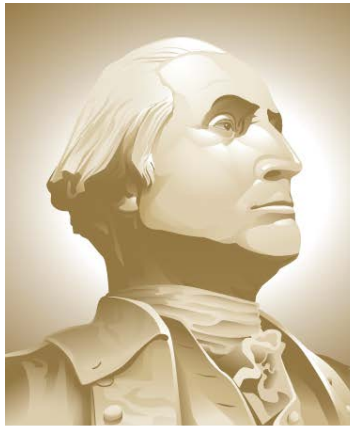


VTRA 2015 Case Q : GW – 487 and VTRA 2015 Calibration Case Comparison



**THE GEORGE
WASHINGTON
UNIVERSITY**

WASHINGTON, DC

VCU

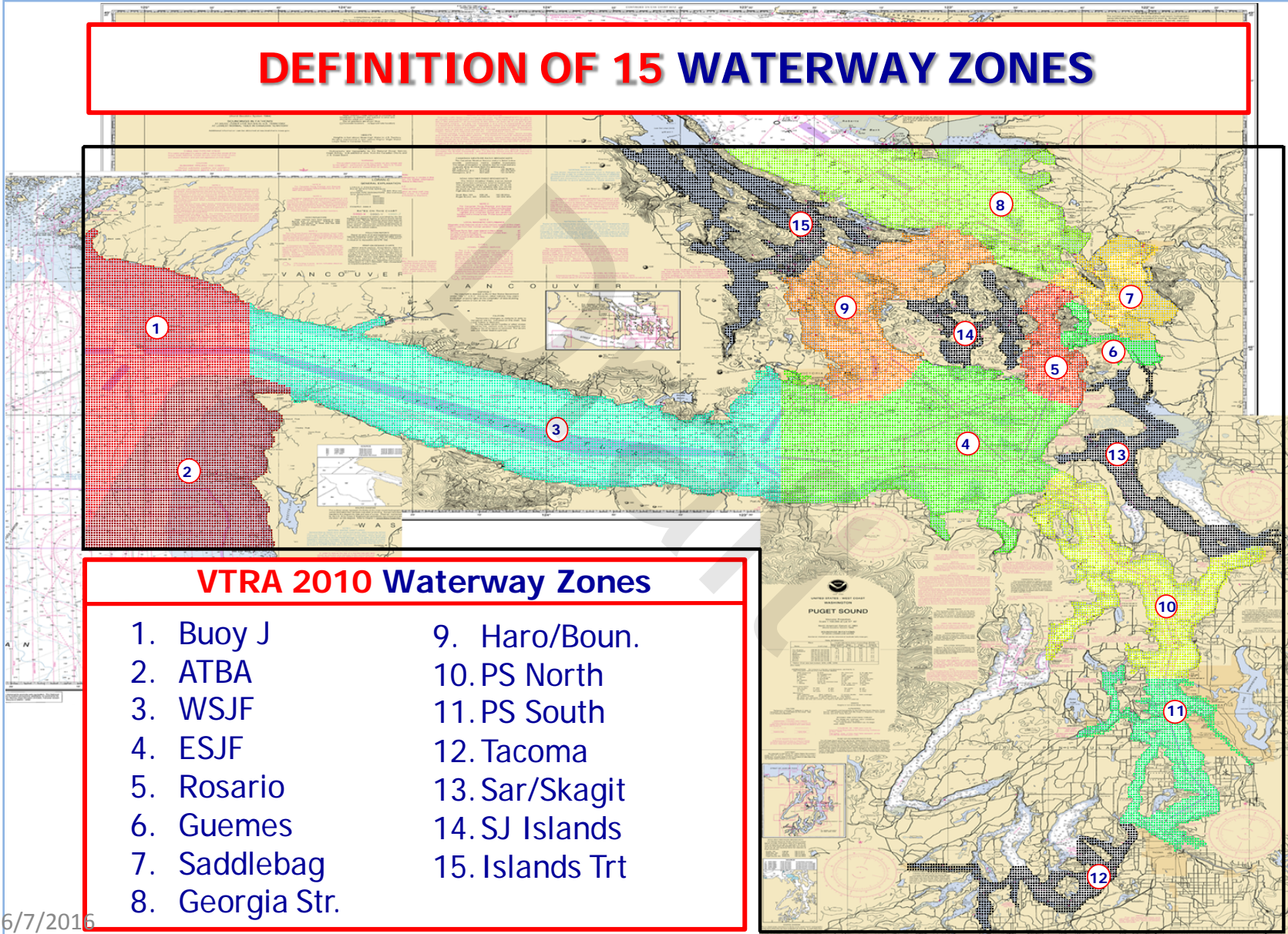
Jason R.W. Merrick (VCU) and J. Rene van Dorp (GW)

June 1st - 2nd, 2016

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



DEFINITION OF 15 WATERWAY ZONES



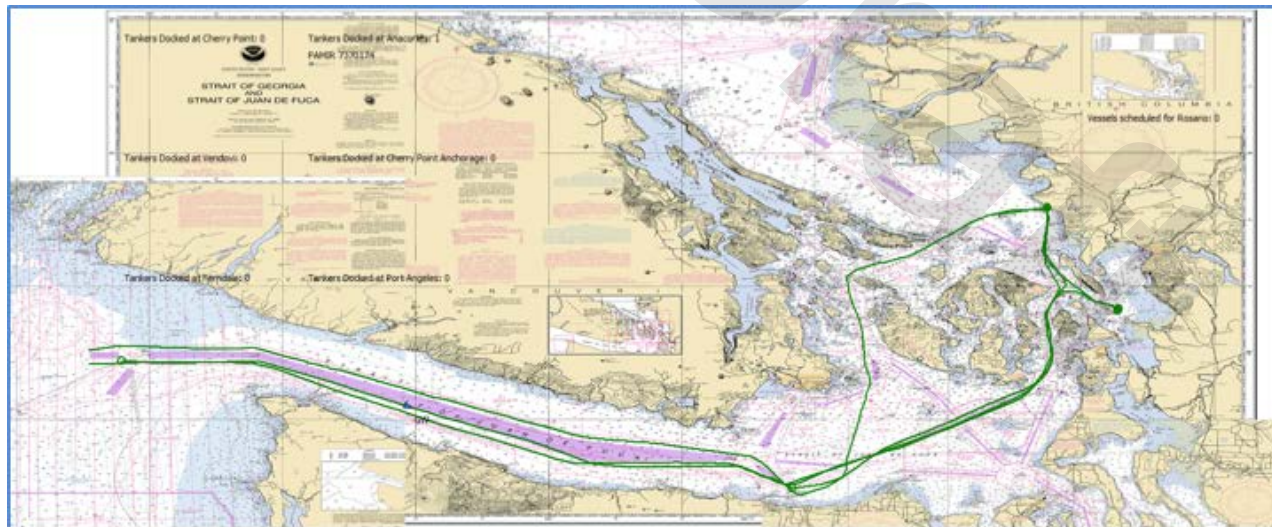
VTRA 2010 Waterway Zones

- | | |
|-----------------|-----------------|
| 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. | |

VTRA '15 Case : Q – GW 487

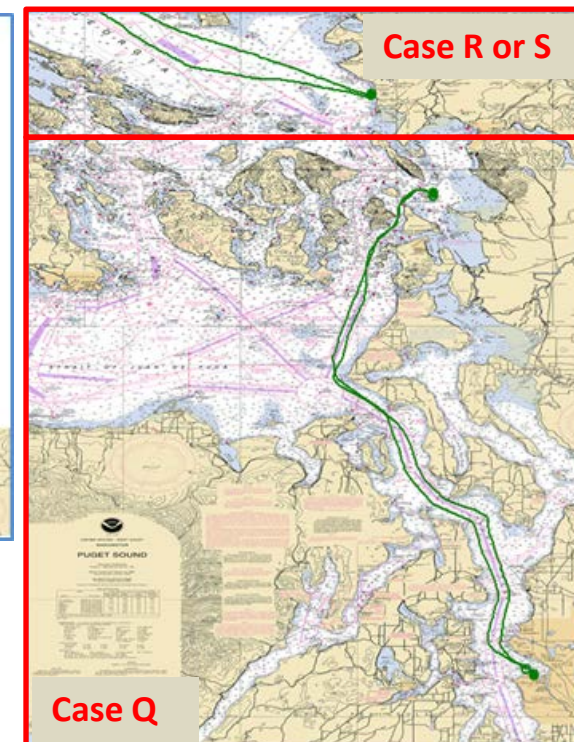
CASE Q	VTRA 2010 Case Q	VTRA 2015 Updated Case Q
Bulk Carriers	487	487
Bunkering Support	229	229

Bulk Carrier Routes – Case Q



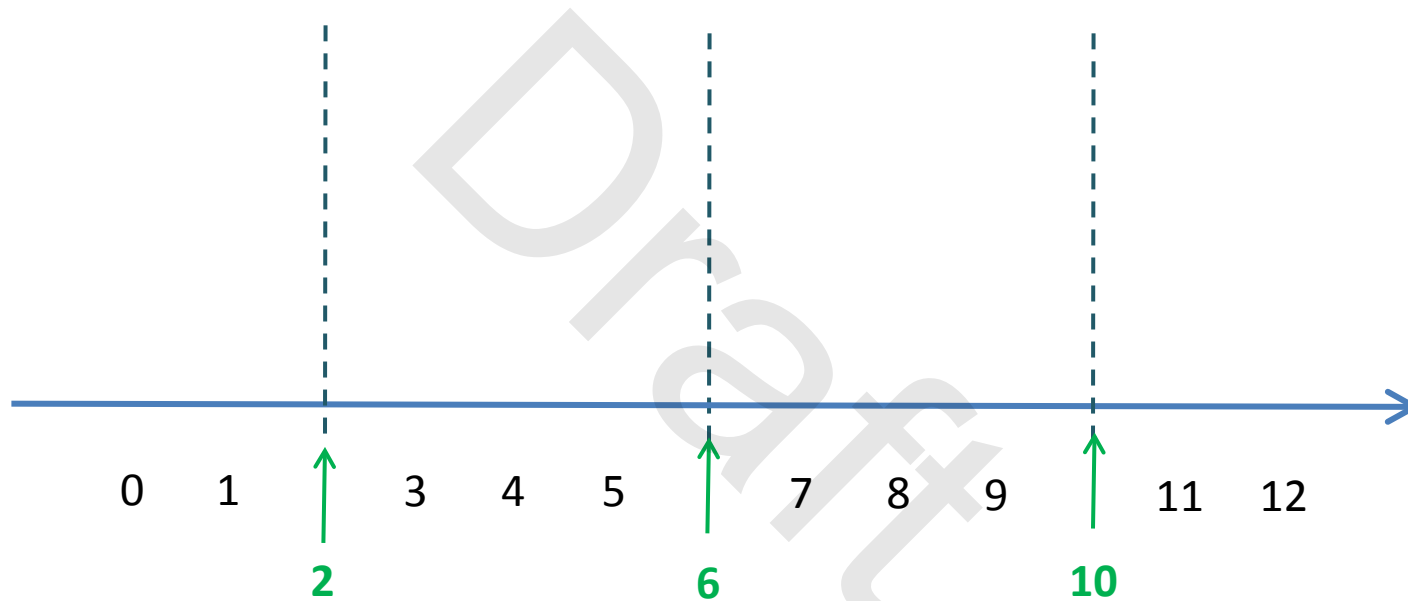
+ Update on Arrival Process

Bunker Routes



NOT SELECTED

VTRA 2010 – What If FV Scheduled Arrival Pattern Model



VTRA 2010 Equidistant Fixed Arrival Pattern (one every 4 days)

