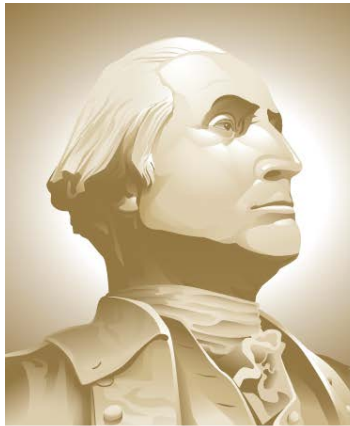


VTRA 2015 Case R : KM – 348 and VTRA 2015 Calibration Case Comparison



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UNIVERSITY**

WASHINGTON, DC

VCU

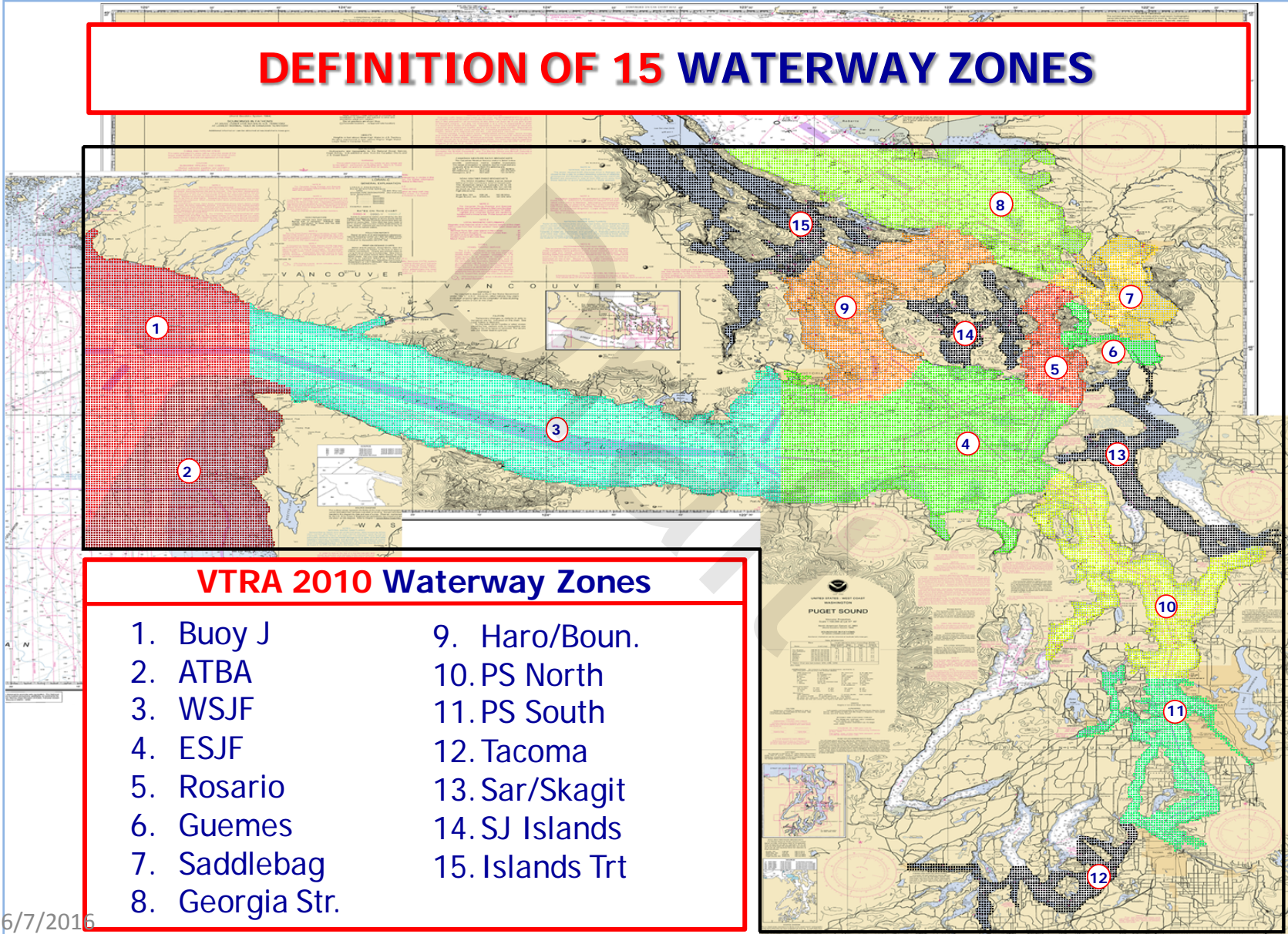
Jason R.W. Merrick (VCU) and J. Rene van Dorp (GW)

