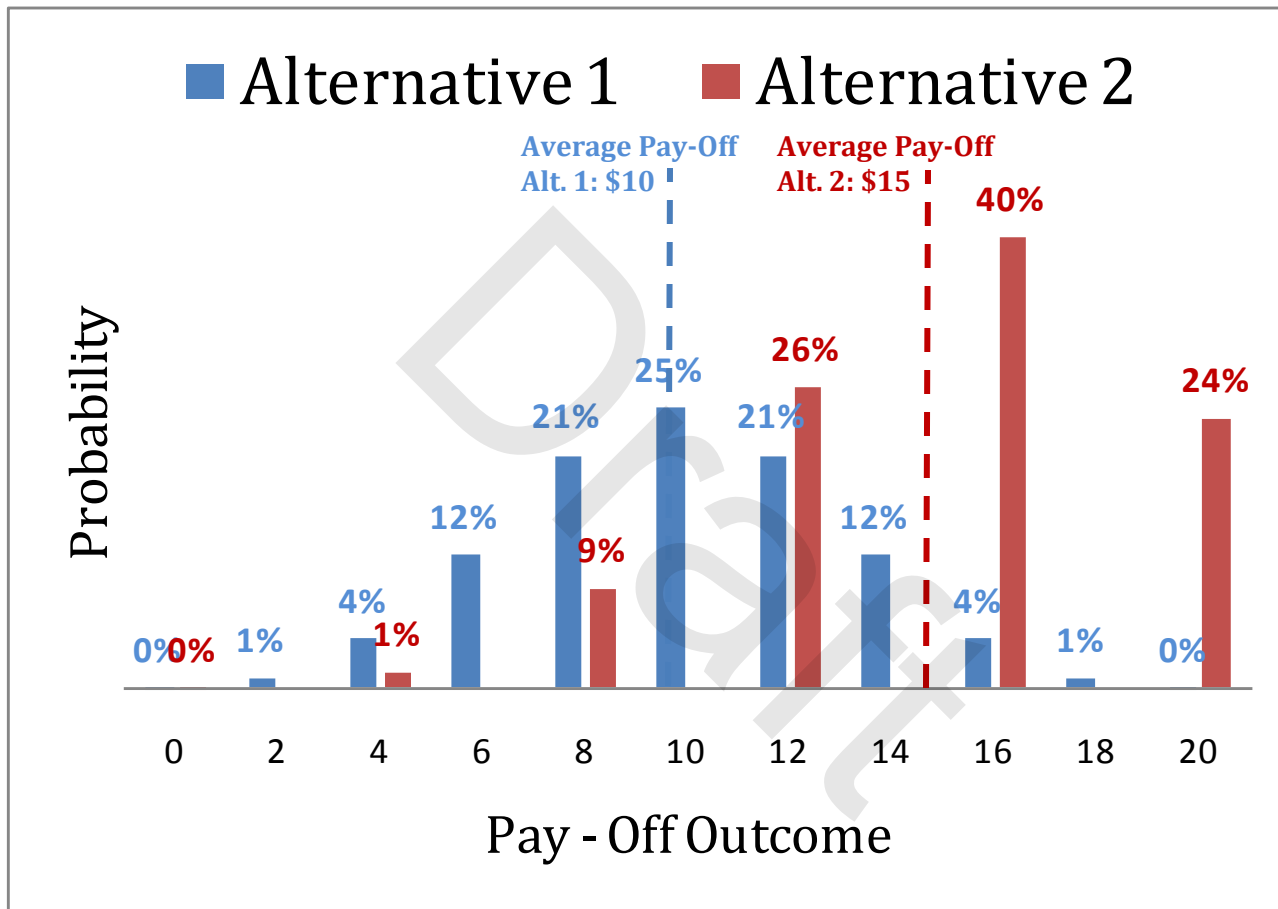
2. Each time heads turns up with Coin 1 you win \$2. Each time heads turns up with Coin 2 you win \$4. When tails turns up you do not get anything.

You have to choose between two ALTERNATIVES
Alternative 1: Throwing **ten times** with Coin 1
Alternative 2: Throwing **five times** with Coin 2

Which alternative would you choose?

Alternative 1 you average $5 * \$2 = \10
Alternative 2 you average $3.75 * \$4 = \15

**CHOOSE
ALTERNATIVE 2**



Our objective is to **maximize pay-off**. So **faced with uncertainty of pay-off outcomes** we choose the alternative with largest average pay-off.

Conclusion?

When choosing between **two alternatives** entailing a series of trials, the following comes into play:

1. The number of trials N in each alternative
2. The probability of success P per trial
3. The pay-off amount W per trial

$$\text{AVERAGE PAY-OFF} = N \times P \times W$$

Is it required to know **the values**
of N , P and W to choose
between these two alternatives?

1. Imagine we have two coins:
 Coin 2 shows heads **1.5 times more** than Coin 1

2. When heads turns up with Coin 2 **you win 2 times the amount** when heads turns up with Coin 1.

You have to choose between **Two Alternatives**
 Alternative 1: Throwing **2*N times** with Coin 1
 Alternative 2: Throwing **N times** with Coin 2

P = % Heads turns up with Coin 1,
 W = \$ amount you win with Coin 1.

Average Pay – Off Alternative 2 : $\cancel{N} \times 1.5 \times \cancel{P} \times \cancel{2} \times \cancel{W}$

Average Pay – Off Alternative 1 : $\cancel{2} \times \cancel{N} \times \cancel{P} \times \cancel{W}$

Average Pay-Off Alt. 2 / Average Pay-Off Alt. 1 = **1.5**

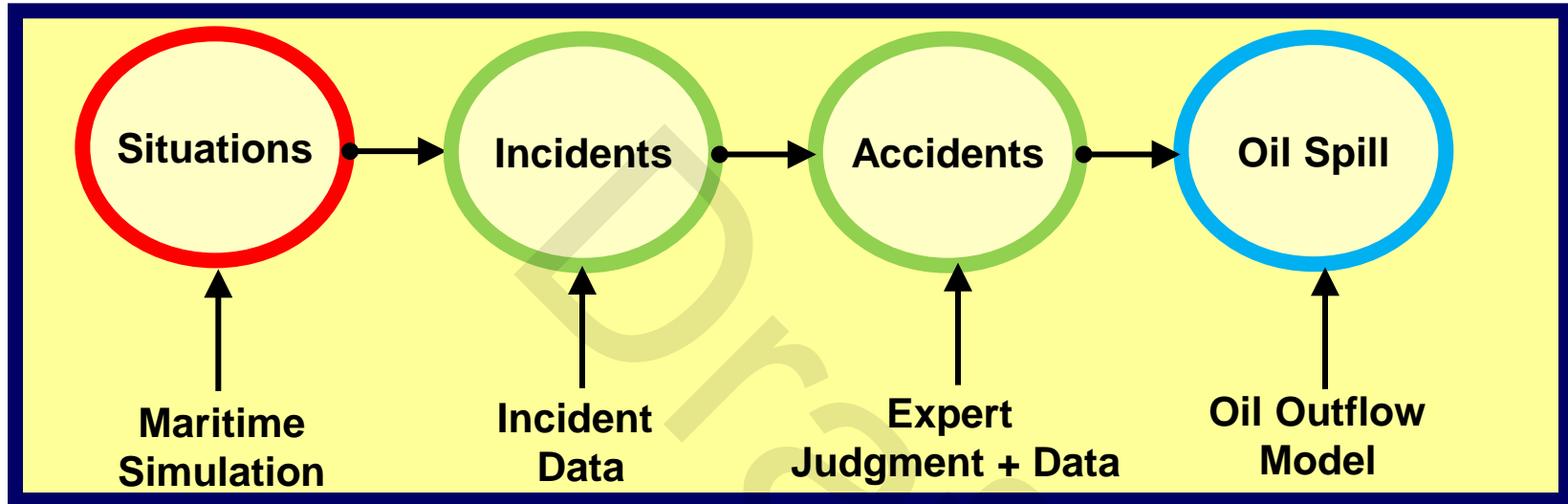
Conclusion?

When choosing between **two alternatives** entailing a series of trials, we can make a choice if we know **the multiplier between the average pay-offs**, even when the absolute pay-off values over the two alternative series are unknown/uncertain

OUTLINE

1. Coin Tosses
2. Decision Making under Uncertainty
3. **VTRA 2010**
 - Base Case Traffic Description
 - What-If and Benchmark Cases

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



$$R = \{ \langle s_i, l_i, x_i \rangle \}_c$$

Traffic Situations Likelihoods Consequences

Risk Analysis Objective:
Evaluate Oil Spill System Risk described by a "complete" set of traffic situations

Coin Toss Analogy:

Trials

% of Heads (P)

Winnings (\$)

Pay-off Risk was defined by N identical Trials

VTRA 2010 Analysis Approach

In light of uncertainties inherent to any risk analysis, we chose not to focus on;

- **evaluations of “average” risk levels,**
but to focus on
- **relative risk changes from a base case scenario** by adding or removing traffic to or from that base case.

VTRA 2010 Analysis Approach

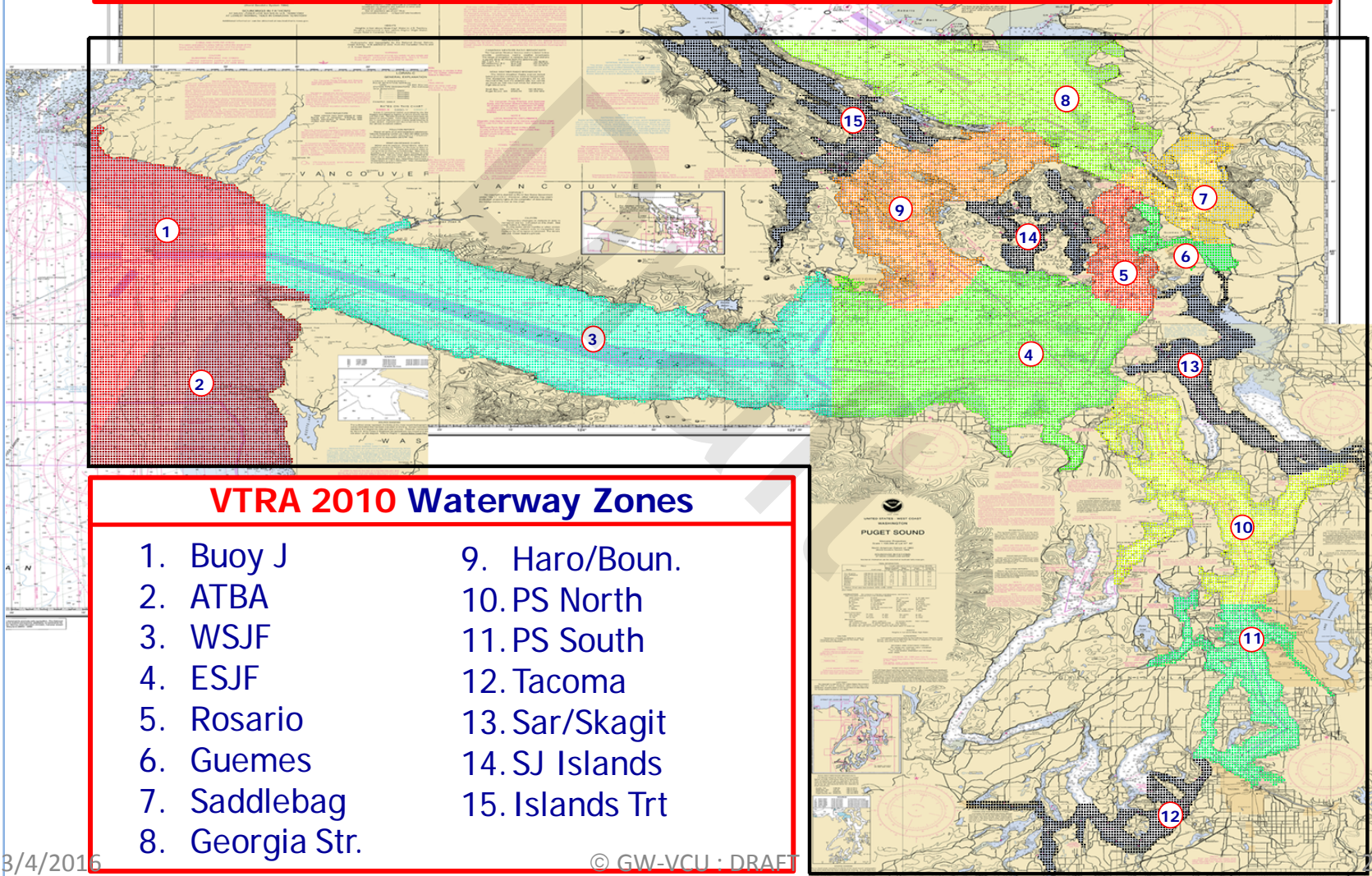
A Base Case (BC) Analysis Framework is constructed while;