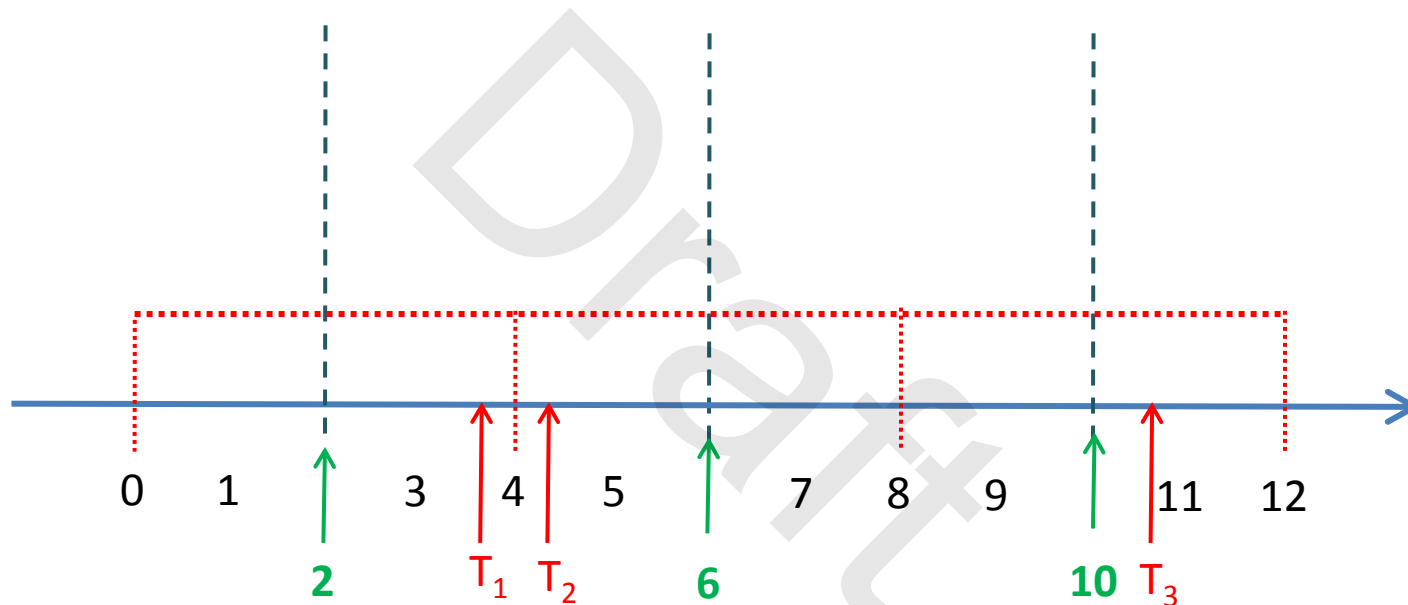
% OF VTRA '10 BASE CASE POTENTIAL TOTAL OIL LOSS: CASE Q: GW - 487 : 112.4%

% OF VTRA '15 BASE CASE POTENTIAL TOTAL OIL LOSS: CASE Q: GW - 487 : 108.3%

NOT SELECTED

VTRA 2015 – What If FV

Complete Random Arrival Pattern Model



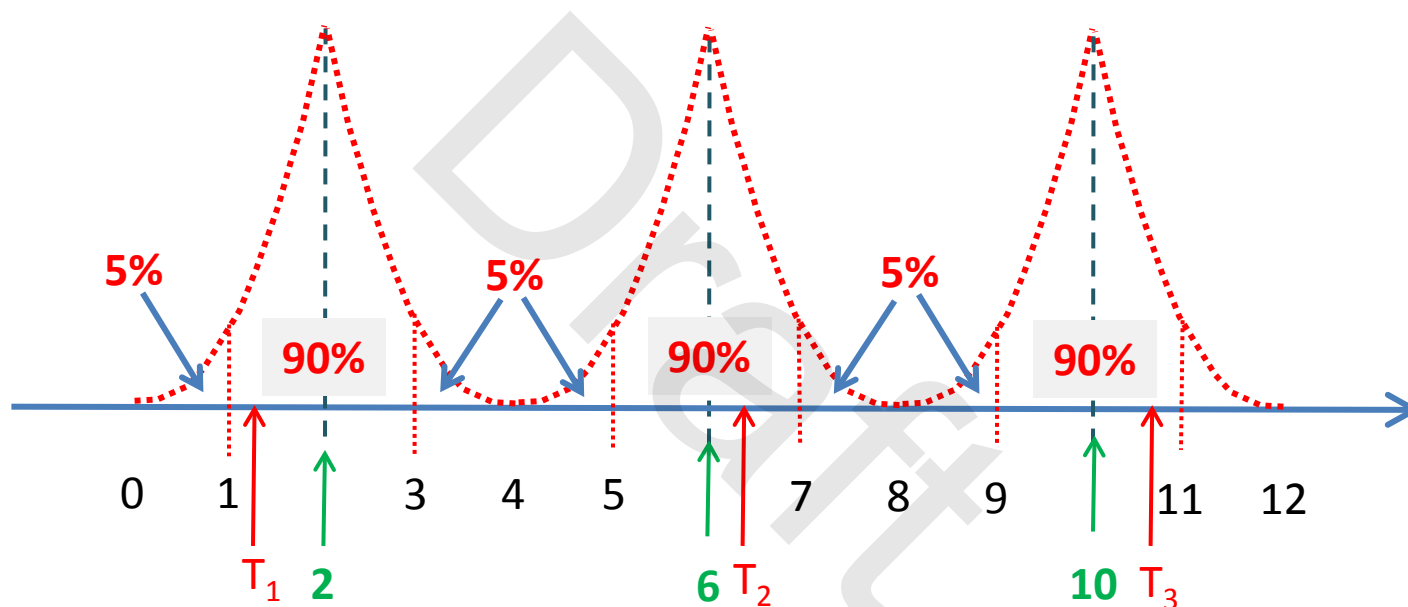
VTRA 2010 Equidistant Fixed Arrival Pattern (one every 4 days)

VTRA 2015 Random Arrival Pattern (3 Random Times in 12 days)

% OF VTRA '10 BASE CASE POTENTIAL TOTAL OIL LOSS: CASE Q: GW - 487 : 112.4%

% OF VTRA '15 BASE CASE POTENTIAL TOTAL OIL LOSS: CASE Q: GW - 487 : 108.5%

SELECTED VTRA 2015 – What If FV Scheduled Random Arrival Pattern Model



VTRA 2010 Equidistant Fixed Arrival Pattern (one every 4 days)

VTRA 2015 Random Arrival Pattern (3 Random Times in 12 days)

% OF VTRA '10 BASE CASE POTENTIAL TOTAL OIL LOSS: CASE Q: GW - 487 : 112.4%

% OF VTRA '15 BASE CASE POTENTIAL TOTAL OIL LOSS: CASE Q: GW - 487 : 106.5%

By Waterway Zone Risk Comparison

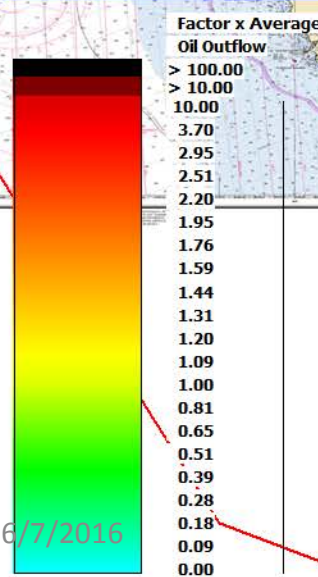
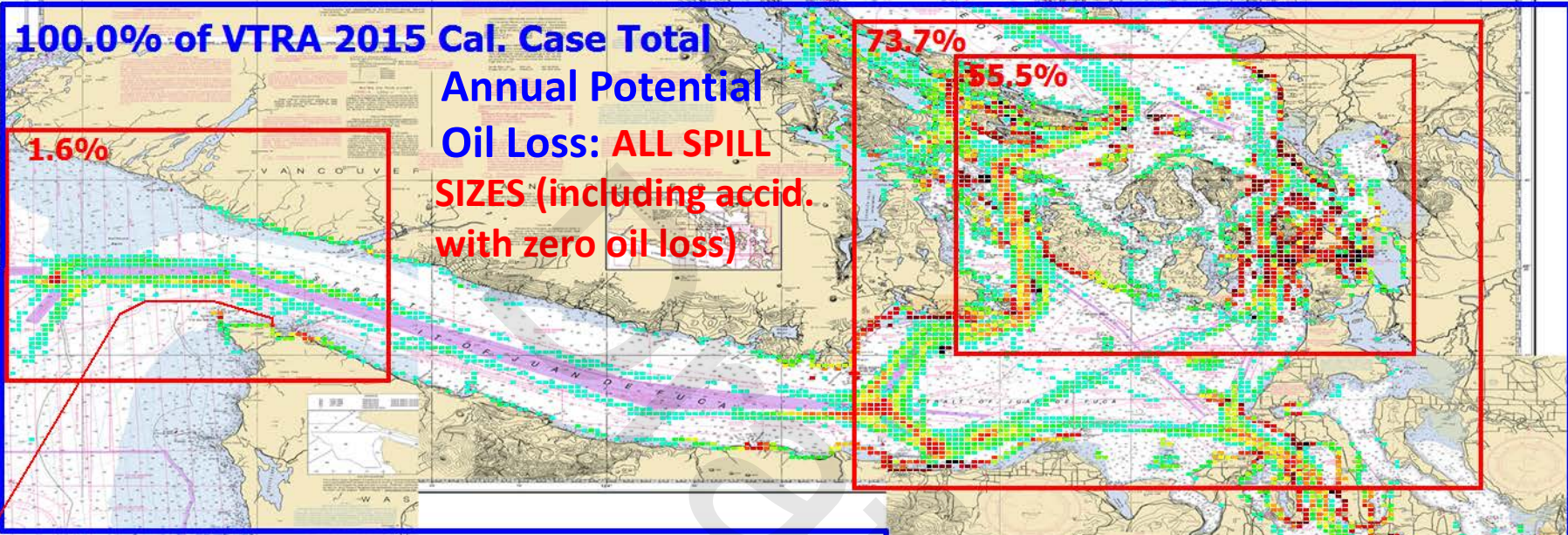
Oil Spill Size Category:

ALL SPILL SIZES

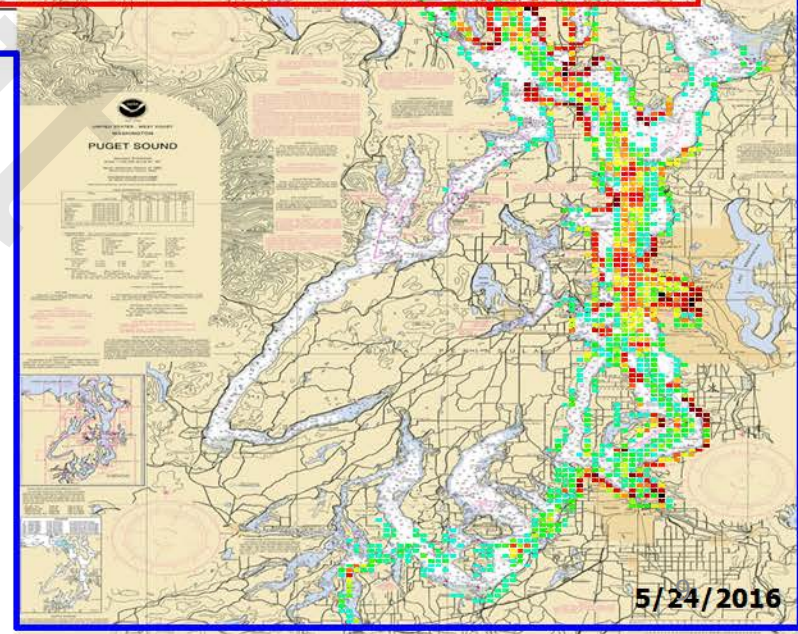
VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



VTRA 2015 CALIBRATION CASE - ALL FV



VTRA '15: Cal. Case
GEOGRAPHIC PROFILE
OF POTENTIAL ANNUAL
OIL LOSS OF ACCIDENTS
IN SPILL SIZE CATEGORY
ALL SPILL SIZES



VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

Q: VTRA 2010 - GATEWAY 487 - ALL FV

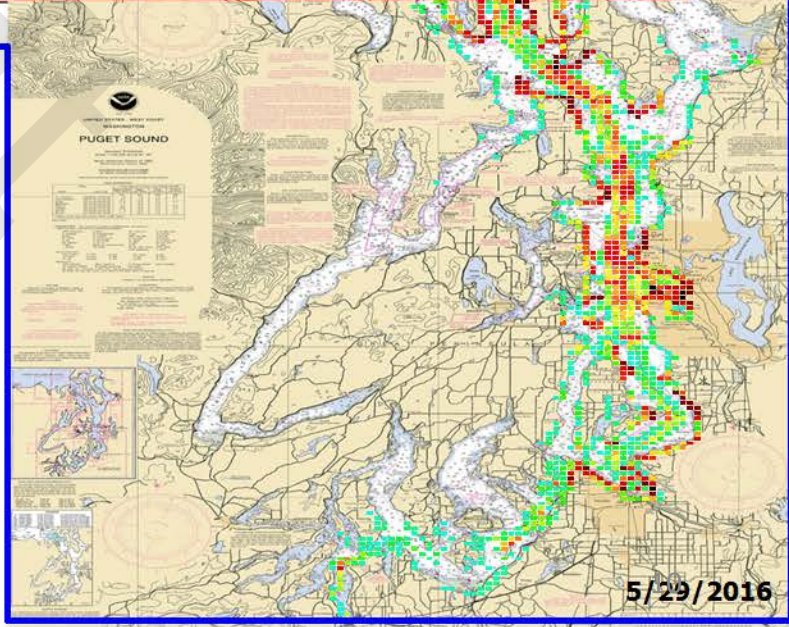
106.5% of VTRA 2015 Cal. Case Total Annual Potential Oil Loss: ALL SPILL SIZES (including accid. with zero oil loss)