June 1st - 2nd, 2016

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



DEFINITION OF 15 WATERWAY ZONES



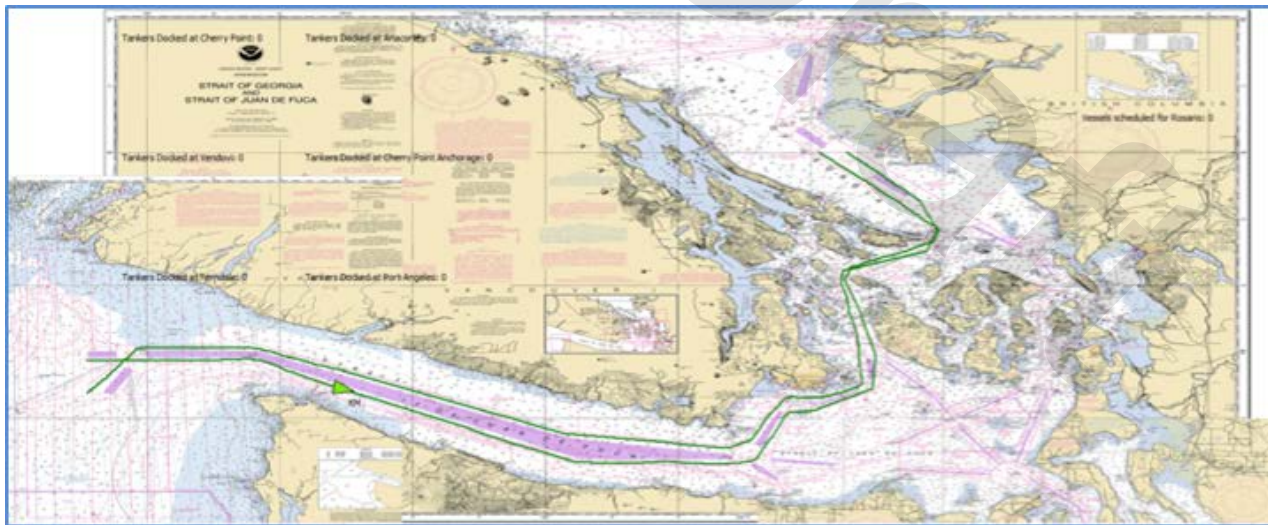
VTRA 2010 Waterway Zones

- | | |
|-----------------|-----------------|
| 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 R : KM - 348 Update

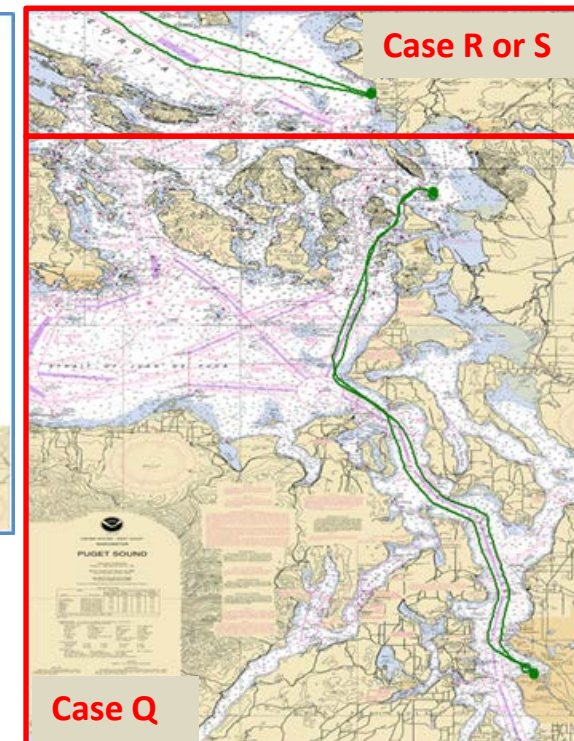
CASE R	VTRA 2010 Case R	VTRA 2015 Updated Case R
Tankers	348	348
Bunkering Support	21	21