- **making reasonable assumptions** (not worst or best case), and
- **What-if (WI), Bench-Mark (BM) and Risk Mitigation Measure (RMM)** cases are analyzed within that framework.

VTRA 2010 Analysis Approach

- Base Case (BC) system wide risk levels are set at 100%, and
- **System wide % changes up or down** are evaluated for What-if (WI), Bench-Mark (BM) and Risk Mitigation Measure (RMM), moreover
- **Location-Specific Multipliers** are evaluated for **15 Waterway Zones**.

DEFINITION OF 15 WATERWAY ZONES

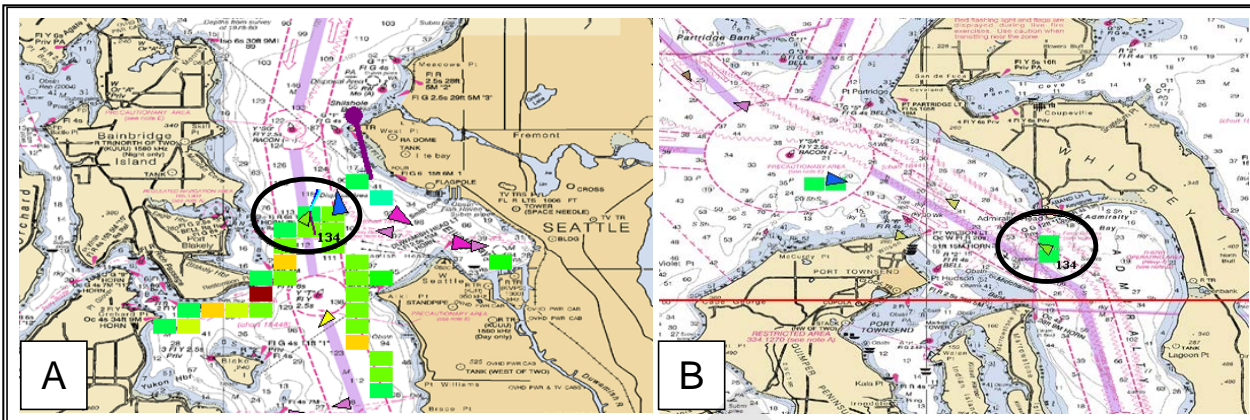


VTRA 2010 Waterway Zones

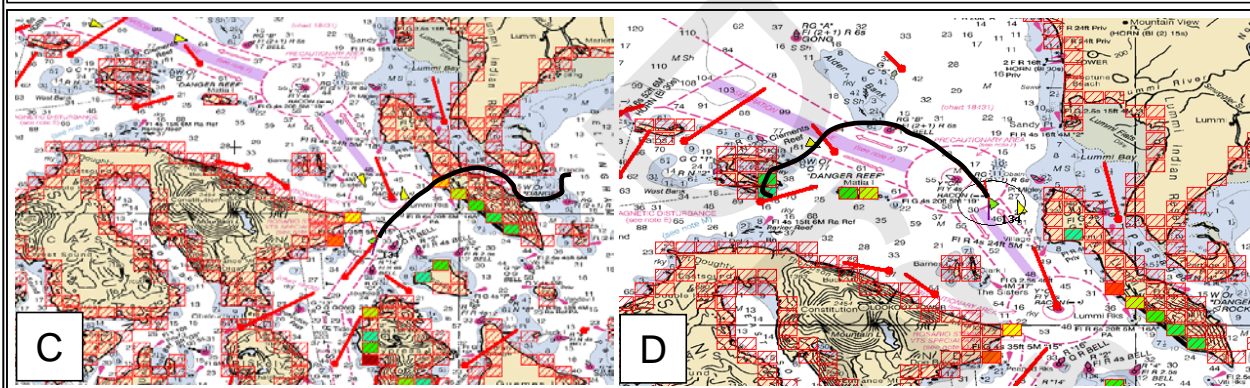
- | | |
|-----------------|-----------------|
| 1. Buoy J | 9. Haro/Boun. |
| 2. ATBA | 10. PS North |
| 3. WSJF | 11. PS South |
| 4. ESJF | 12. Tacoma |
| 5. Rosario | 13. Sar/Skagit |
| 6. Guemes | 14. SJ Islands |
| 7. Saddlebag | 15. Islands Trt |
| 8. Georgia Str. | |

Generating Traffic Situations:

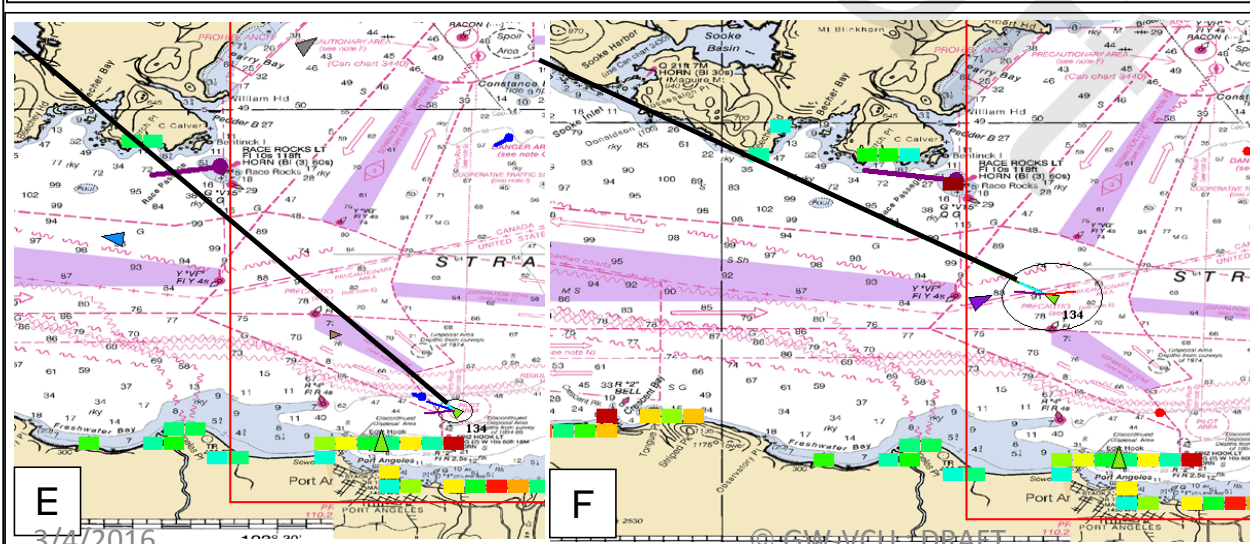
Counting Collision Accident Scenario's



Counting Drift Grounding Accident Scenario's



Counting Powered Grounding Accident Scenario's

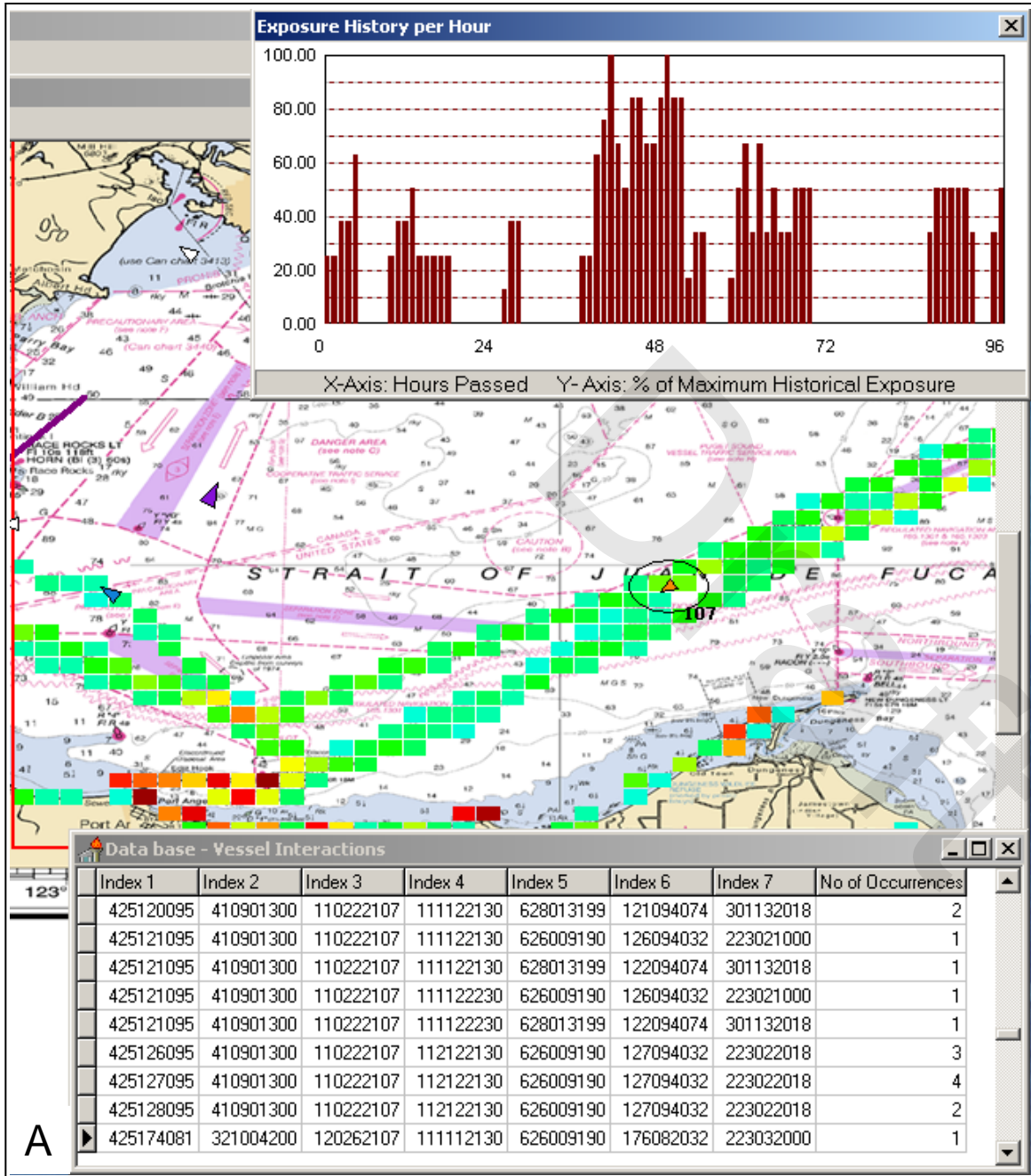


VTRA 2010 Analysis Approach

- Map is divided in squares of grid cells with dimension half nautical mile by half nautical mile and The VTRA 2010

Evaluates per Grid Cell!