79.3%
60.3%

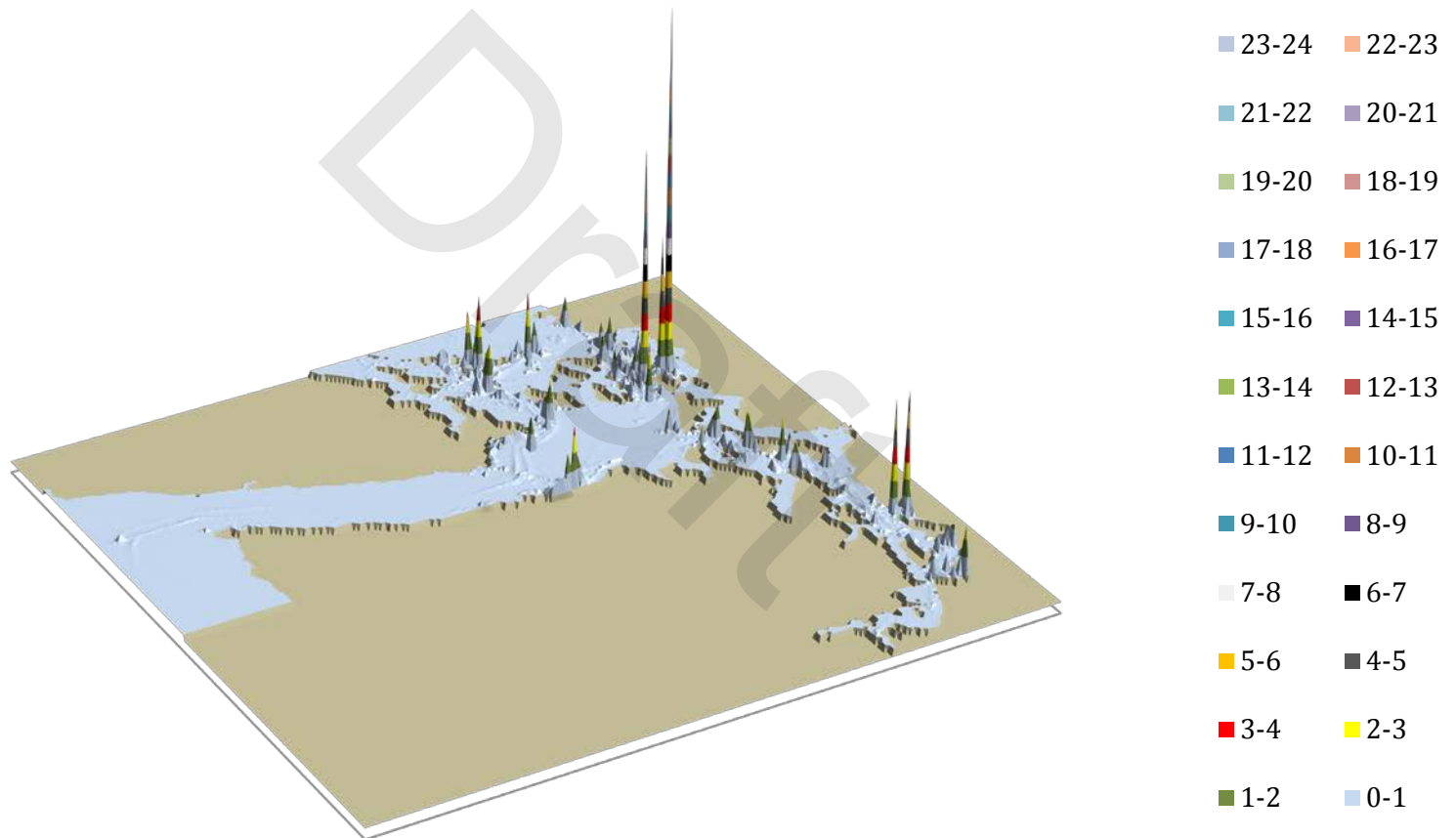
1.8%



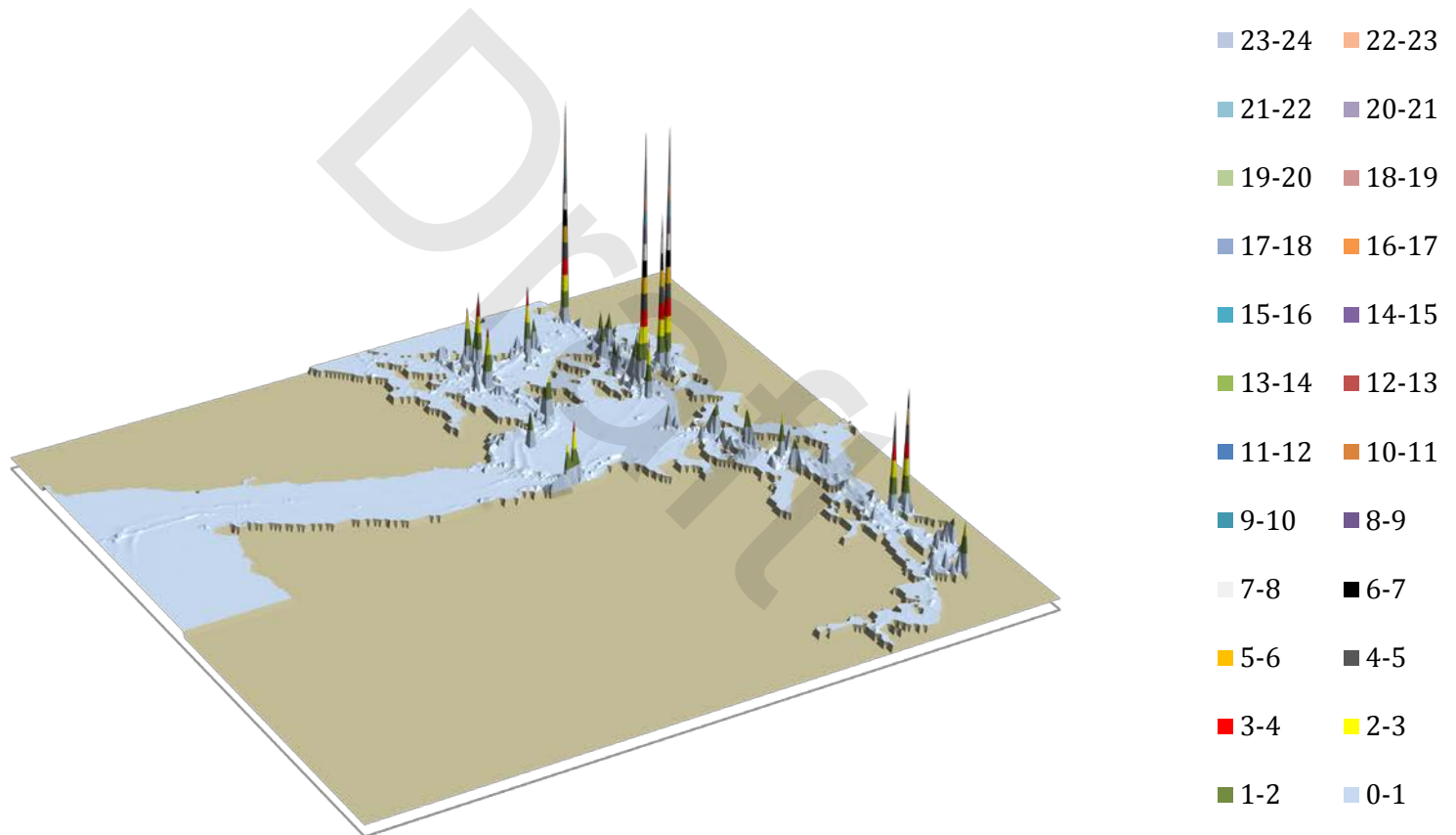
VTRA '15 Case Q: GW - 487
GEOGRAPHIC PROFILE OF POTENTIAL ANNUAL OIL LOSS OF ACCIDENTS IN SPILL SIZE CATEGORY **ALL SPILL SIZES**



VTRA '15: Call. Case 3D Risk Profile All FV - Pot.Grou+Coll.+All.Oil Loss: 100% of Cal. Case POL



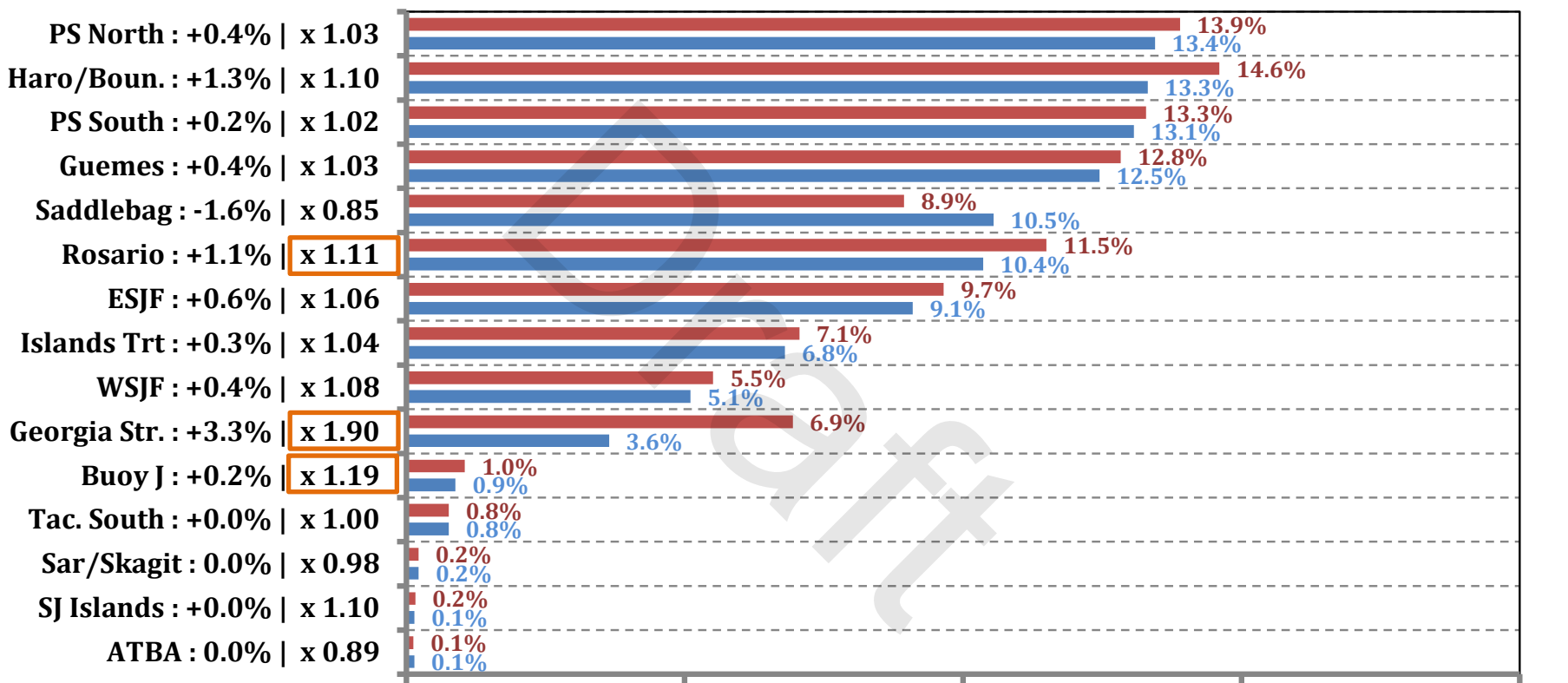
Q: GW - 487 3D Risk Profile All FV - Pot. Grou+Coll.Oil Loss: 107% of Cal. Case POL



VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



% Base Case Oil (Coll. + Grou. + All.) Loss - ALL_FV



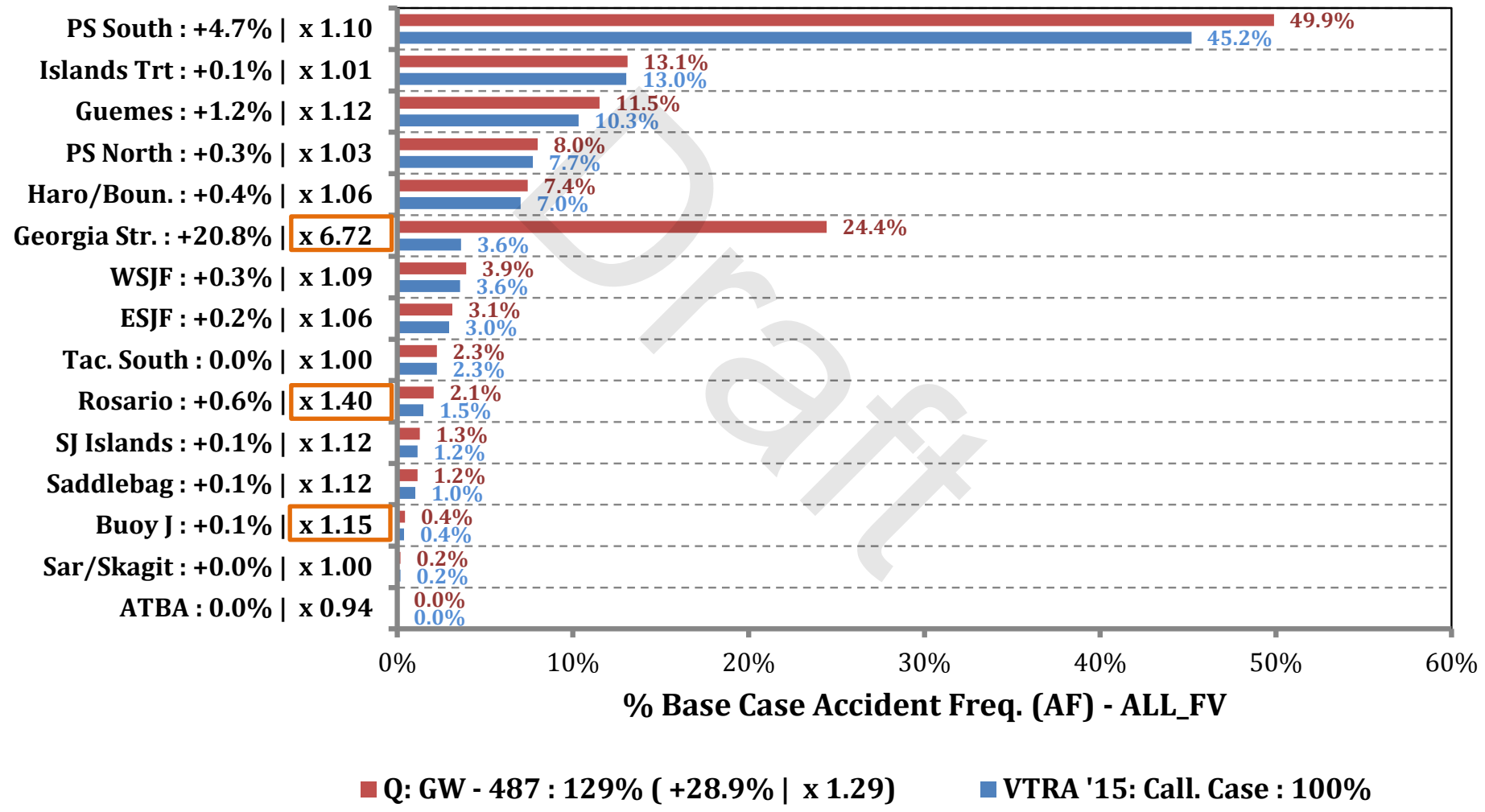
% Base Case Oil (Coll.+Grou.) Loss (OL) - ALL_FV

■ Q: GW - 487 : 107% (+6.5% | x 1.07) ■ VTRA '15: Call. Case : 100%

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



% Base Case Accident (C+G+A) Frequency - ALL_FV



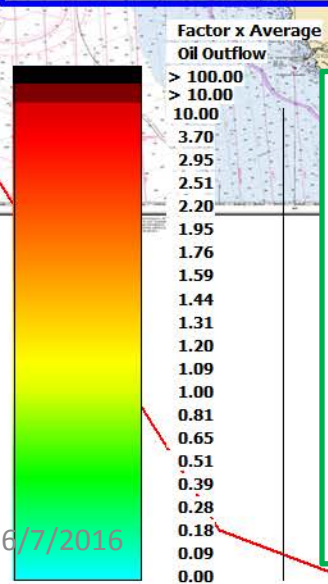
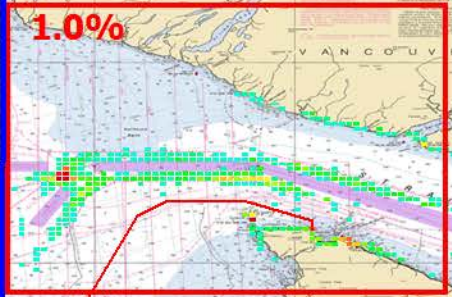
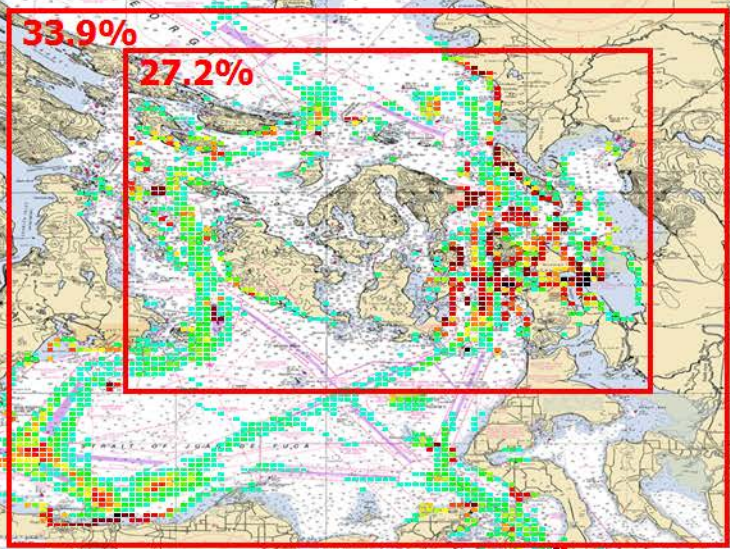
By Waterway Zone Risk Comparison

Oil Spill Size Category:
2500 m³ or more

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

VTRA 2015 CALIBRATION CASE - ALL FV

39.8% of VTRA 2015 Cal. Case Total Annual Potential Oil Loss:
SPILL SIZES LARGER THAN 2,500 m³



VTRA '15: Cal. Case
GEOGRAPHIC PROFILE
OF POTENTIAL
ANNUAL OIL LOSS
OF ACCIDENTS
WITH SPILL SIZE
2,500 m³ or more

≈ 0.47% Probability
of Spill Occurrence
in 10 years

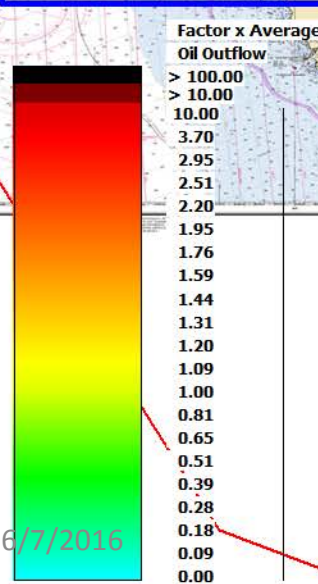
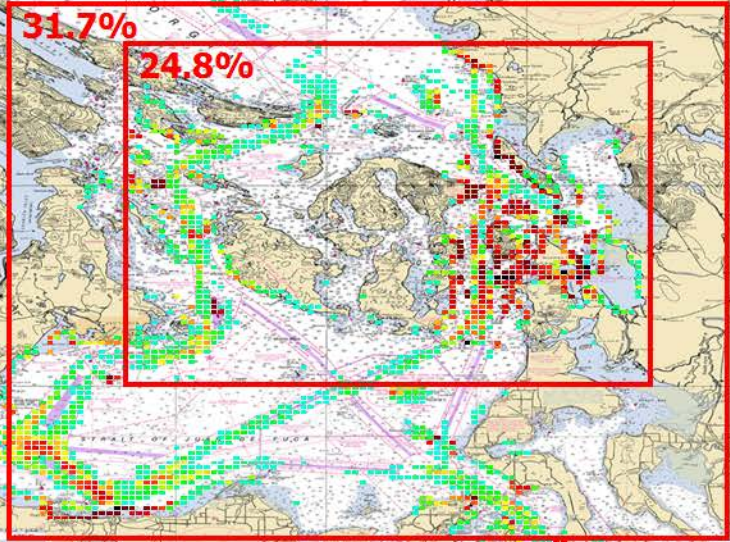
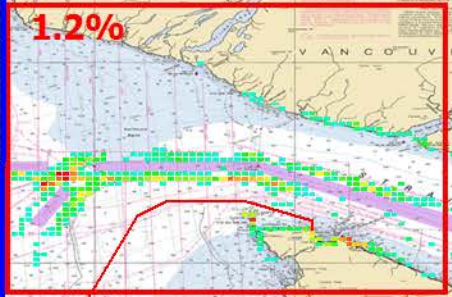
Average of ≈ 5,746 m³
Per Potential Spill
(≈ 4,942 Metric. Tons)

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

Q: VTRA 2010 - GATEWAY 487 - ALL FV

37.8% of VTRA 2015 Cal. Case Total Annual Potential Oil Loss:

SPILL SIZES LARGER THAN 2,500 m³



VTRA '15 Case Q: GW - 487

GEOGRAPHIC PROFILE OF POTENTIAL ANNUAL OIL LOSS OF ACCIDENTS WITH SPILL SIZE 2,500 m³ or more

≈ 0.43% Probability of Spill Occurrence in 10 years

Average of ≈ 5,846 m³ Per Potential Spill (≈ 5,028 Metric Tons)