Tanker Routes



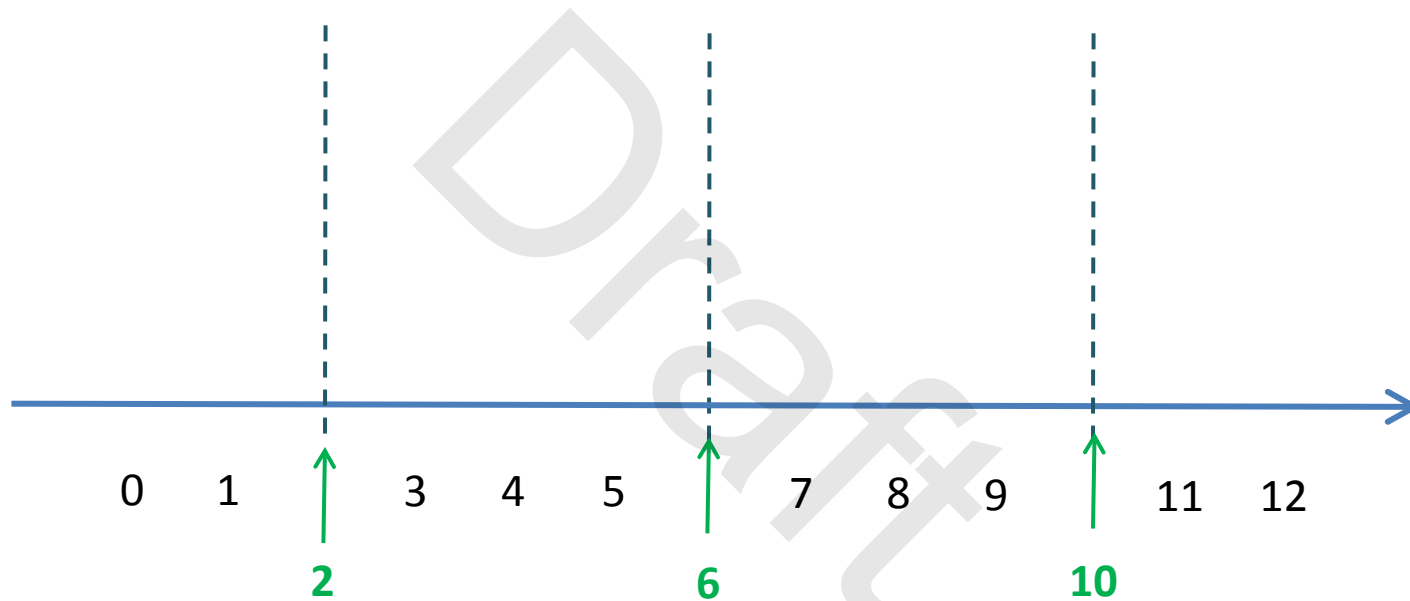
+ Update on Arrival Process

Bunker Routes



NOT SELECTED

VTRA 2010 – What If FV Scheduled Arrival Pattern Model

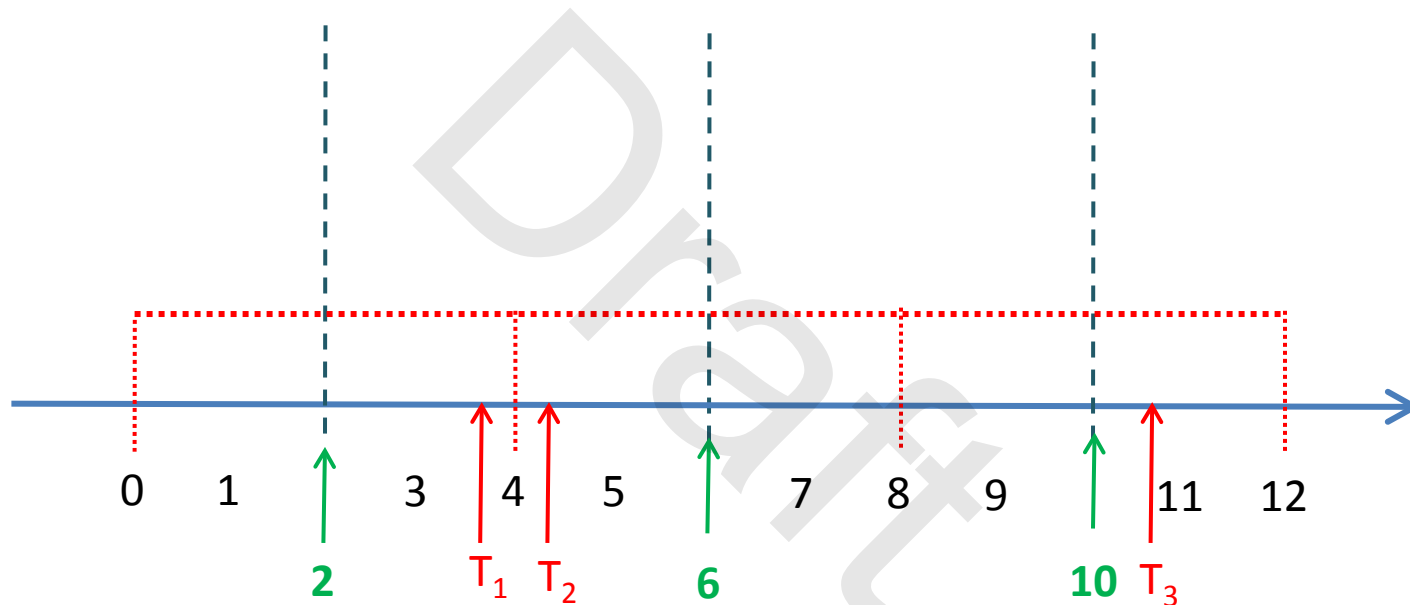


VTRA 2010 Equidistant Fixed Arrival Pattern (one every 4 days)