- # of traffic situations per year
- potential accident frequency per year
- potential oil loss per year



```

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; { 260000000}
  VOI_X             : longint; { 5000000}
  VOI_Y             : longint; { 500}

  {Index 2 - VOI Attributes}
  VOI_Location      : longint; { 900000000}
  VOI_Inbound_Outbound : longint; { 200000000}
  VOI_Speed         : longint; { 3000000}
  VOI_DP            : longint; { 12500}
  IV_Cargo          : longint; { 20}
  IV_Barge_Type     : longint; { 5}

  {Index 3 - VOI Attributes}
  VOI_Cargo         : longint; { 200000000}
  VOI_Tethered_State : longint; { 2000000}
  VOI_Barge_Type    : longint; { 50000}
  VOI_Hook_Up       : longint; { 4000}
  VOI_ID            : longint; { 999}

  {Index 4 - Environment Info}
  Visibility         : longint; { 200000000}
  wind_Direction    : longint; { 200000000}
  Wind_Speed        : longint; { 4000000}
  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; { 5000000}
  Time_To_Shore    : longint; { 300}

  {Index 6 - Interacting Vessel Location}
  IV_X              : longint; { 5000000000}
  IV_Y              : longint; { 5000000}
  IV_DP             : longint; { 125}

  {Index 7 - Interacting Vessel Info}
  IV_TrafficScenario : longint; { 4000000000}
  IV_TrafficType     : longint; { 250000000}
  IV_Speed           : longint; { 3000000}
  IV_ProxVessel      : longint; { 2000}
  IV_InterAngle     : longint; { 180}

end;

```

Recall Coin Toss Analogy: Trials (N) % of Heads (P) Winnings (W)

$$\text{EVALUATE AVERAGE PAY-OFF} = N \times P \times W$$

Risk Assessment: Traffic Situations Likelihoods Consequences

$$R = \{ \langle s_i, l_i, x_i \rangle \}_c$$

Oil Spill System Risk is described by "complete" set of traffic situations

Per Grid Cell!!

Display results visually in 2D and 3D geographic profiles



VTRA 2010 Analysis Approach

Collision System Exposure in Base Case:

- Approximately **10,000 grid cells of 0.5 x 0.5 mile** in VTRA study area with Vessel to Vessel traffic situations.
- Approximately **1.8 Million Vessel to Vessel Traffic Situations per year** generated by VTRA 2010 Model.
- **Vessel to Vessel Traffic Situations per cell per year range from 1 – 7,000** (or on average about 0 – 20 per day per cell) .

Recall Coin Toss – Traffic Situation Analogy:

“1.8 Million Coin Tosses with very small probability of Tails”

VTRA 2010 Analysis Approach

Grounding System Risk in Base Case:

- Approximately **4,000 grid cells of 0.5 x 0.5 mile** in VTRA study area with Vessel to Shore traffic situations.
- Approximately **10 Million Vessel to Shore Traffic Situations per year** generated by VTRA 2010 Model.
- **Vessel to Shore Traffic Situations per cell per year range from 1 – 55,000** (or on average about 0 – 150 per day) .

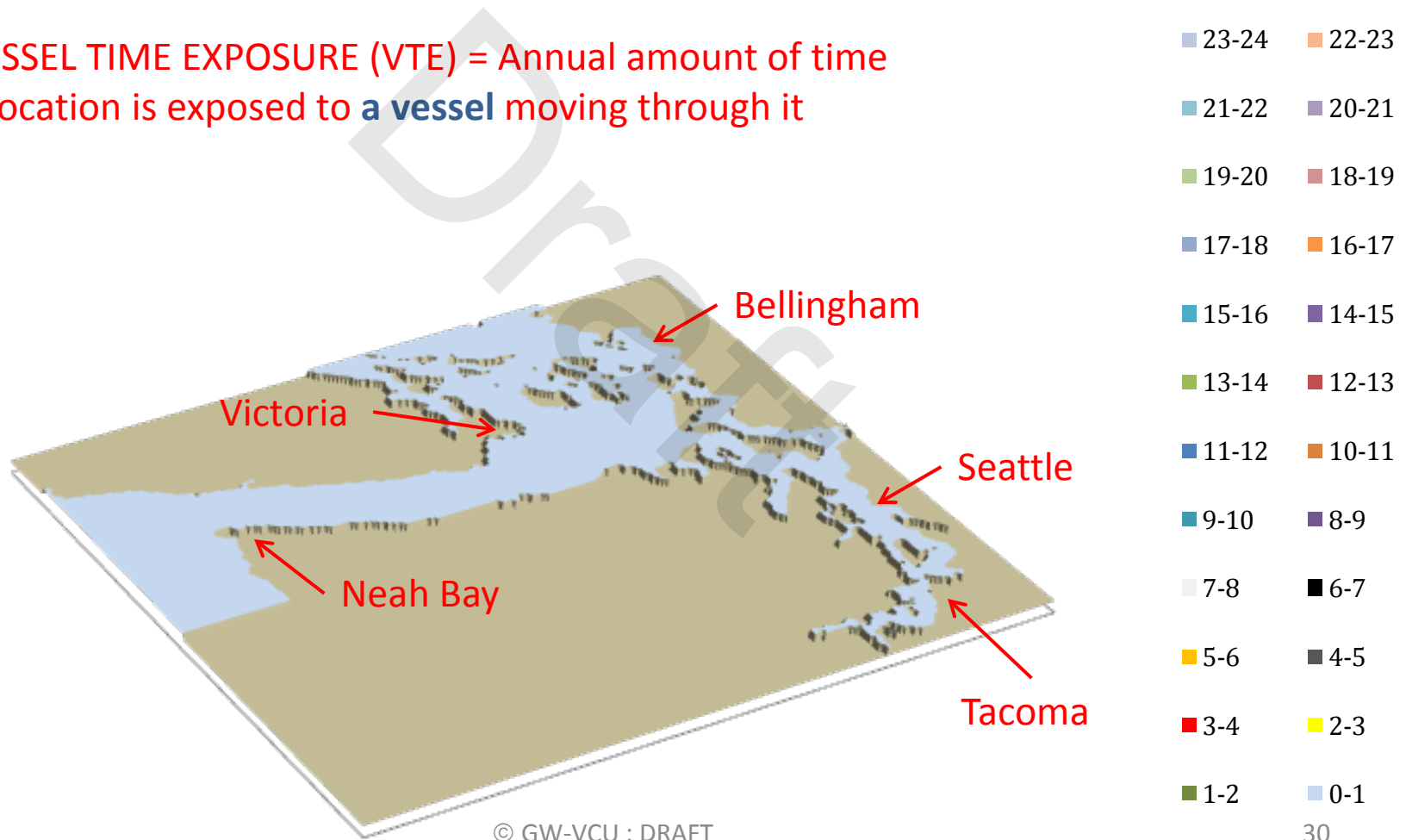
**Recall Coin Toss – Traffic Situation Analogy:
“10 Million Coin Tosses with very small probability of Tails”**

OUTLINE

1. Coin Tosses
2. Decision Making under Uncertainty
3. **VTRA 2010**
 - **Base Case Traffic Description**
 - **What-If and Benchmark Cases**
4. Return Time Uncertainty

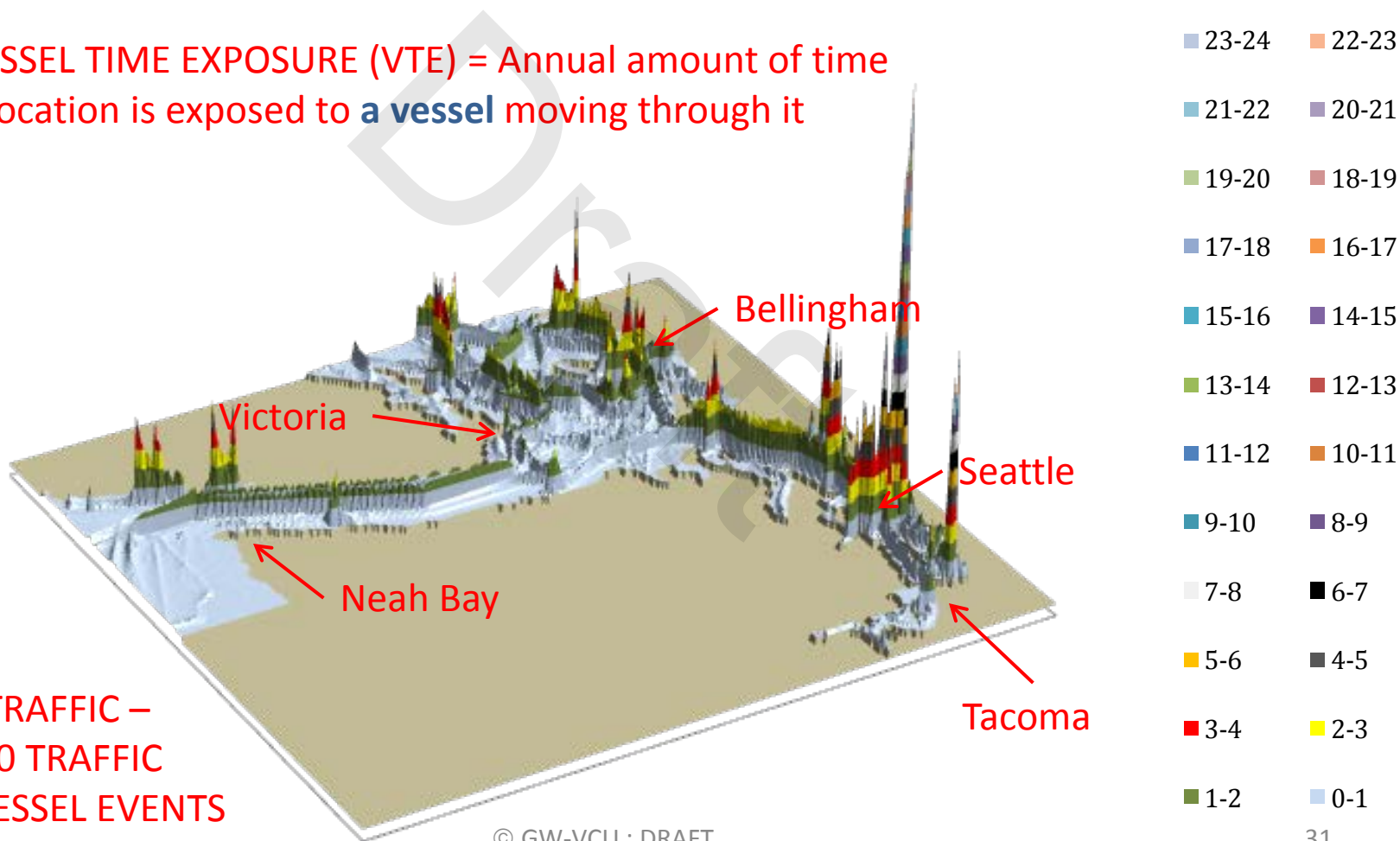
P: Base Case 3D Risk Profile MAP TO DISPLAY - Vessel Time Exposure