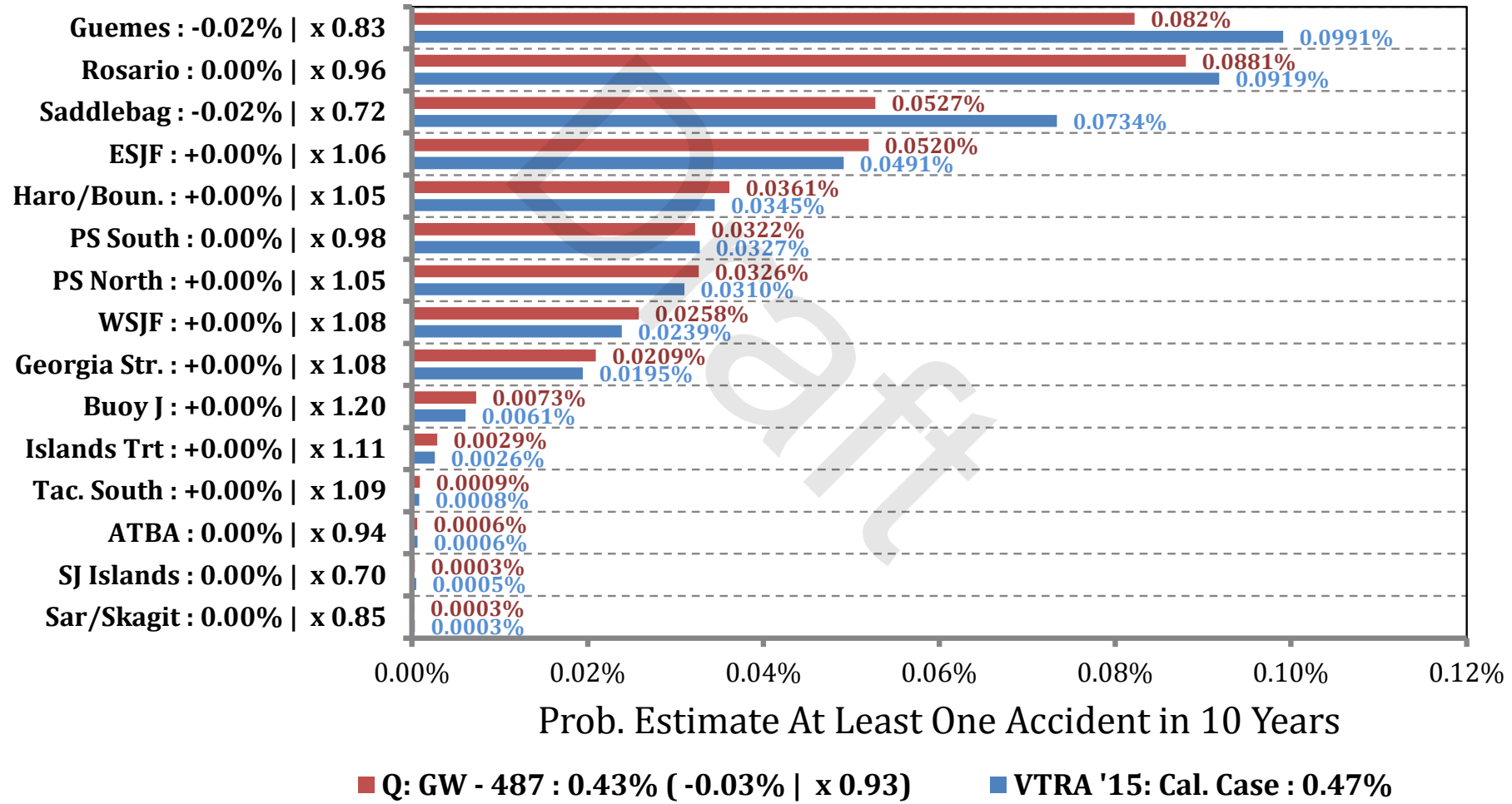
6/7/2016

5/29/2016

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



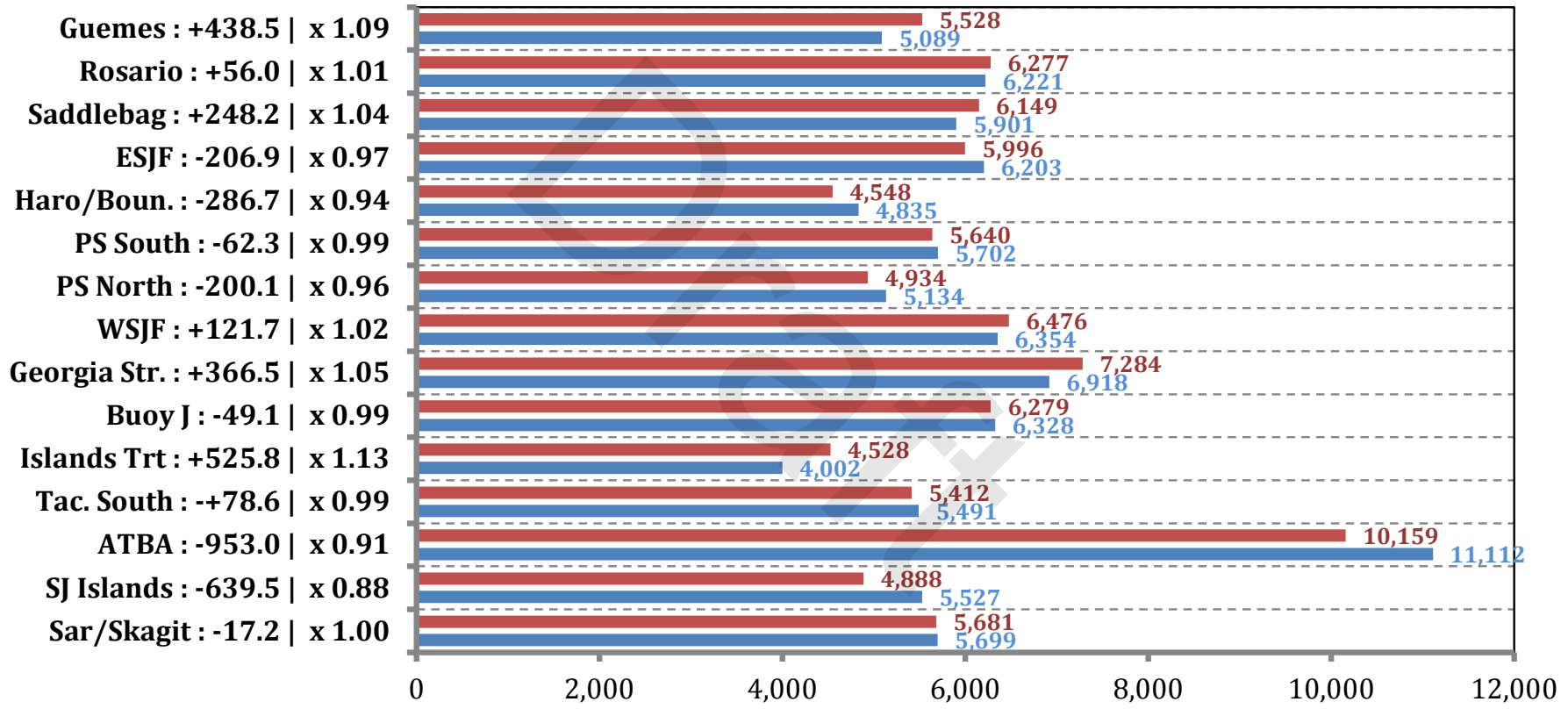
Prob. Estimate At Least One Accident in 10 Years - ALL_FV - Oil Spill Size Category: 2500 cubic meters or more



VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



Potential Spill Size (m3) per Accident - ALL_FV - Oil Spill Size Category: 2500 cubic meters or more



■ Q: GW - 487 : 5846 m3 (+99.7 | x 1.02) ■ VTRA '15: Cal. Case : 5746 m3

By Waterway Zone Risk Comparison

Oil Spill Size Category:

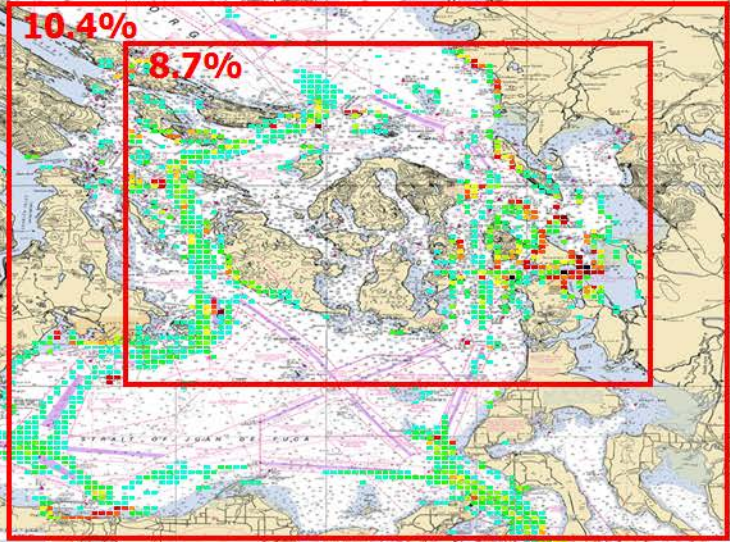
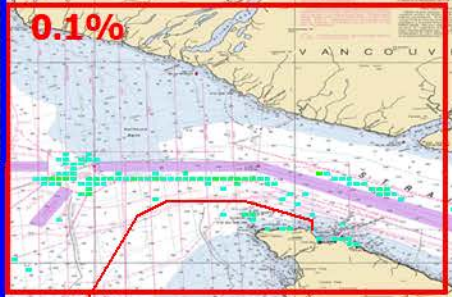
1000 m³ - 2500 m³

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

VTRA 2015 CALIBRATION CASE - ALL FV

12.2% of VTRA 2015 Cal. Case Total Annual Potential Oil Loss:

SPILL SIZES BETWEEN 1,000 m³ - 2,500 m³



VTRA '15: Cal. Case
GEOGRAPHIC PROFILE OF POTENTIAL ANNUAL OIL LOSS OF ACCIDENTS WITH SPILL SIZE **BETWEEN 1,000 m³ - 2,500 m³**

≈ 0.50% Probability of Spill Occurrence in 10 years

Average of ≈ 1,628 m³ Per Potential Spill (≈ 1,400 Metric Tons)

6/7/2016

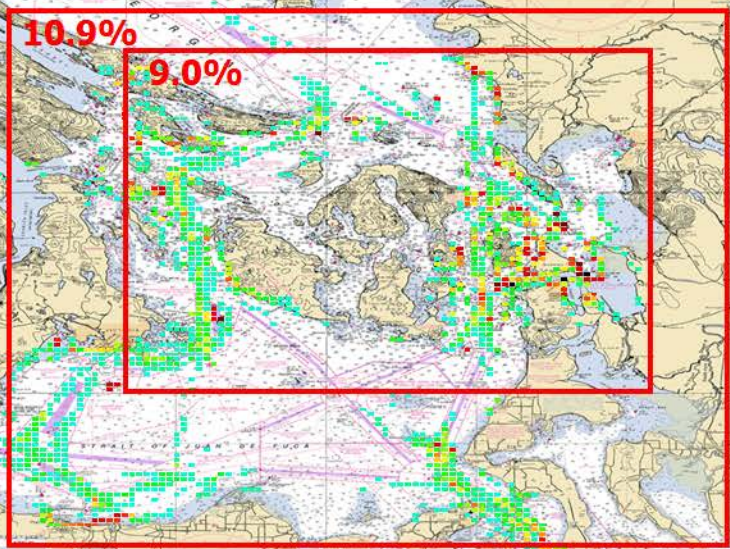
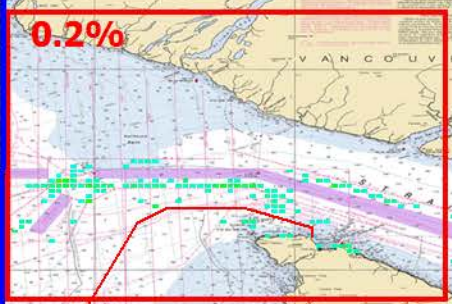
5/24/2016

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

Q: VTRA 2010 - GATEWAY 487 - ALL FV

13.0% of VTRA 2015 Cal. Case Total Annual Potential Oil Loss:

Oil Loss: SPILL SIZES BETWEEN 1,000 m³ - 2,500 m³



VTRA '15 Case Q: GW - 487
GEOGRAPHIC PROFILE OF POTENTIAL ANNUAL OIL LOSS OF ACCIDENTS WITH SPILL SIZE **BETWEEN 1,000 m³ - 2,500 m³**

≈ 0.55% Probability of Spill Occurrence in 10 years

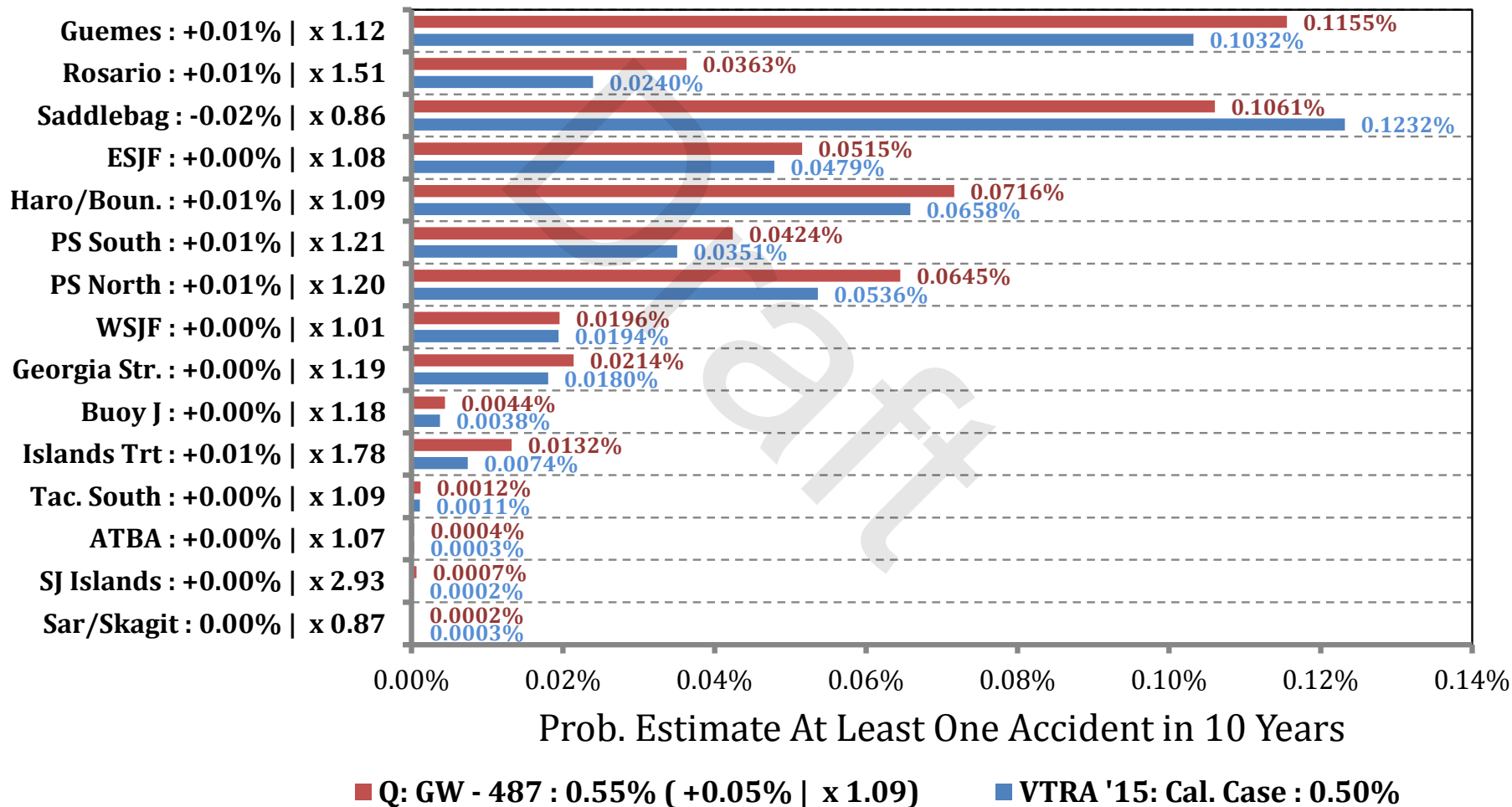
Average of ≈ 1,596 m³ Per Potential Spill (≈ 1,373 Metric Tons)