% OF VTRA '10 BASE CASE POTENTIAL TOTAL OIL LOSS: CASE R: KM – 348: 136%

% OF VTRA '15 CAL. CASE POTENTIAL TOTAL OIL LOSS: CASE R: KM – 348: 128%

NOT SELECTED VTRA 2015 – What If FV Complete Random Arrival Pattern Model



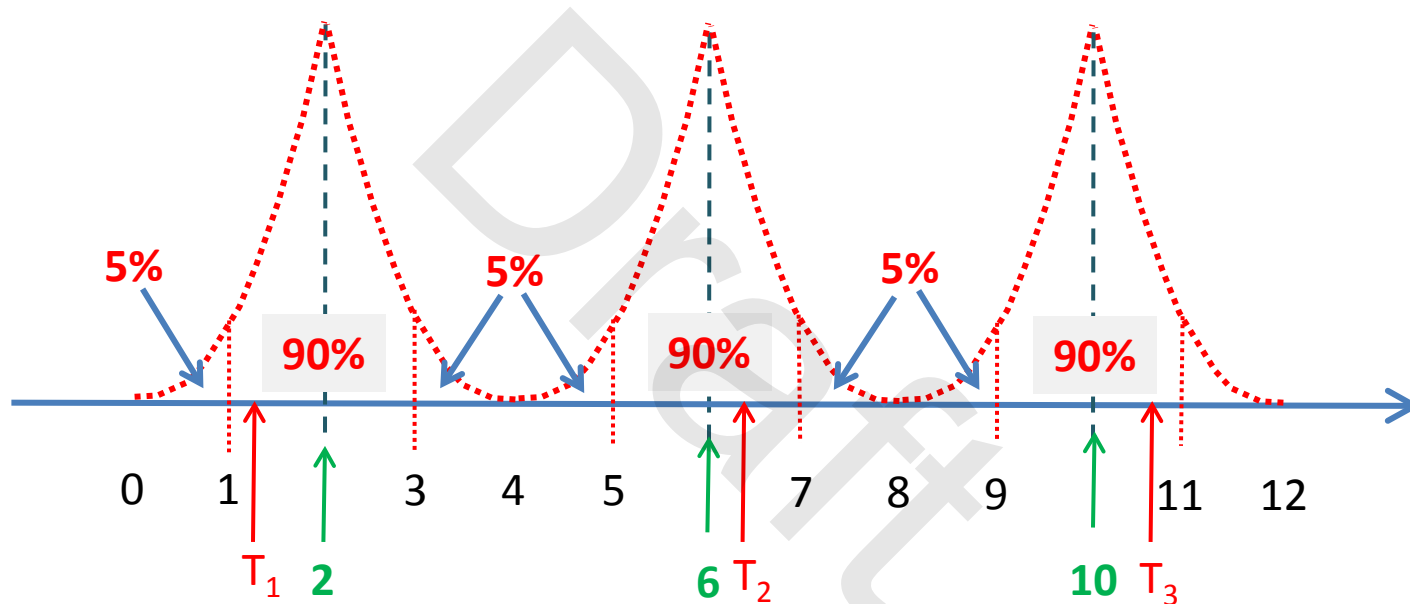
VTRA 2010 Equidistant Fixed Arrival Pattern (one every 4 days)