VESSEL TIME EXPOSURE (VTE) = Annual amount of time a location is exposed to a vessel moving through it



P: Base Case 3D Risk Profile ALL TRAFFIC - Vessel Time Exposure: 100% Total VTE

VESSEL TIME EXPOSURE (VTE) = Annual amount of time a location is exposed to a vessel moving through it



ALL VTRA TRAFFIC –
VTOSS 2010 TRAFFIC
+ SMALL VESSEL EVENTS

3/4/2016

© GW-VCU : DRAFT

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VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2010

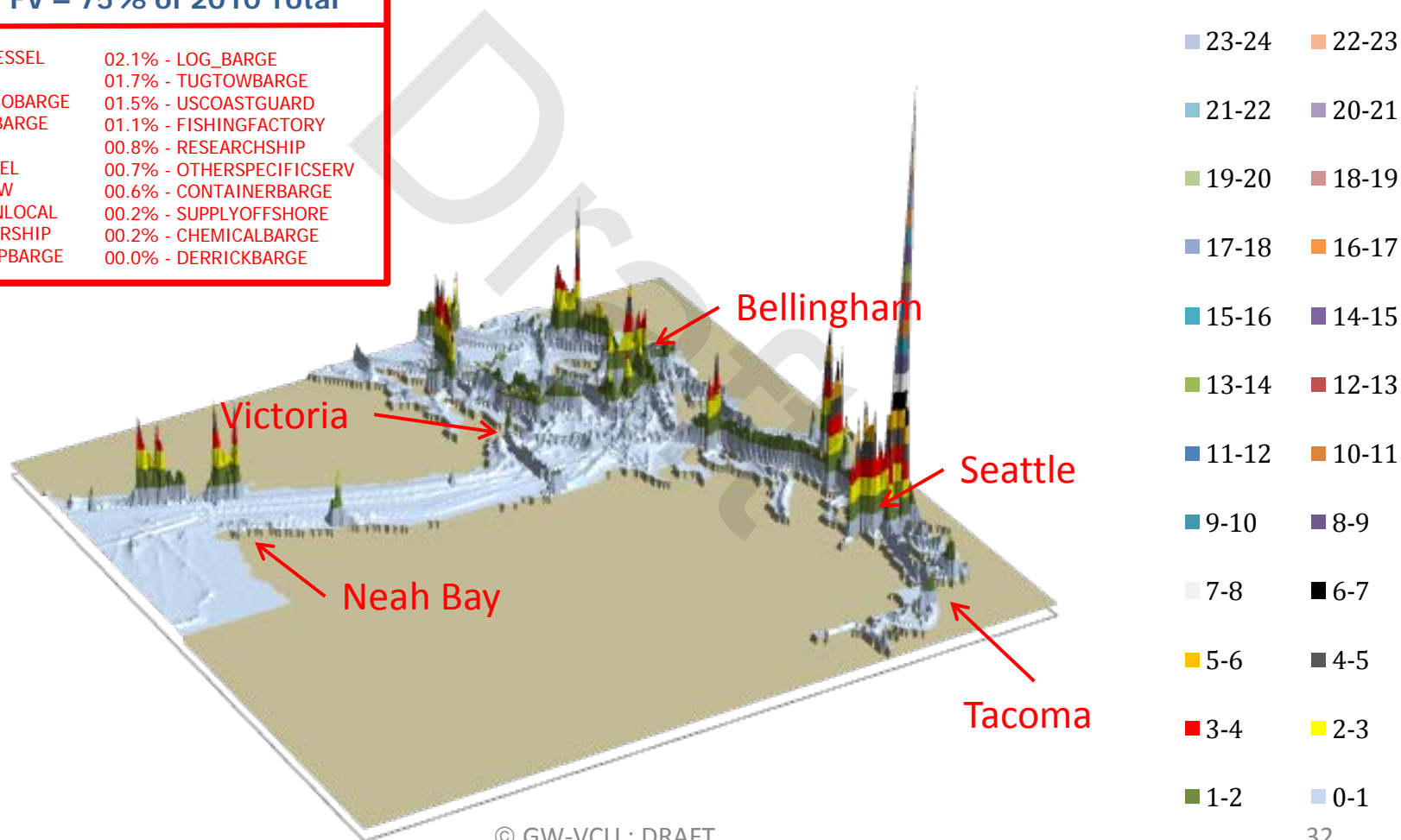
NON – FV TRAFFIC

P: Base Case 3D Risk Profile

NON FV - Vessel Time Exposure: 75% Total VTE

2010 NON FV – 75% of 2010 Total

41.3% - FISHINGVESSEL	02.1% - LOG_BARGE
18.1% - FERRY	01.7% - TUGTOWBARGE
06.8% - BULKCARGOBARGE	01.5% - USCOASTGUARD
06.0% - UNLADENBARGE	01.1% - FISHINGFACTORY
04.0% - YACHT	00.8% - RESEARCHSHIP
03.9% - NAVYVESSEL	00.7% - OTHERSPECIFICSERV
03.3% - TUGNOTOW	00.6% - CONTAINERBARGE
02.8% - FERRYNONLOCAL	00.2% - SUPPLYOFFSHORE
02.7% - PASSENGERSHIP	00.2% - CHEMICALBARGE
02.2% - WOODCHIPBARGE	00.0% - DERRICKBARGE

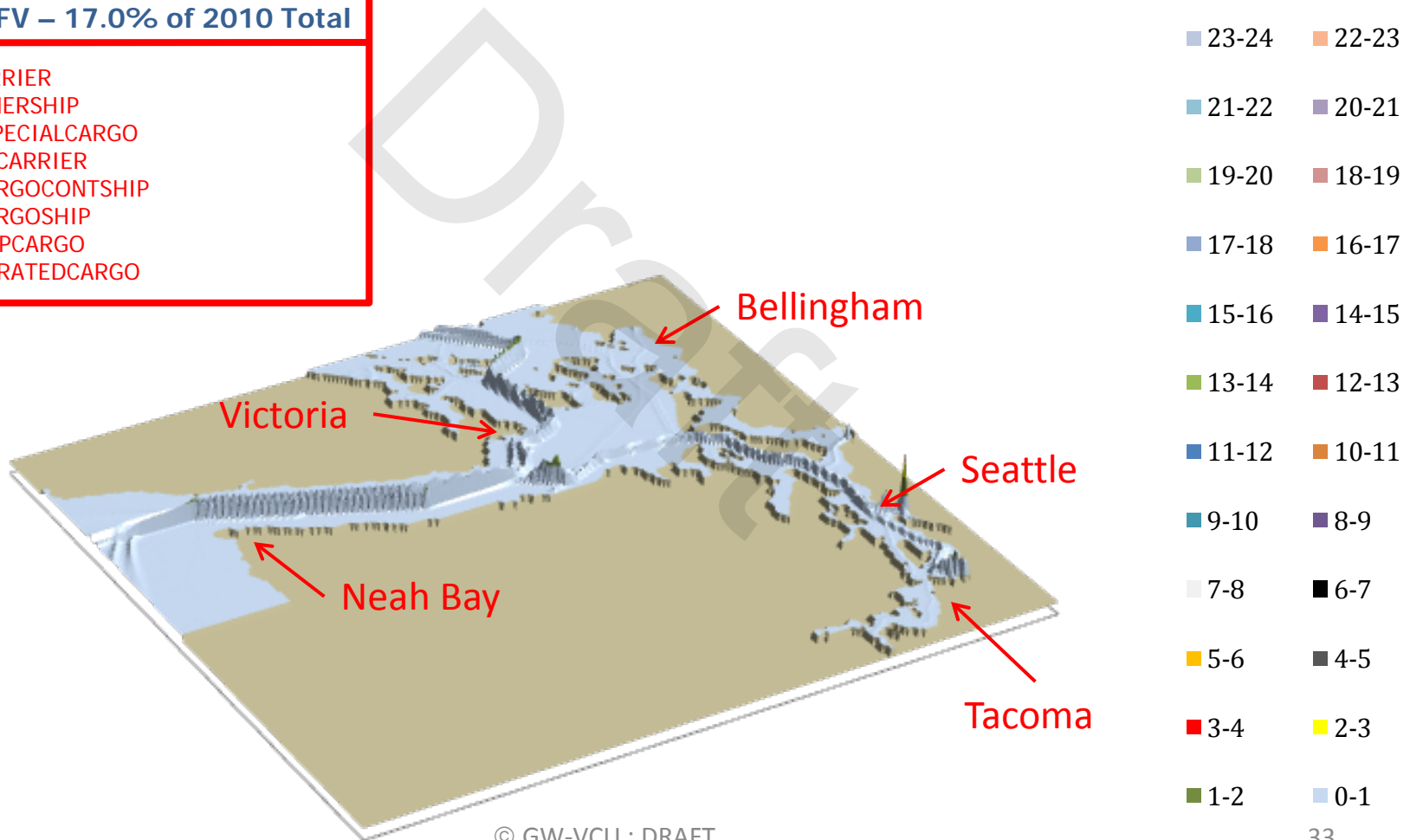


VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2010

P: Base Case 3D Risk Profile Cargo FV - Vessel Time Exposure: 17% of Base Case VTE

2010 CARGO FV – 17.0% of 2010 Total

- 54.6% - BULKCARRIER
- 27.8% - CONTAINERSHIP
- 08.1% - OTHERSPECIALCARGO
- 04.9% - VEHICLECARRIER
- 02.3% - ROROCARGOCONTSHIP
- 01.1% - ROROCARGOSHIP
- 00.8% - DECKSHIPCARGO
- 00.4% - REFRIGERATEDCARGO