6/7/2016

5/29/2016

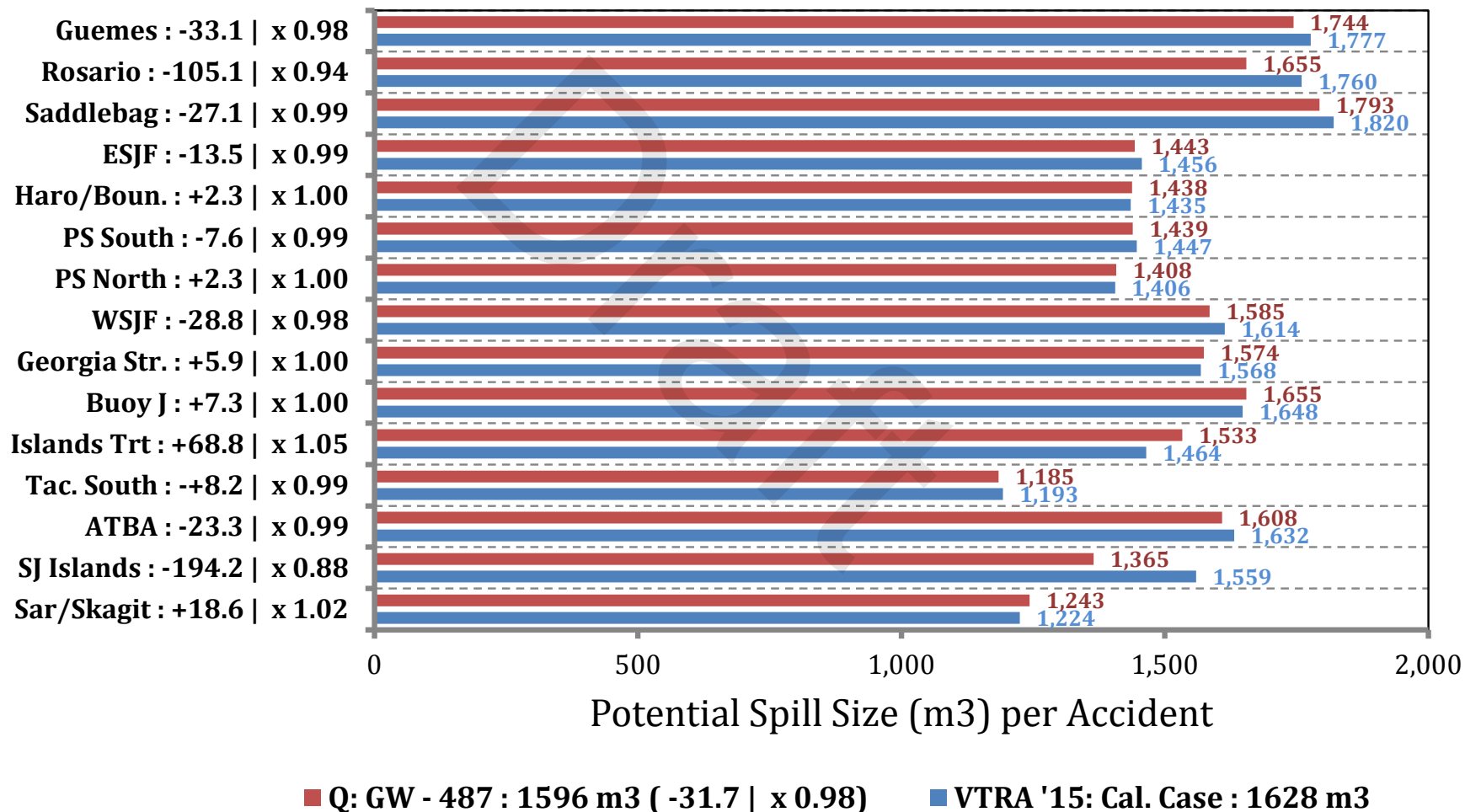
VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

Prob. Estimate At Least One Accident in 10 Years - ALL_FV - Oil Spill Size Category: 1000 - 2500 m3



VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

Potential Spill Size (m³) per Accident - ALL_FV - Oil Spill Size Category: 1000 - 2500 m³



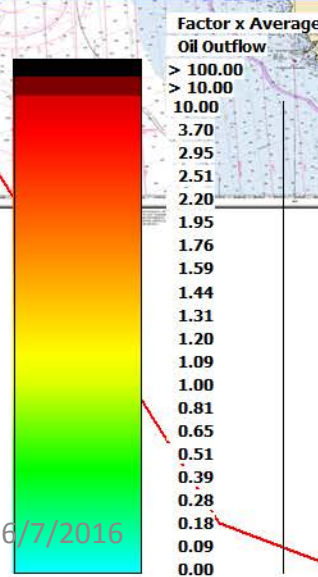
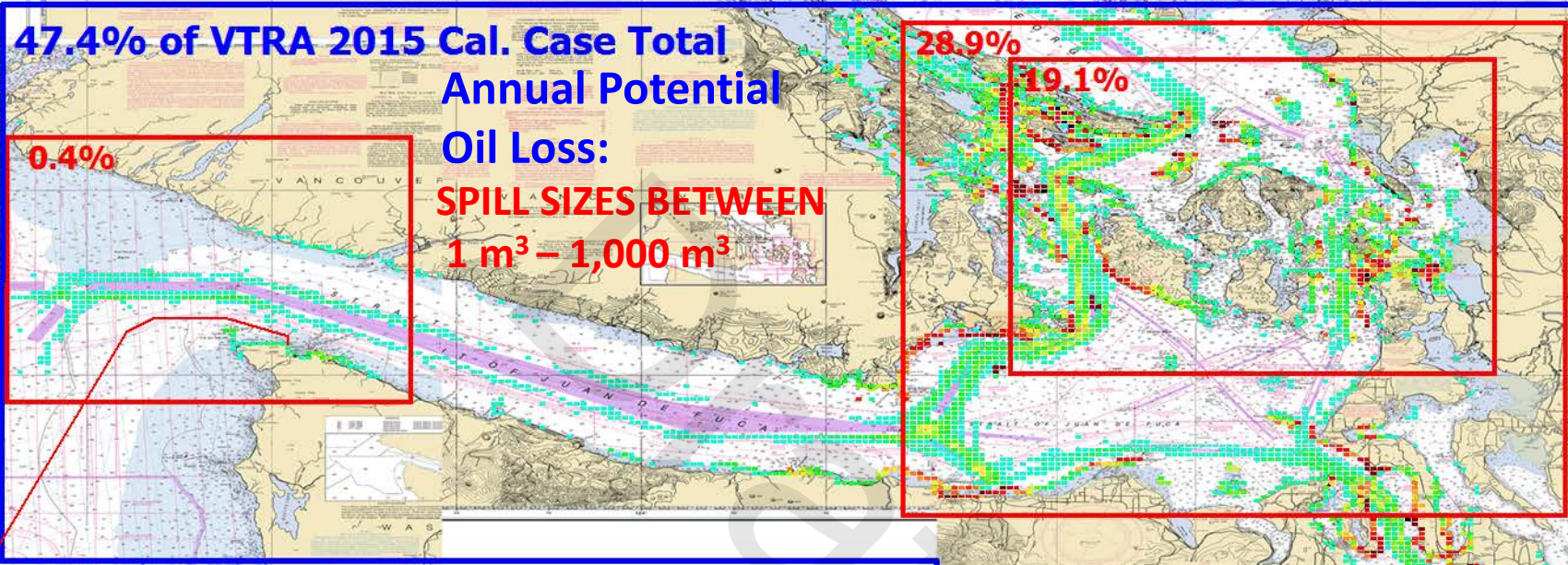
By Waterway Zone Risk Comparison

Oil Spill Size Category:

$1 \text{ m}^3 - 1000 \text{ m}^3$

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

VTRA 2015 CALIBRATION CASE - ALL FV



VTRA '15: Cal. Case
GEOGRAPHIC PROFILE
OF ANNUAL
POTENTIAL OIL LOSS
OF ACCIDENTS
WITH SPILL SIZE
BETWEEN 1 m³ - 1000 m³

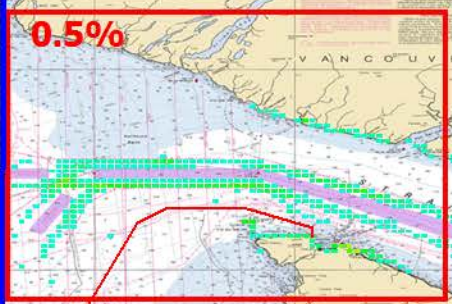
≈ 53.1% Probability
of Spill Occurrence
in 10 years

Average of ≈ 42 m³
Per Potential Spill
(≈ 265 barrels)

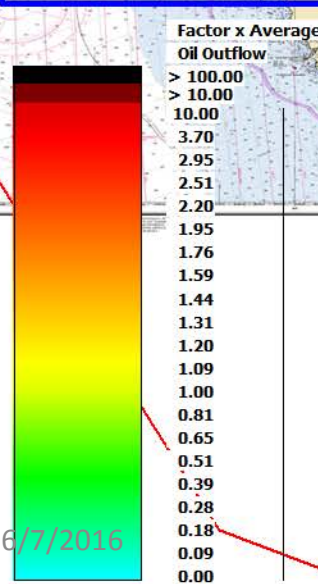
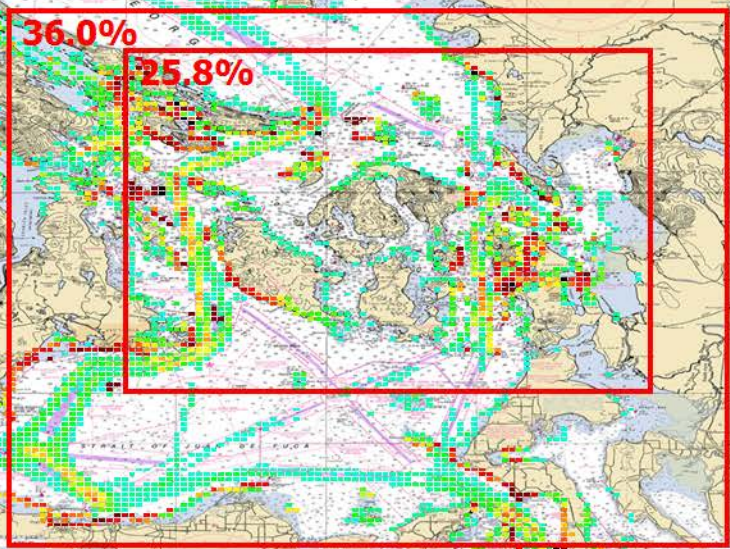
VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

Q: VTRA 2010 - GATEWAY 487 - ALL FV

54.9% of VTRA 2015 Cal. Case Total Annual Potential Oil Loss:



**Oil Loss:
SPILL SIZES BETWEEN
1 m³ - 1,000 m³**



VTRA '15 Case Q: GW - 487
GEOGRAPHIC PROFILE
OF ANNUAL
POTENTIAL OIL LOSS
OF ACCIDENTS
WITH SPILL SIZE
BETWEEN 1 m³ - 1000 m³

≈ 65.0% Probability
of Spill Occurrence
in 10 years

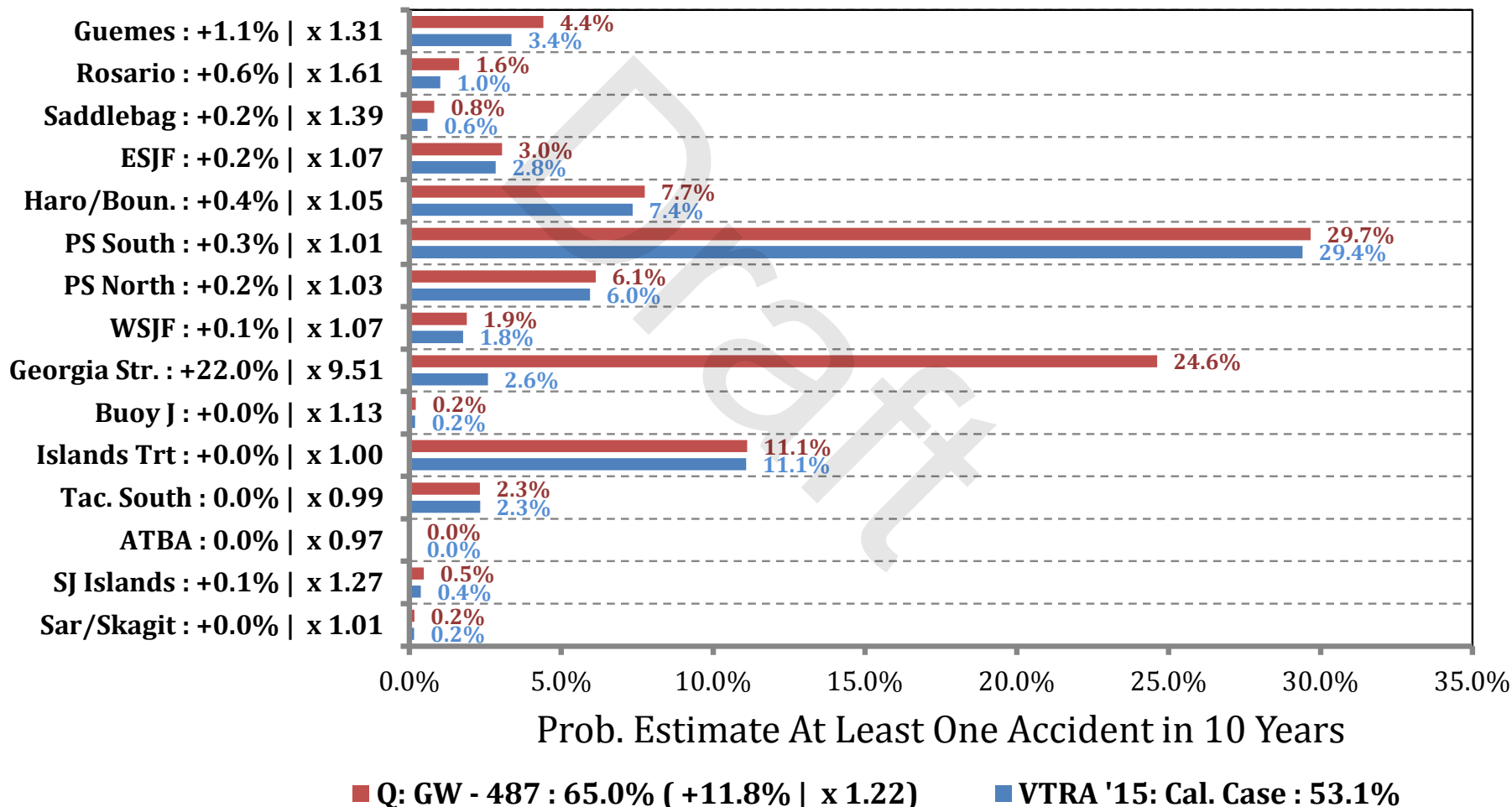
Average of ≈ 35 m³
Per Potential Spill
(≈ 220 Barrels)