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

% OF VTRA '10 BASE CASE POTENTIAL TOTAL OIL LOSS: CASE R: KM – 348: 1.36

% OF VTRA '15 CAL. CASE POTENTIAL TOTAL OIL LOSS: CASE R: KM – 348: 1.29

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 R: KM – 348: 1.36

% OF VTRA '10 BASE CASE POTENTIAL TOTAL OIL LOSS: CASE: R KM – 348: 1.30

By Waterway Zone Risk Comparison

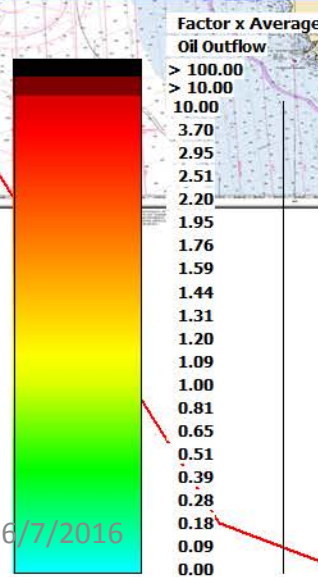
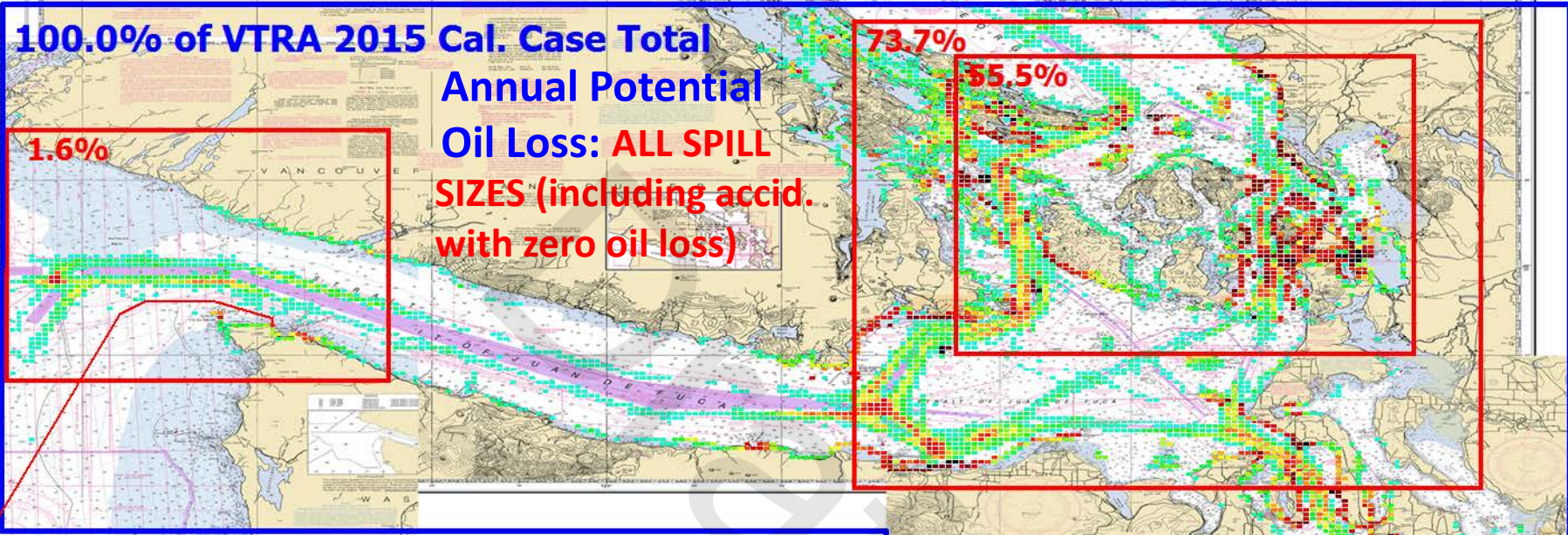
Oil Spill Size Category:

ALL SPILL SIZES

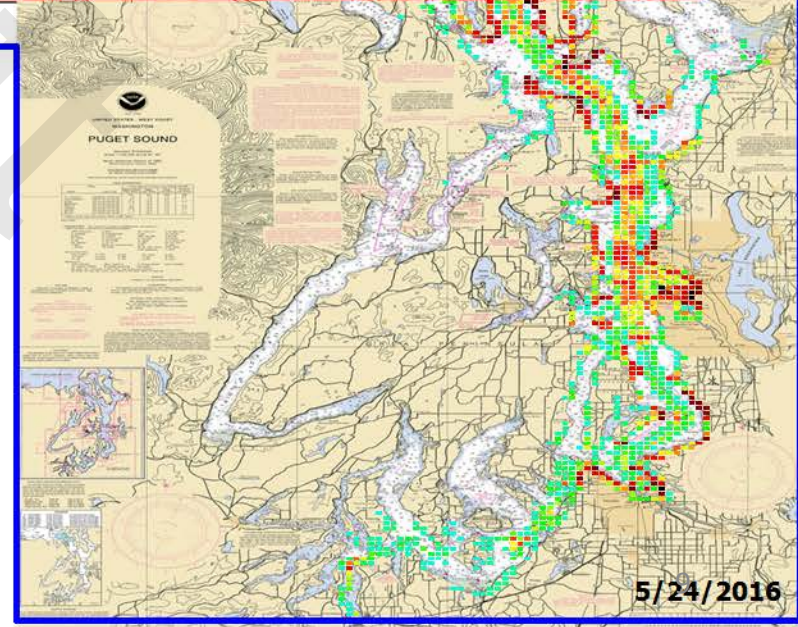
VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