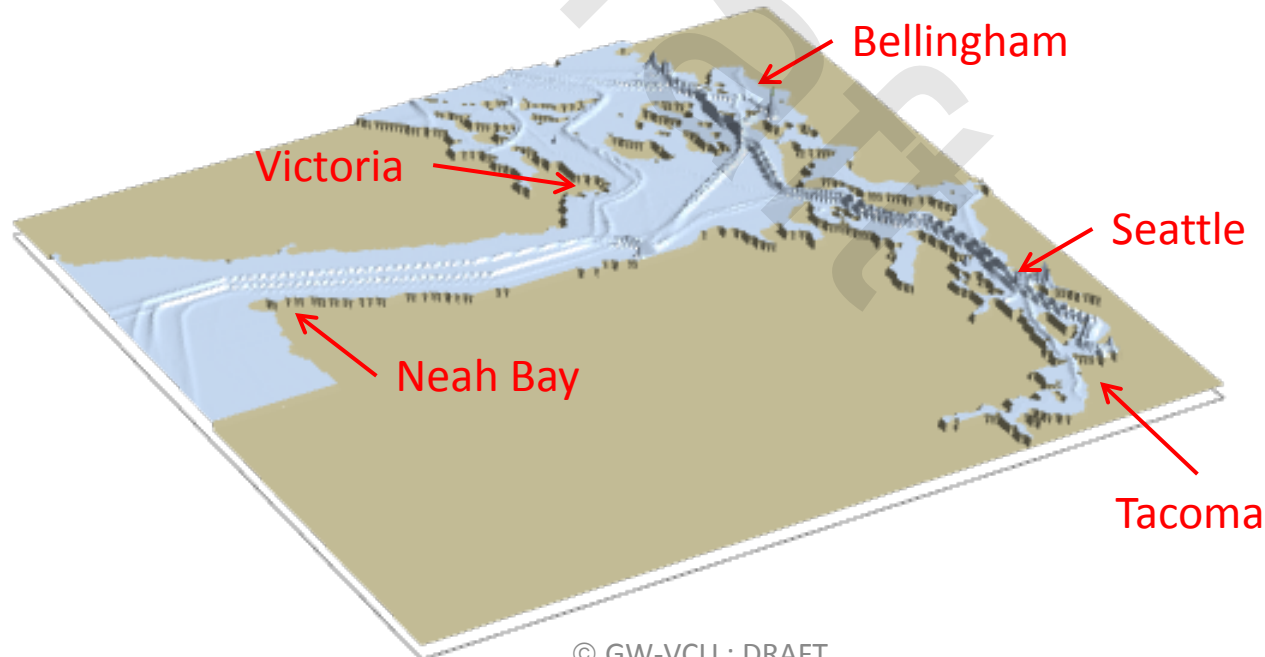


VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2010

P: Base Case 3D Risk Profile Tank FV - Vessel Time Exposure: 8% of Base Case VTE

2010 TANK FV – 8% of 2010 Total

54.5% - OILBARGE
24.4% - OILTANKER
11.3% - CHEMICALCARRIER
09.8% - ATB



VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2010

FV = Focus Vessel

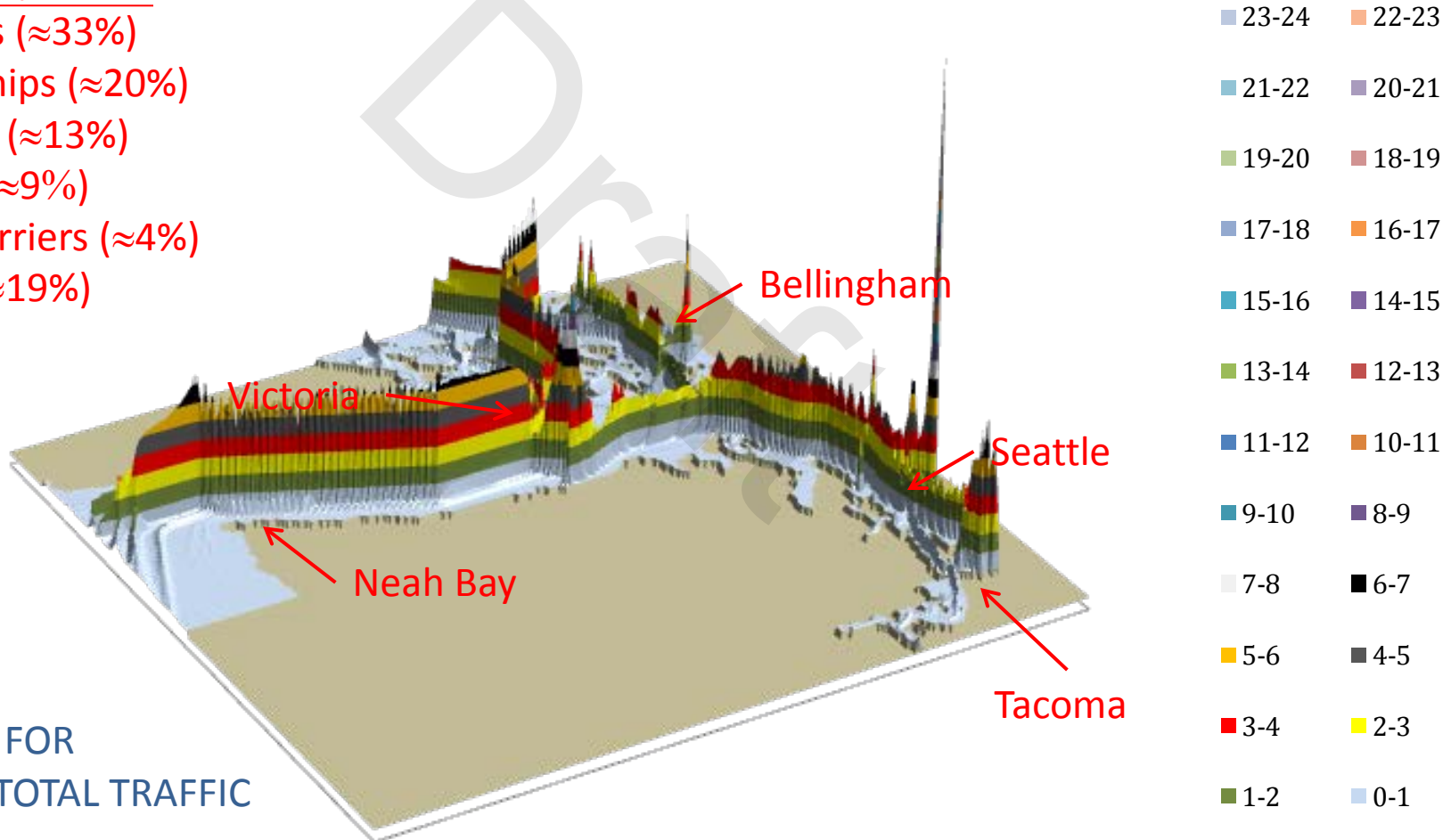
P: Base Case 3D Risk Profile

All FV - Vessel Time Exposure: 100% of Base Case VTE

Where do Focus Vessels Travel?

ALL FV (100%)

- Bulk Carriers (≈33%)
- Container Ships (≈20%)
- Other Cargo (≈13%)
- Oil Tankers (≈9%)
- Chemical Carriers (≈4%)
- Oil Barges (≈19%)
- ATB's (≈3%)



FV TRAFFIC
ACCOUNTS FOR
(≈25%) OF TOTAL TRAFFIC

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2010

FV = Focus Vessel

P: Base Case 3D Risk Profile

Tanker - Vessel Time Exp.: 9% of Base Case VTE

Where do Tankers Travel?

ALL FV

Bulk Carriers

Container Ships

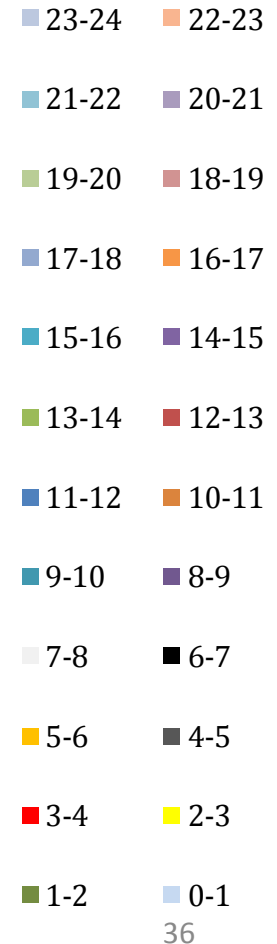
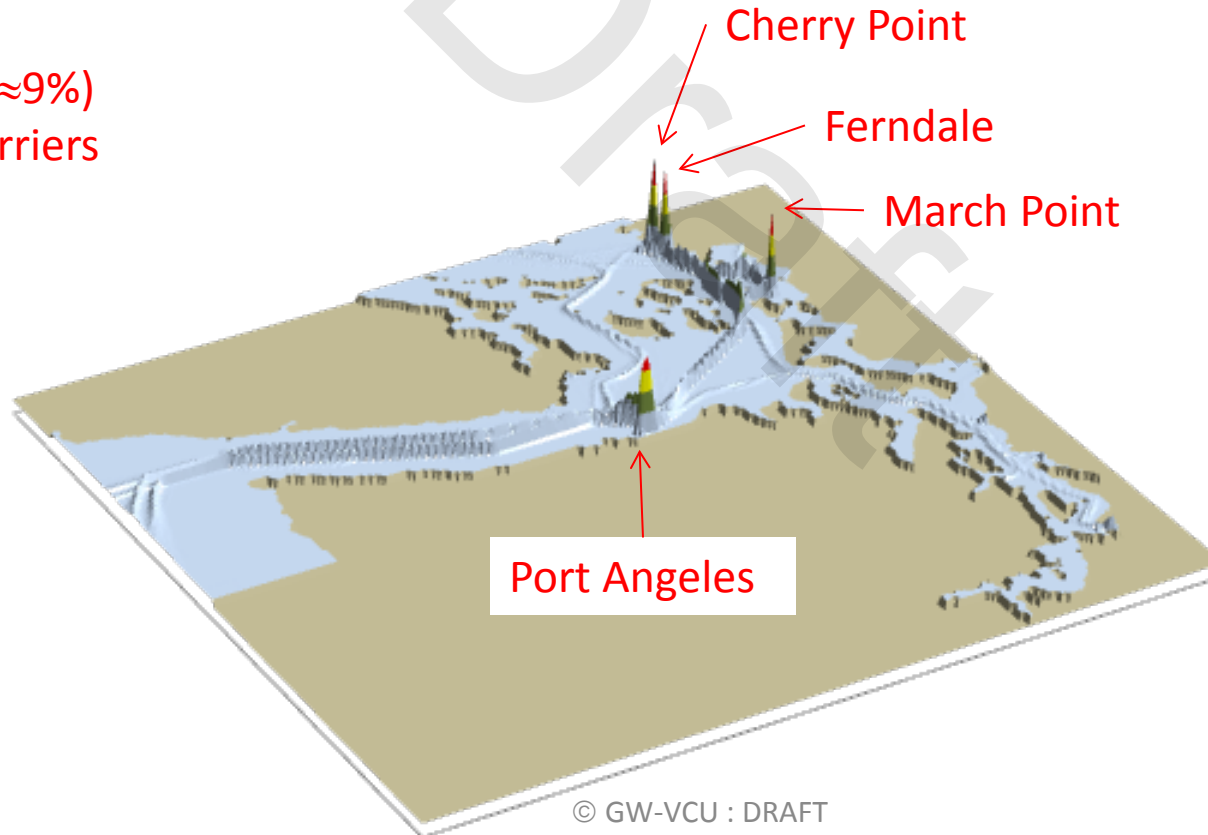
Other Cargo