6/7/2016

5/29/2016

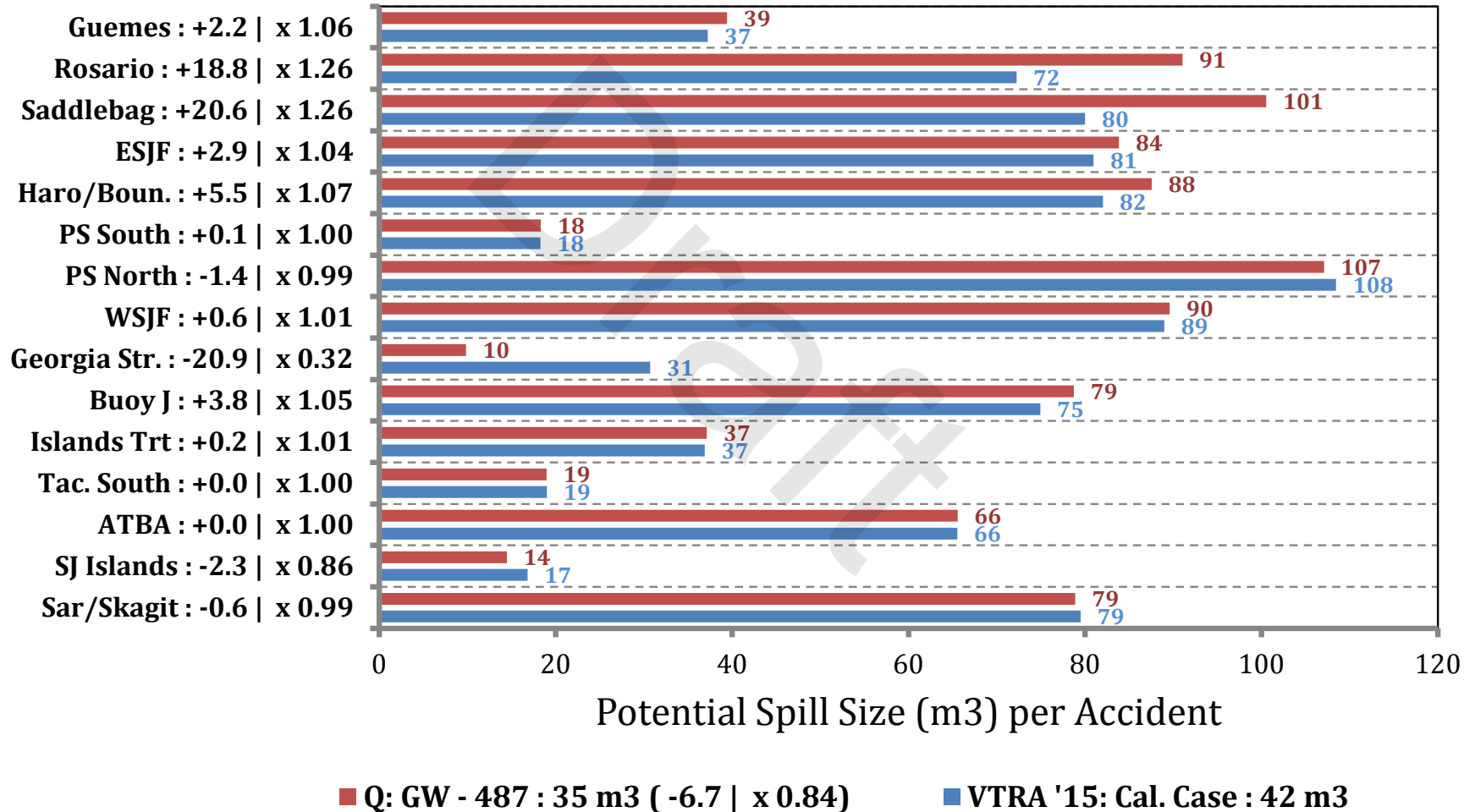
VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

Prob. Estimate At Least One Accident in 10 Years - ALL_FV - Oil Spill Size Category: 1 - 1000 m3



VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

Potential Spill Size (m³) per Accident - ALL_FV - Oil Spill Size Category: 1 - 1000 m³



By Waterway Zone Risk Comparison

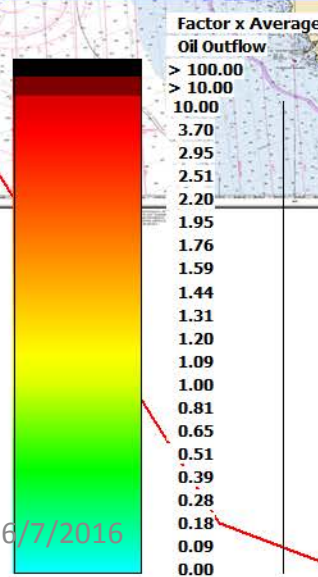
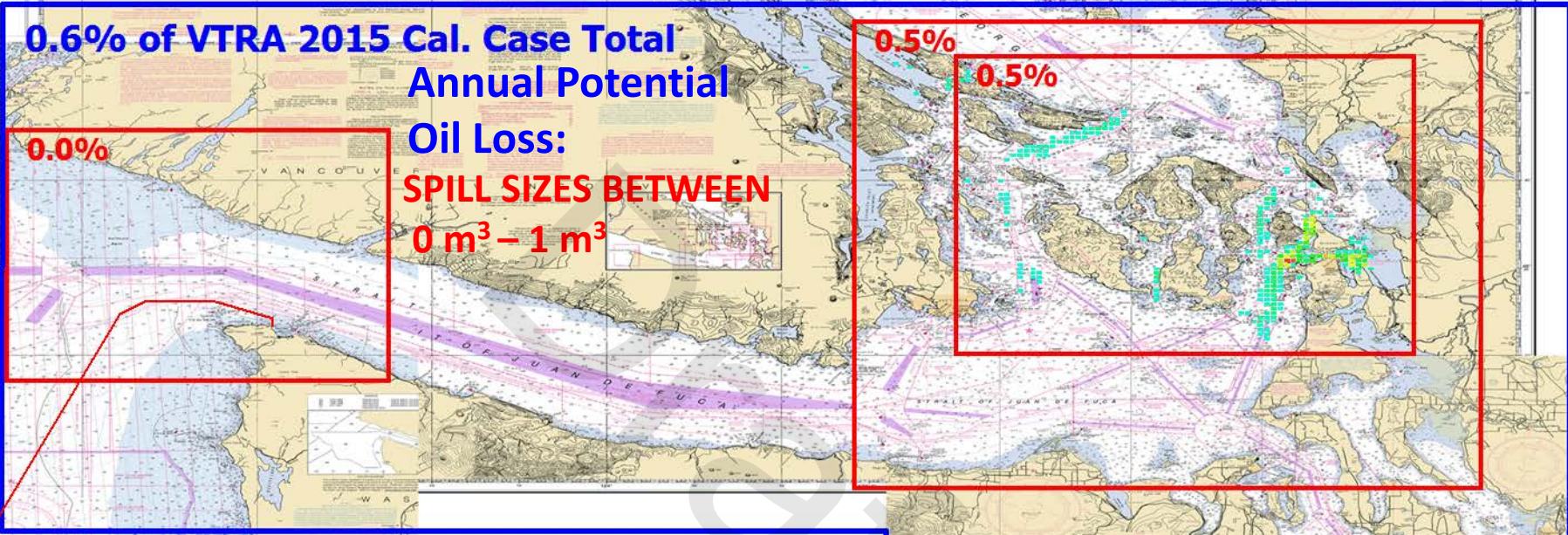
Oil Spill Size Category:

$0 \text{ m}^3 - 1 \text{ m}^3$

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



VTRA 2015 CALIBRATION CASE - ALL FV



VTRA '15: Cal. Case
GEOGRAPHIC PROFILE
OF ANNUAL
POTENTIAL OIL LOSS
OF ACCIDENTS
WITH SPILL SIZE
BETWEEN 0 m³ - 1 m³

≈ 100% Probability
of Spill Occurrence
in 10 years

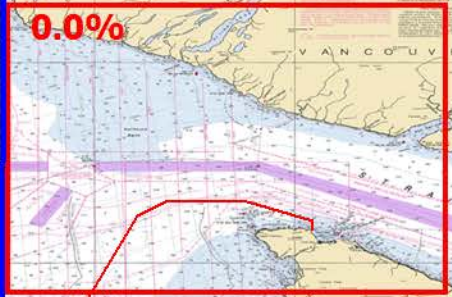
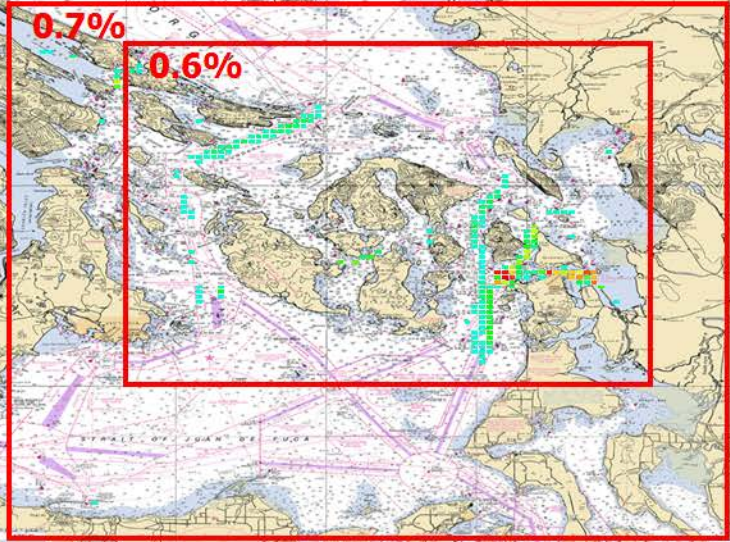
Average of ≈ 0.01 m³
Per Potential Spill
(≈ 2.4 gallons)

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

Q: VTRA 2010 - GATEWAY 487 - ALL FV

0.7% of VTRA 2015 Cal. Case Total Annual Potential Oil Loss:

SPILL SIZES BETWEEN $0\text{ m}^3 - 1\text{ m}^3$



GEOGRAPHIC PROFILE OF ANNUAL POTENTIAL OIL LOSS OF ACCIDENTS WITH SPILL SIZE BETWEEN $0\text{ m}^3 - 1\text{ m}^3$

≈ 100% Probability of Spill Occurrence in 10 years

Average of ≈ 0.01 m^3 Per Potential Spill (= 2.4 gallons)

6/7/2016

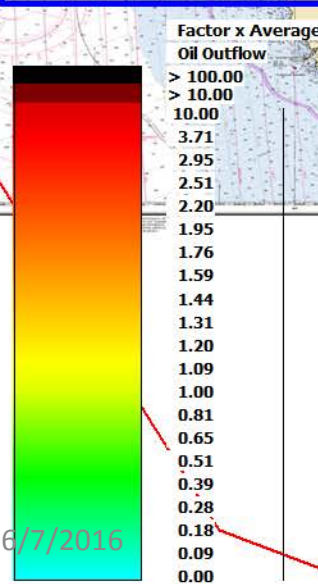
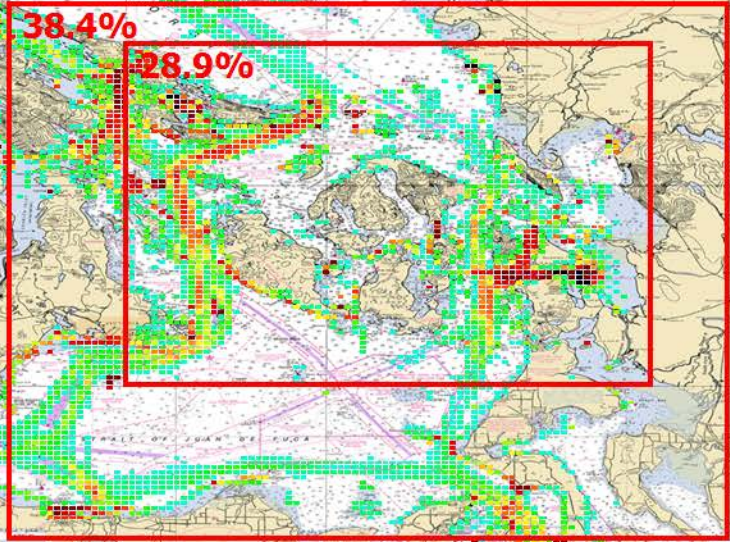
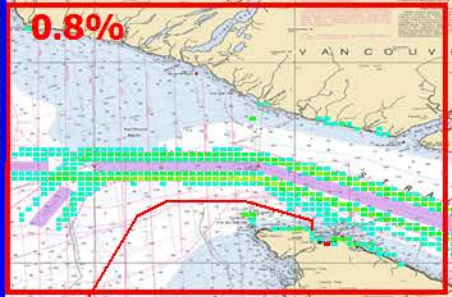
5/29/2016