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

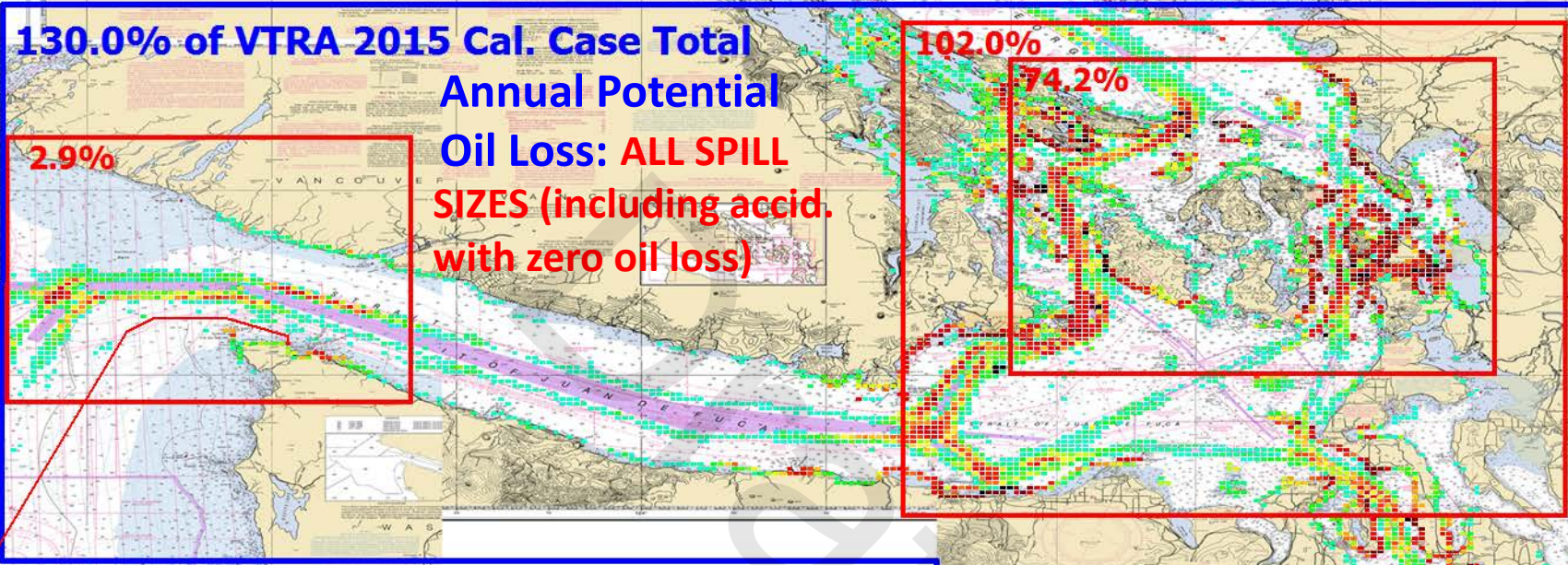


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5/24/2016

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

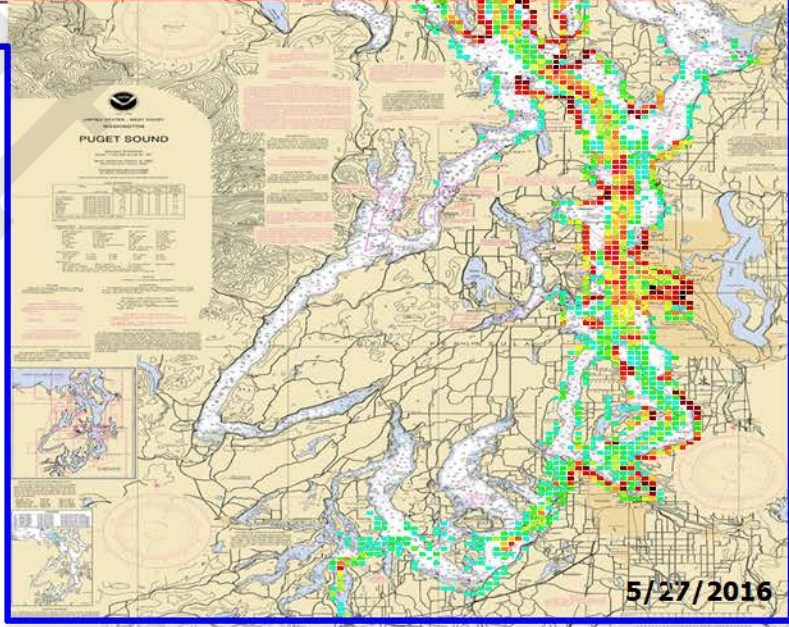
R: VTRA 2015 - Kinder Morgan 348 - ALL FV