Oil Tankers (≈9%)

Chemical Carriers

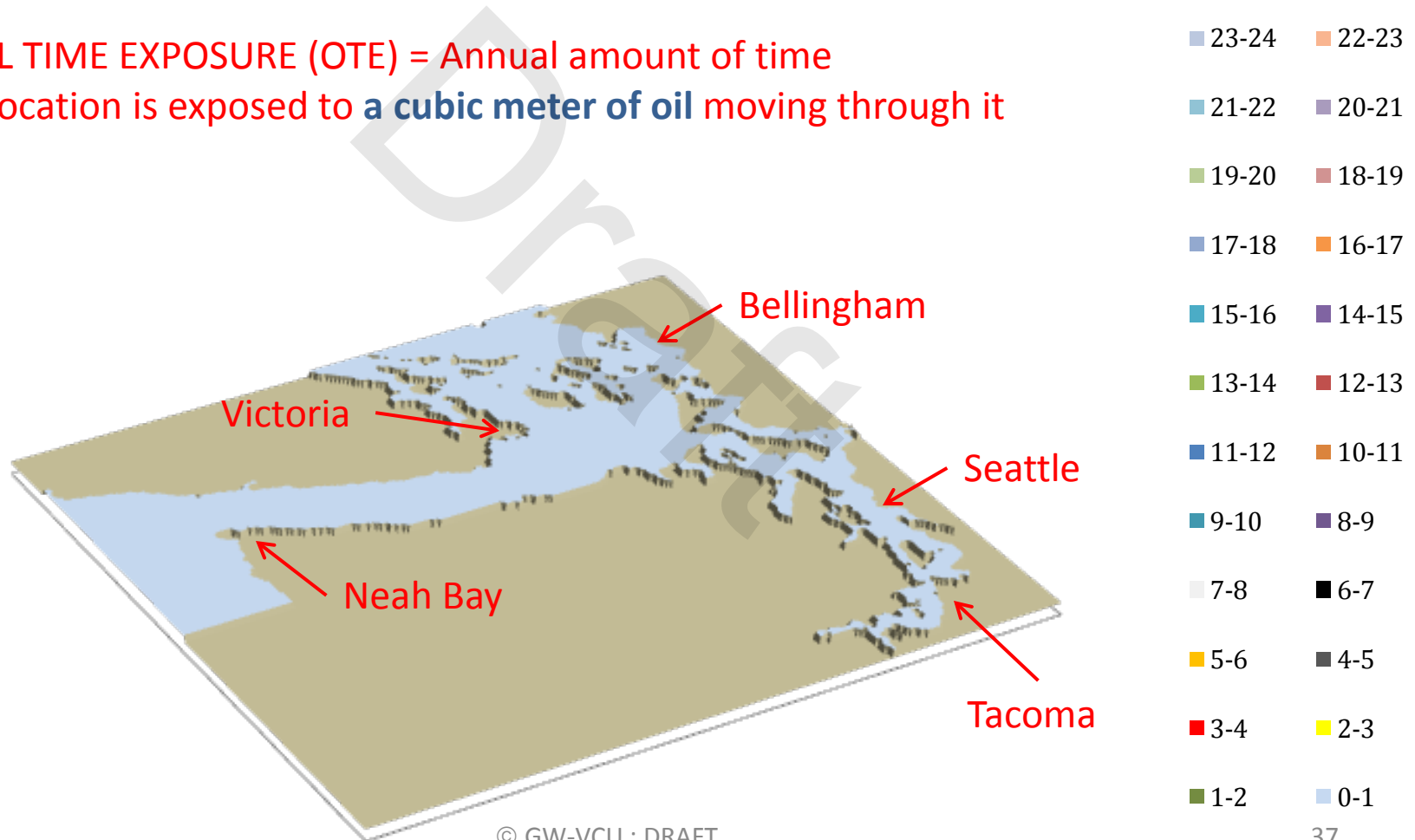
Oil Barges

ATB's



P: Base Case 3D Risk Profile MAP TO DISPLAY - ~~Vessel Time Exposure~~ Oil

OIL TIME EXPOSURE (OTE) = Annual amount of time a location is exposed to a cubic meter of oil moving through it



VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2010

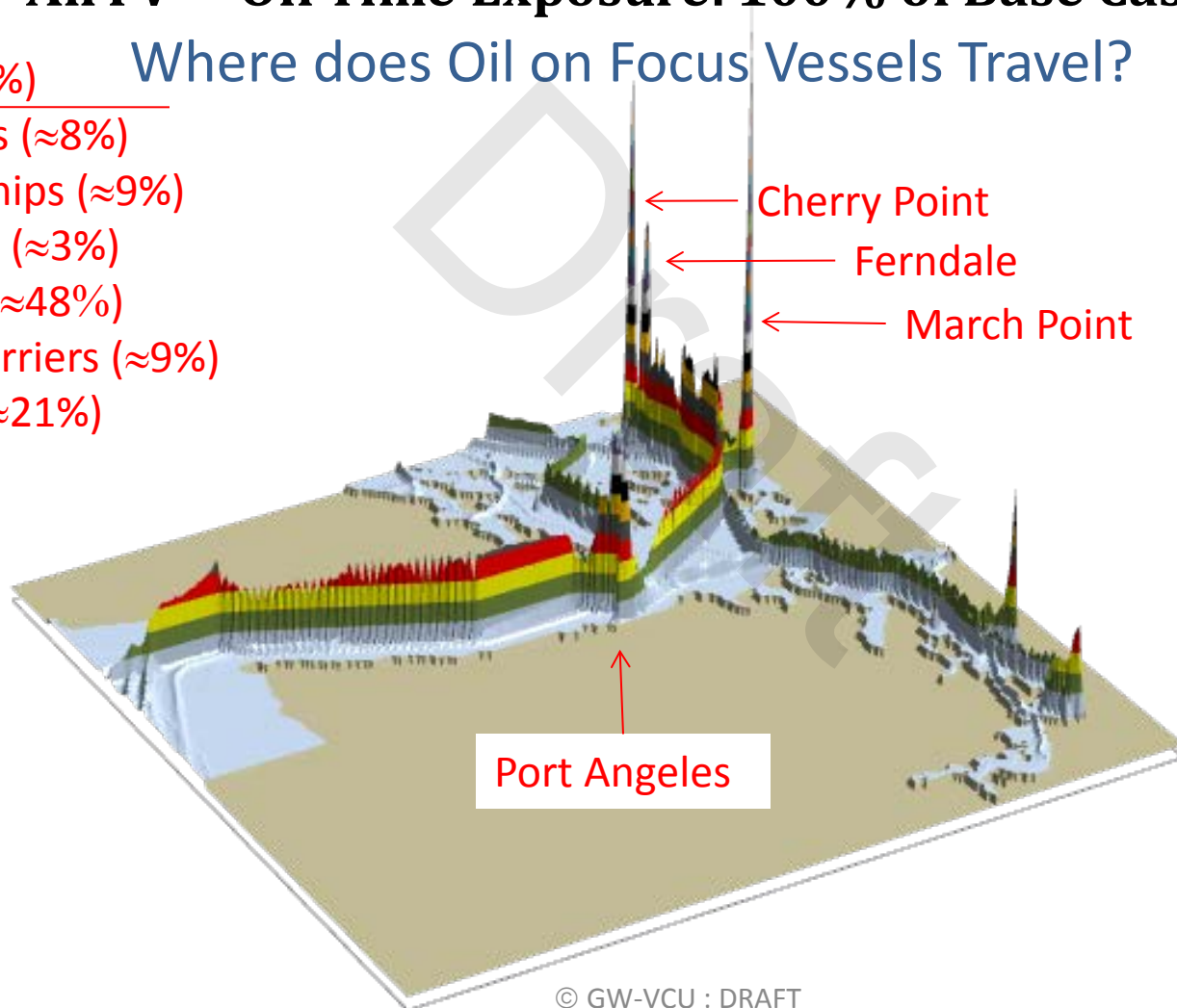
FV = Focus Vessel

P: Base Case 3D Risk Profile

All FV - Oil Time Exposure: 100% of Base Case OTE

ALL FV (100%) Where does Oil on Focus Vessels Travel?

- Bulk Carriers (≈8%)
- Container Ships (≈9%)
- Other Cargo (≈3%)
- Oil Tankers (≈48%)
- Chemical Carriers (≈9%)
- Oil Barges (≈21%)
- ATB's (≈3%)



VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2010

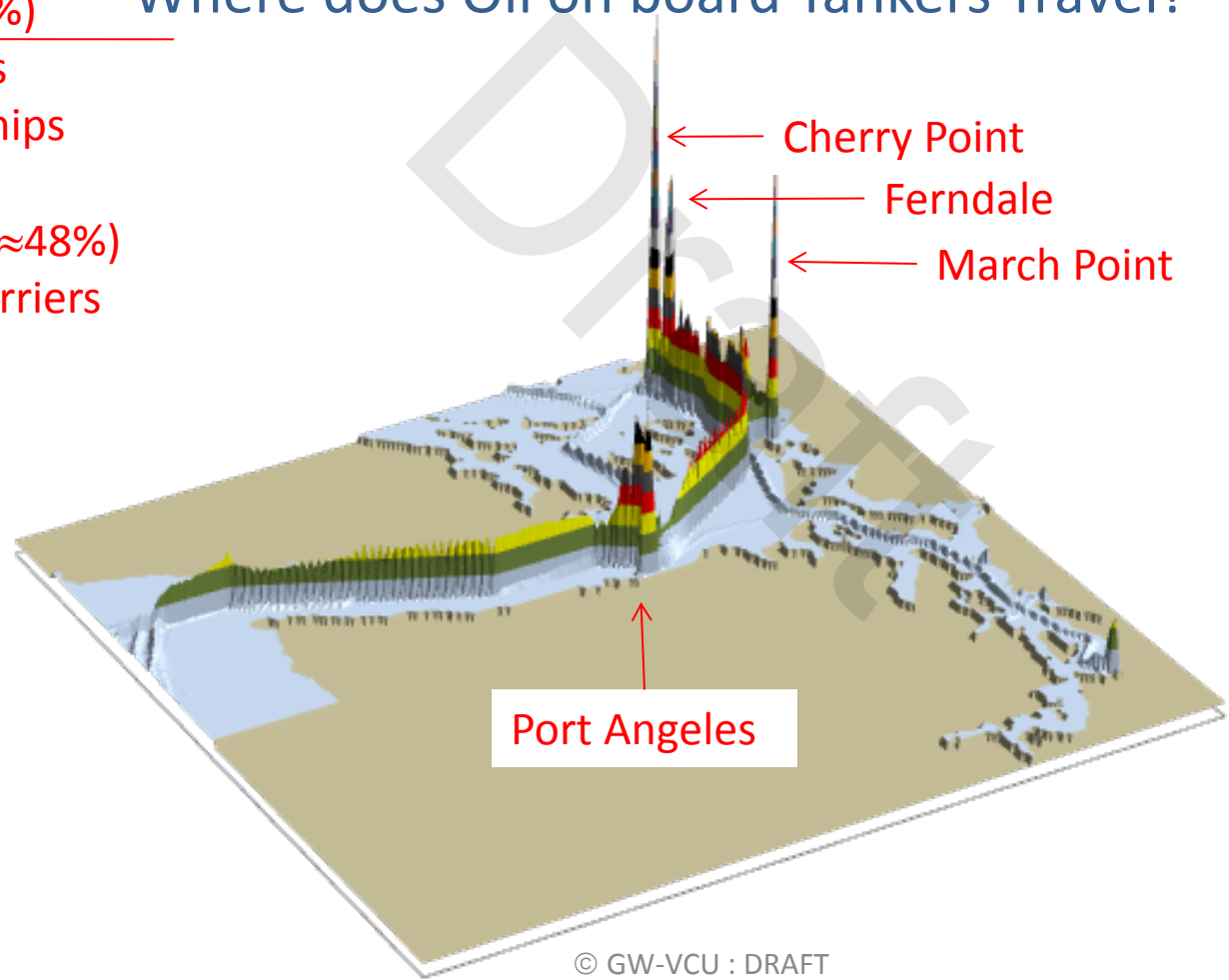
FV = Focus Vessel

P: Base Case 3D Risk Profile

Tanker - Oil Time Exposure: 48% of Base Case OTE

Where does Oil on board Tankers Travel?

- ALL FV (100%)
- Bulk Carriers
 - Container Ships
 - Other Cargo
 - Oil Tankers (≈48%)
 - Chemical Carriers
 - Oil Barges
 - ATB's

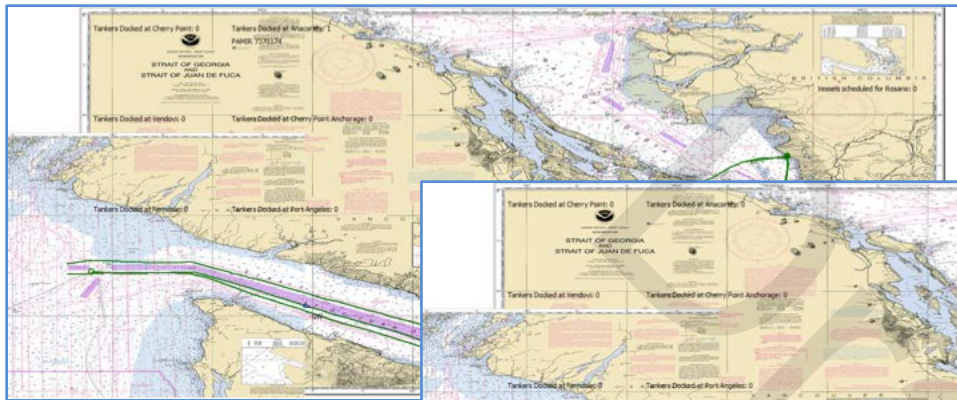


- | | |
|-------|-------|
| 23-24 | 22-23 |
| 21-22 | 20-21 |
| 19-20 | 18-19 |
| 17-18 | 16-17 |
| 15-16 | 14-15 |
| 13-14 | 12-13 |
| 11-12 | 10-11 |
| 9-10 | 8-9 |
| 7-8 | 6-7 |
| 5-6 | 4-5 |
| 3-4 | 2-3 |
| 1-2 | 0-1 |

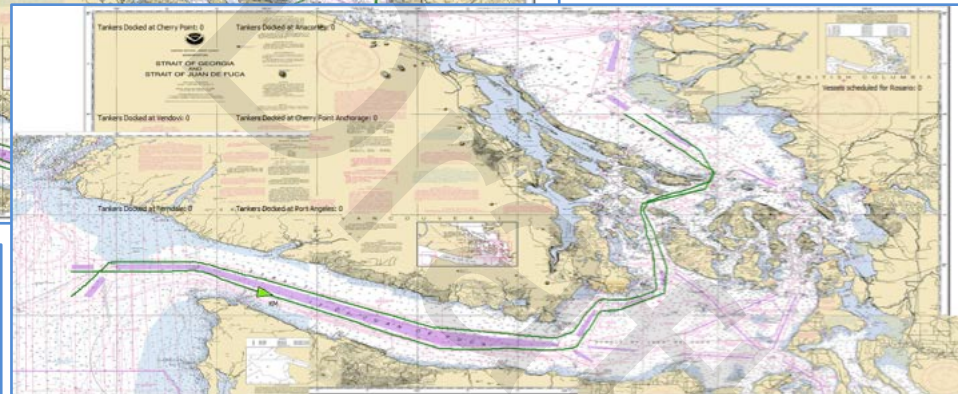
OUTLINE

1. Coin Tosses
2. Decision Making under Uncertainty
3. **VTRA 2010**
 - **Base Case Traffic Description**
 - **What-If and Benchmark Cases**

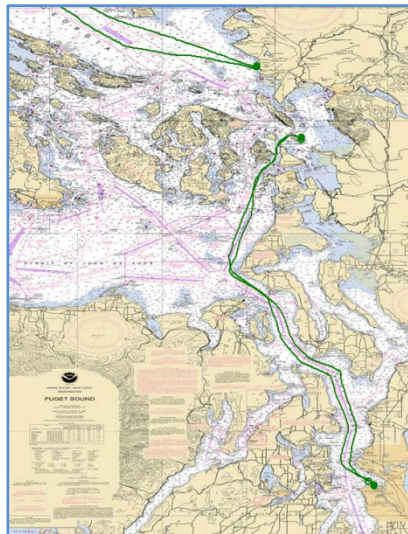
WHAT – IF SCENARIO ROUTES



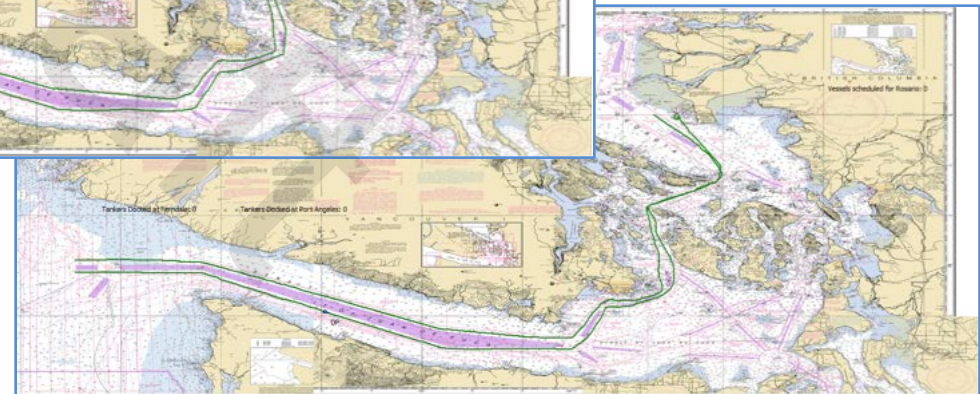
**GW487: + 487 BULK CARRIERS
+ Bunkering Support**



**KM348: + 348 TANKERS
+ Bunkering Support**



**BUNKERING SUPPORT
ROUTES**

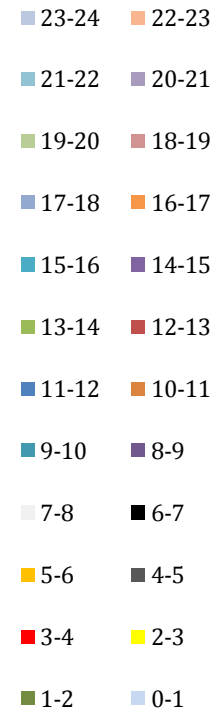
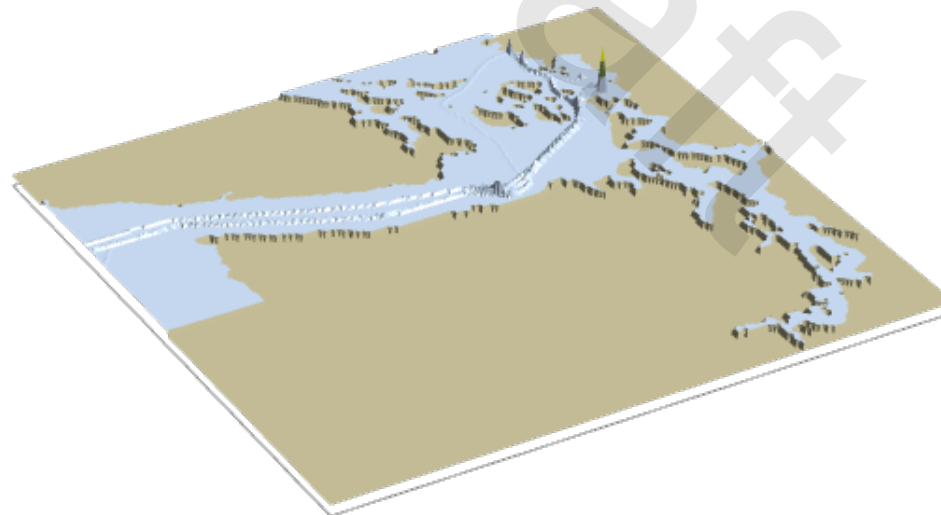


**DP415: 348 BULK CARRIERS
+ 67 CONTAINER SHIPS
+ Bunkering Support**

BENCH-MARK TANKER ROUTES

P: BC & HIGH TAN 3D Risk Profile
What-If FV - Vessel Time Exp.: 2% of Base Case VTE

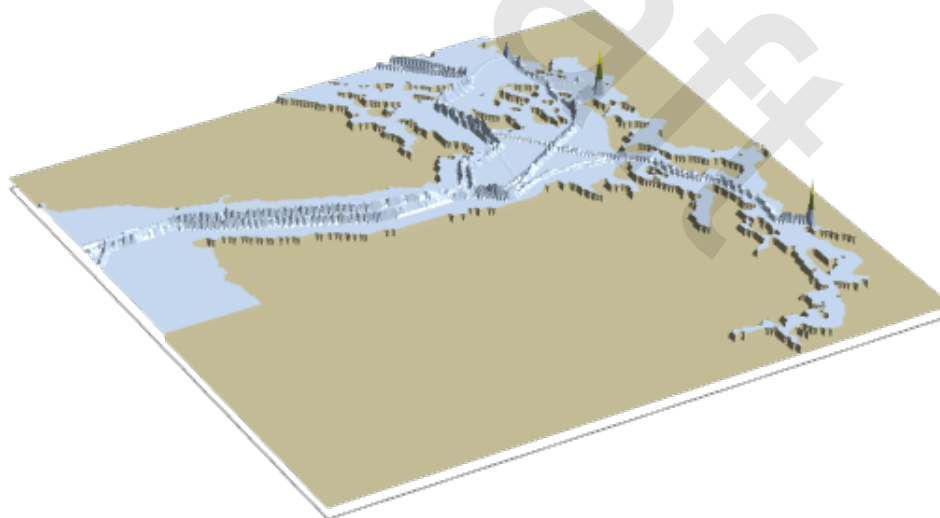
+ 142 Tankers added to Base Case
(2007 Historical High Year)