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

VTRA 2015 CALIBRATION CASE - ALL FV

98.2% of VTRA 2015 Cal. Case Total Potential Annual # Accidents:

SPILL SIZES BETWEEN $0\text{ m}^3 - 1\text{ m}^3$



VTRA '15 Case Q: GW - 487
GEOGRAPHIC PROFILE OF ANNUAL POTENTIAL OIL LOSS OF ACCIDENTS WITH SPILL SIZE BETWEEN $0\text{ m}^3 - 1\text{ m}^3$

≈ 100% Probability of Spill Occurrence in 10 years

Average of ≈ 0.01 m^3 Per Potential Spill (≈ 2.4 gallons)

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

Q: VTRA 2010 - GATEWAY 487 - ALL FV

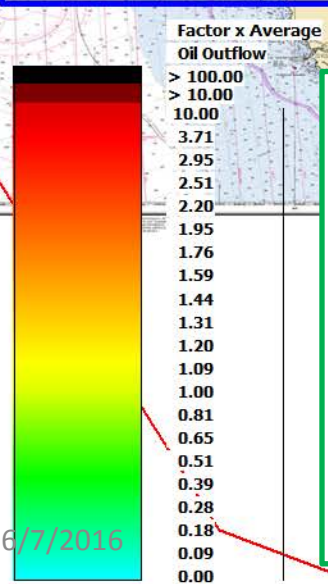
126.4% of VTRA 2015 Cal. Case Total Potential Annual # Accidents:

1.0%

SPILL SIZES BETWEEN 0 m³ - 1 m³

61.3%

51.6%



VTRA '15 Case R: KM - 348
GEOGRAPHIC PROFILE OF ANNUAL POTENTIAL OIL LOSS OF ACCIDENTS WITH SPILL SIZE BETWEEN 0 m³ - 1 m³

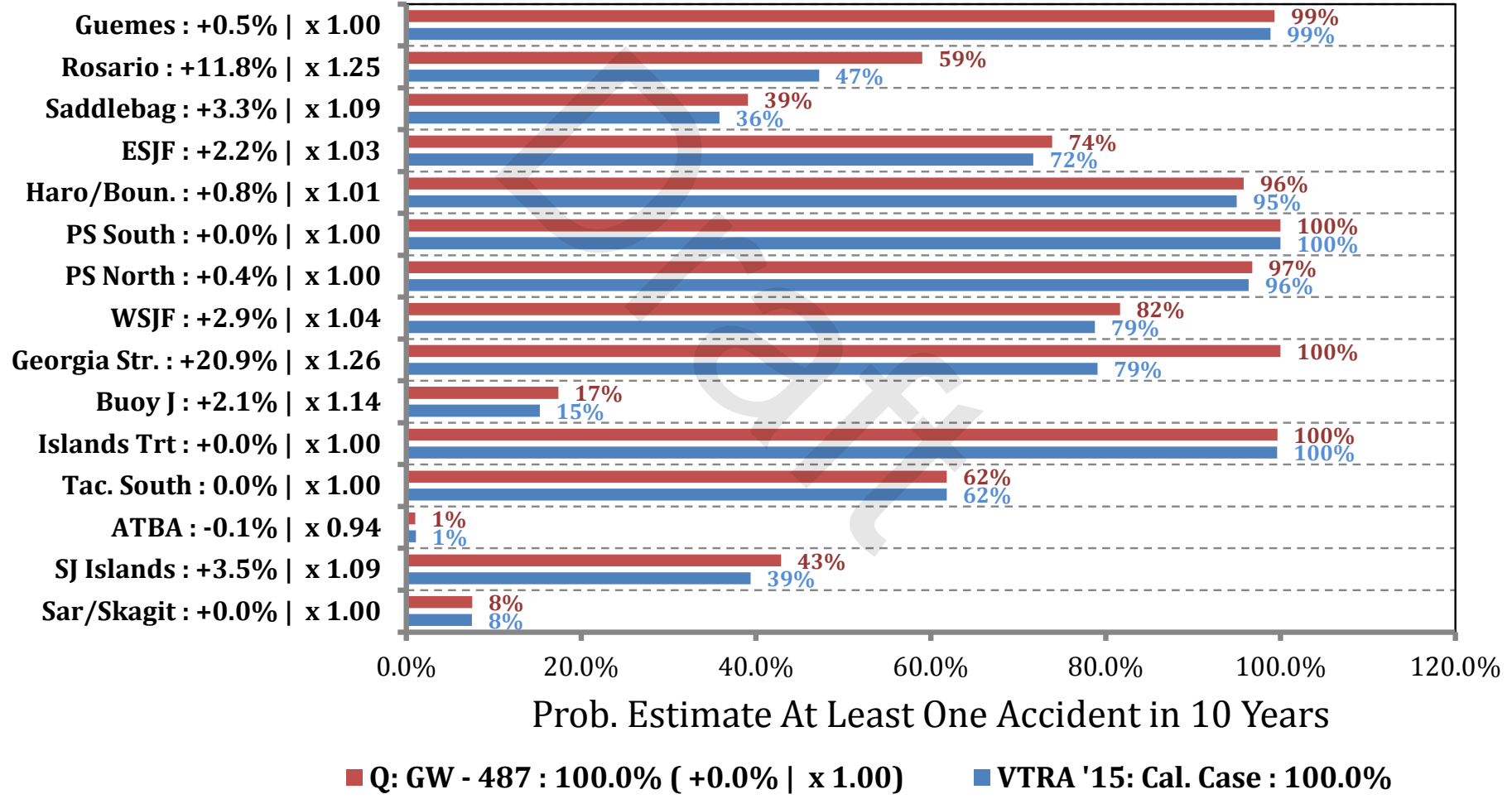
≈ 100% Probability of Spill Occurrence in 10 years

Average of ≈ 0.01 m³ Per Potential Spill (= 2.4 gallons)

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

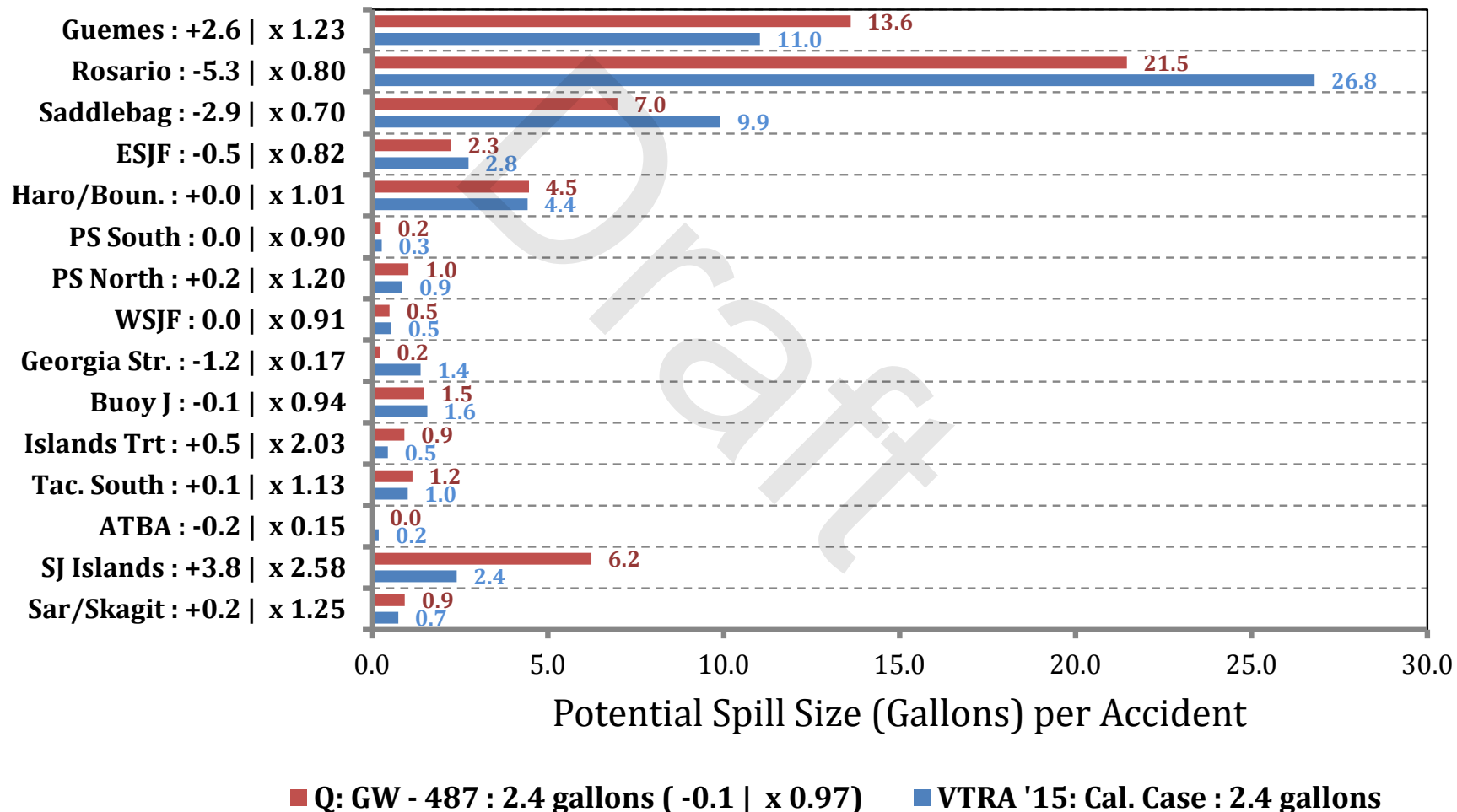


Prob. Estimate At Least One Accident in 10 Years - ALL_FV - Oil Spill Size Category: 0 - 264 Gallons



VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

Potential Spill Size (Gallons) per Accident - ALL_FV - Oil Spill Size Category: 0 - 264 Gallons



Summary Risk Comparison

Oil Spill Size Category:
All Spill Sizes

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



Summary Risk Comparison

		OIL_2500_MORE	OIL_1000_2500	OIL_1_1000	OIL_0_1	ANY SIZE
VTRA '15 CAL. CASE	Base Case % Potential Annual Oil Loss	39.8%	12.2%	47.4%	0.6%	100.0%
	Base Case % Potential Annual Accident Frequency	0.01%	0.01%	1.7%	98.2%	100.0%
	Average potential spill size per accident (in m ³)	5,745	1,627	42.0	0.01	1.5
	Probability of at least one accident in 1 year by spill size	0.05%	0.05%	7.3%	98.7%	98.8%
	Probability of at least one accident in 10 years by spill size	0.47%	0.50%	53.2%	100.0%	100.0%
	Probability of at least one accident in 25 years by spill size	1.16%	1.25%	85.0%	100.0%	100.0%
		OIL_2500_MORE	OIL_1000_2500	OIL_1_1000	OIL_0_1	ANY SIZE
VTRA '15 CASE Q: GW - 487	Base Case % Potential Annual Oil Loss	37.8% (-2.0% x0.95)	13.0% (+0.8% x1.07)	54.9% (+7.5% x1.16)	0.7% (+0.15% x1.25)	106.5% (+6.5% x1.07)
	Base Case % Potential Annual Accident Frequency	0.01% (0.00% x0.93)	0.01% (+0.00% x1.09)	2.4% (+0.7% x1.38)	126.4% (+28.1% x1.29)	128.8% (+28.8% x1.29)
	Average potential spill size per accident (in m ³)	5845 (+99.7 x1.02)	1596 (-31.5 x0.98)	35.2 (-6.8 x0.84)	0.01 (0.0 x0.97)	1.3 (-0.3 x0.83)
	Probability of at least one accident in 1 year by spill size	0.04% (0.00% x0.93)	0.05% (+0.00% x1.09)	10.0% (+2.7% x1.36)	99.6% (+1.0% x1.01)	99.6% (+0.9% x1.01)
	Probability of at least one accident in 10 years by spill size	0.43% (-0.03% x0.93)	0.55% (+0.05% x1.09)	65.0% (+11.8% x1.22)	100.0% (0.0% x1.00)	100.0% (0.0% x1.00)
	Probability of at least one accident in 25 years by spill size	1.08% (-0.08% x0.93)	1.36% (+0.11% x1.09)	92.8% (+7.7% x1.09)	100.0% (0.0% x1.00)	100.0% (0.0% x1.00)