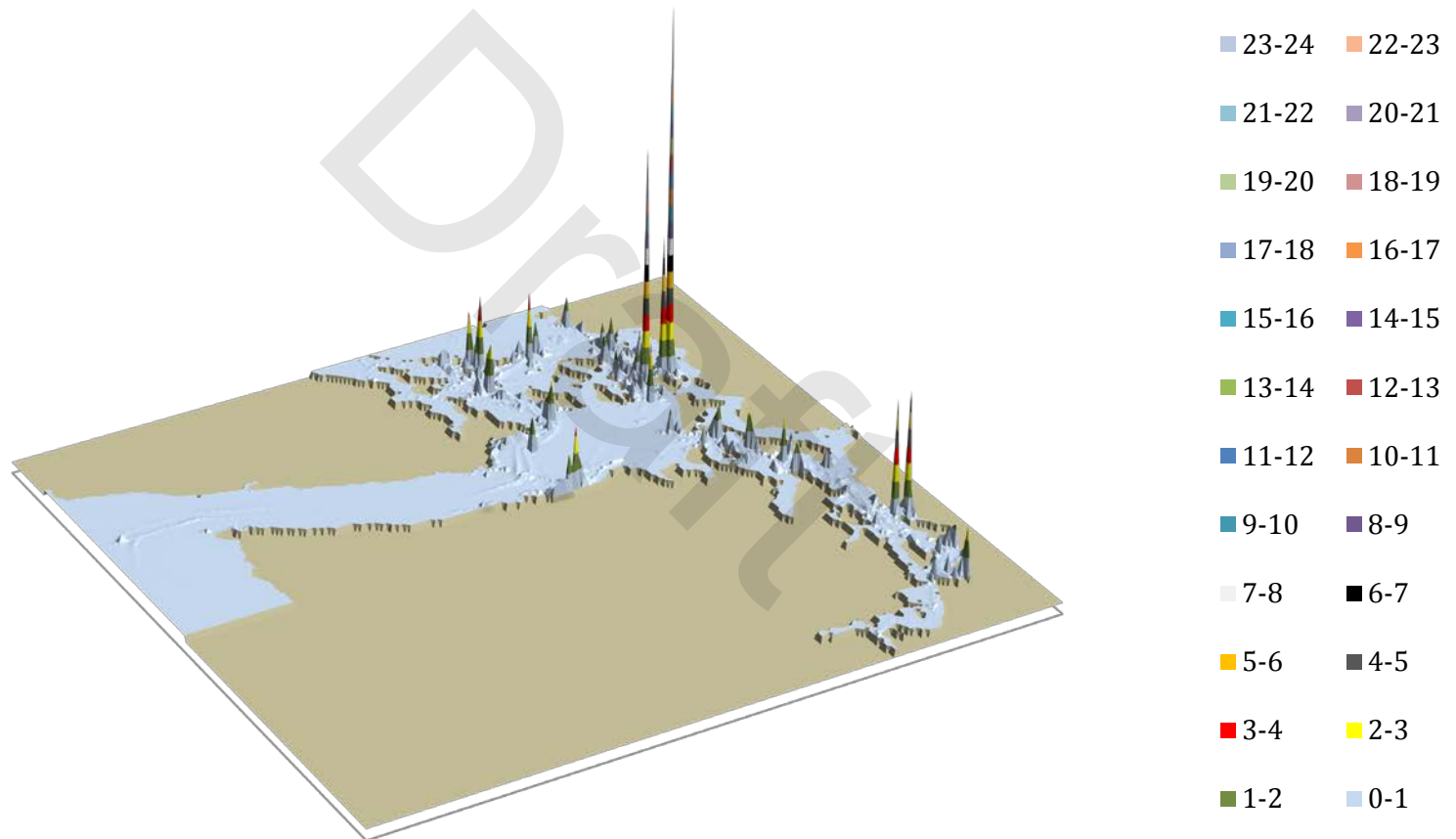
VTRA '15 Case R: KM - 348

GEOGRAPHIC PROFILE OF POTENTIAL ANNUAL OIL LOSS OF ACCIDENTS IN SPILL SIZE CATEGORY