BENCH-MARK TANKER + CARGO ROUTES

P: BC & HIGH TAN + CFV 3D Risk Profile
What-If FV - Vessel Time Exp.: 6% of Base Case VTE

**+ 142 Tankers added to Base Case 2010
(2007 Historical High Year)**
**+ 287 Cargo Vessels added to Base Case 2010
(2011 Historical High Year)**



WHAT – IF SCENARIO ANALYSES

WHAT IF SCENARIO ANALYSIS				
	Vessel Time Exposure (VTE)	Oil Time Exposure (OTE)	Pot. Accident Frequency (PAF)	Pot. Oil Loss (POL)
P - Base Case	100%	100%	100%	100%

WHAT IF SCENARIO ANALYSIS	
P - Base Case	Modeled Base Case 2010 year informed by VTOSS 2010 data amongst other sources.
Q - GW - 487	Gateway expansion scenario with 487 additional bulk carriers and bunkering support
R - KM - 348	Transmountain pipeline expansion with additional 348 tankers and bunkering support
S - DP - 415	Delta Port Expansion with additional 348 bulk carriers and 67 container vessels
T - GW - KM - DP	Combined expansion scenario of above three expansion scenarios

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

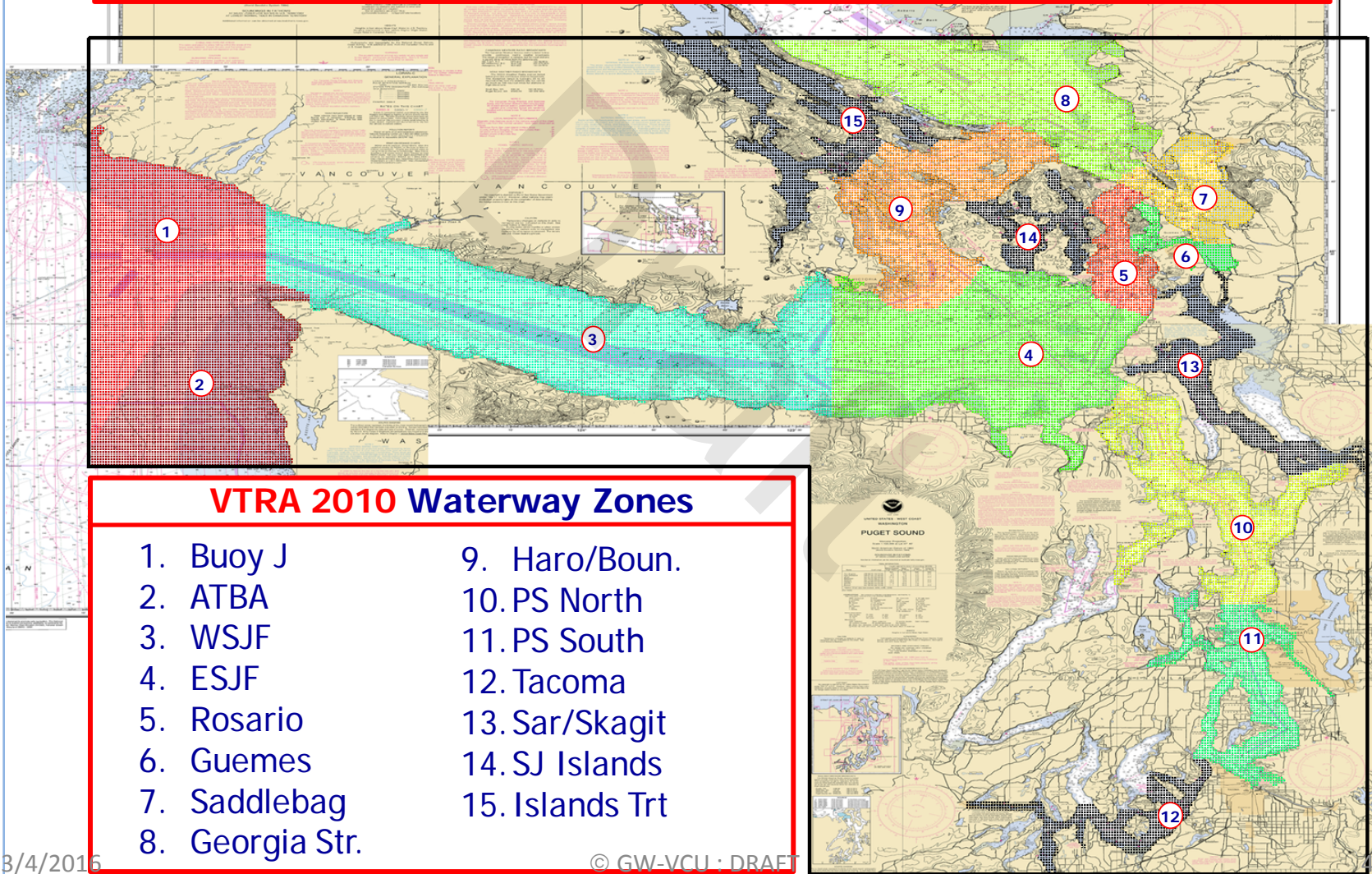
BENCH MARK ANALYSES ON CASE P

P - RMM SCENARIO REFERENCE POINT				
	Vessel Time Exposure (VTE)	Oil Time Exposure (OTE)	Pot. Accident Frequency (PAF)	Pot. Oil Loss (POL)
P - Base Case	100%	100%	100%	100%

CASE P BENCHMARK (BM) & SENSITIVITY ANALYSIS	
P - Base Case	Modeled Base Case 2010 year informed by VTOSS 2010 data amongst other sources.
P - BC & LOW TAN + CFV	Base Case with Tankers and Cargo Focus Vessels set at a low historical year
P - BC & LOW TAN	Base Case with Tankers set at a low historical year
P - BC & HIGH TAN	Base Case with Tankers set at a high historical year
P - BC & HIGH TAN + CFV	Base Case with Tankers and Cargo Focus Vessels set at a high historical year

CASE P BENCHMARK (BM) & SENSITIVITY ANALYSIS				
	Vessel Time Exposure (VTE)	Oil Time Exposure (OTE)	Pot. Accident Frequency (PAF)	Pot. Oil Loss (POL)
P - Base Case	100%	100%	100%	100%
P - BC & LOW TAN + CFV	-3% 97%	-14% 86%	-5% 95%	-20% 80%
P - BC & LOW TAN	-2% 98%	-13% 87%	-4% 96%	-22% 78%
P - BC & HIGH TAN	+2% 102%	+14% 114%	+3% 103%	+9% 109%
P - BC & HIGH TAN + CFV	+7% 107%	+15% 115%	+4% 104%	+8% 108%

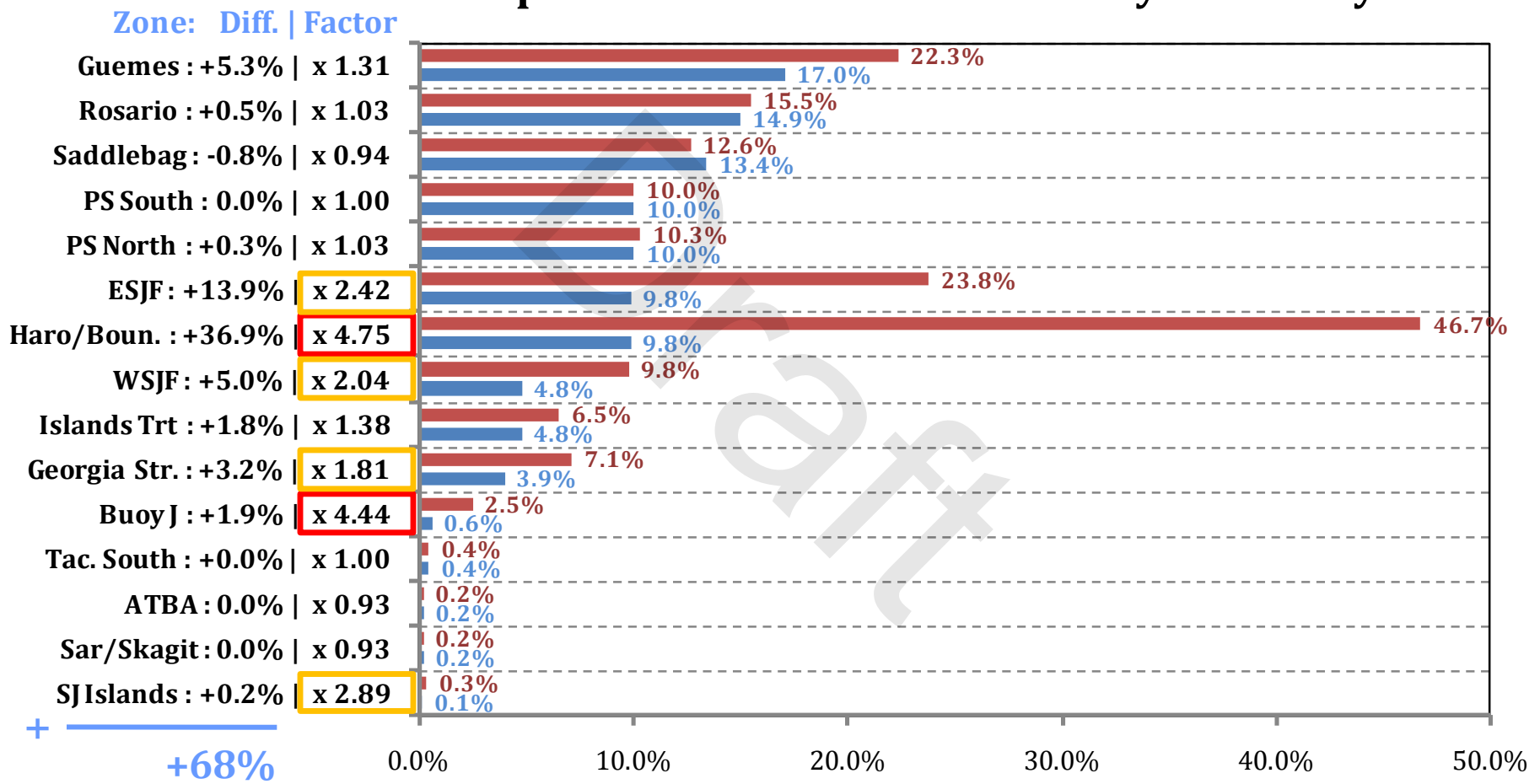
DEFINITION OF 15 WATERWAY ZONES



VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2010



Comparison of Potential Oil Loss by Waterway Zone



% Base Case Pot. Oil Loss (POL) - ALL_FV

QUESTIONS?