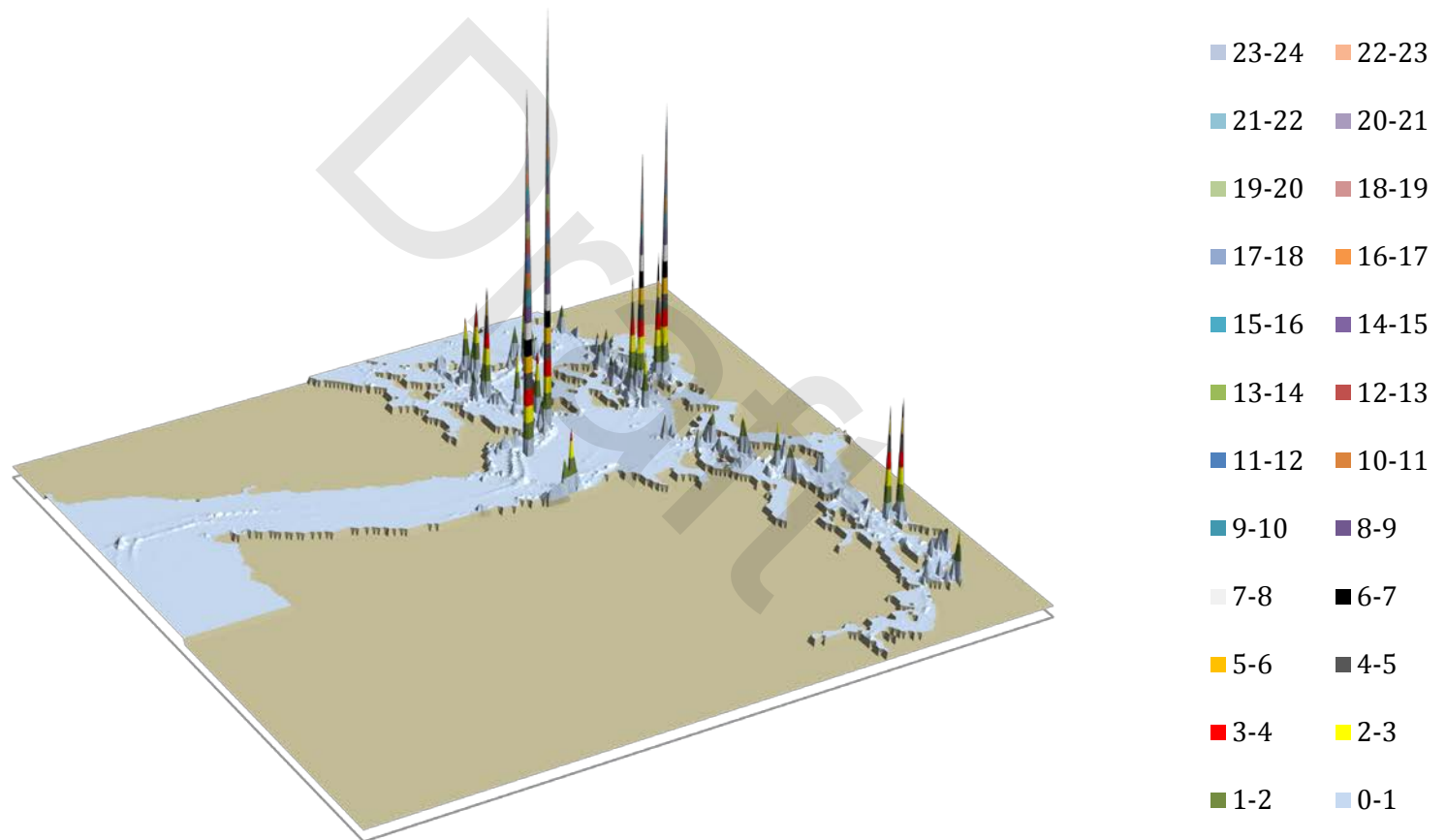
ALL SPILL SIZES



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

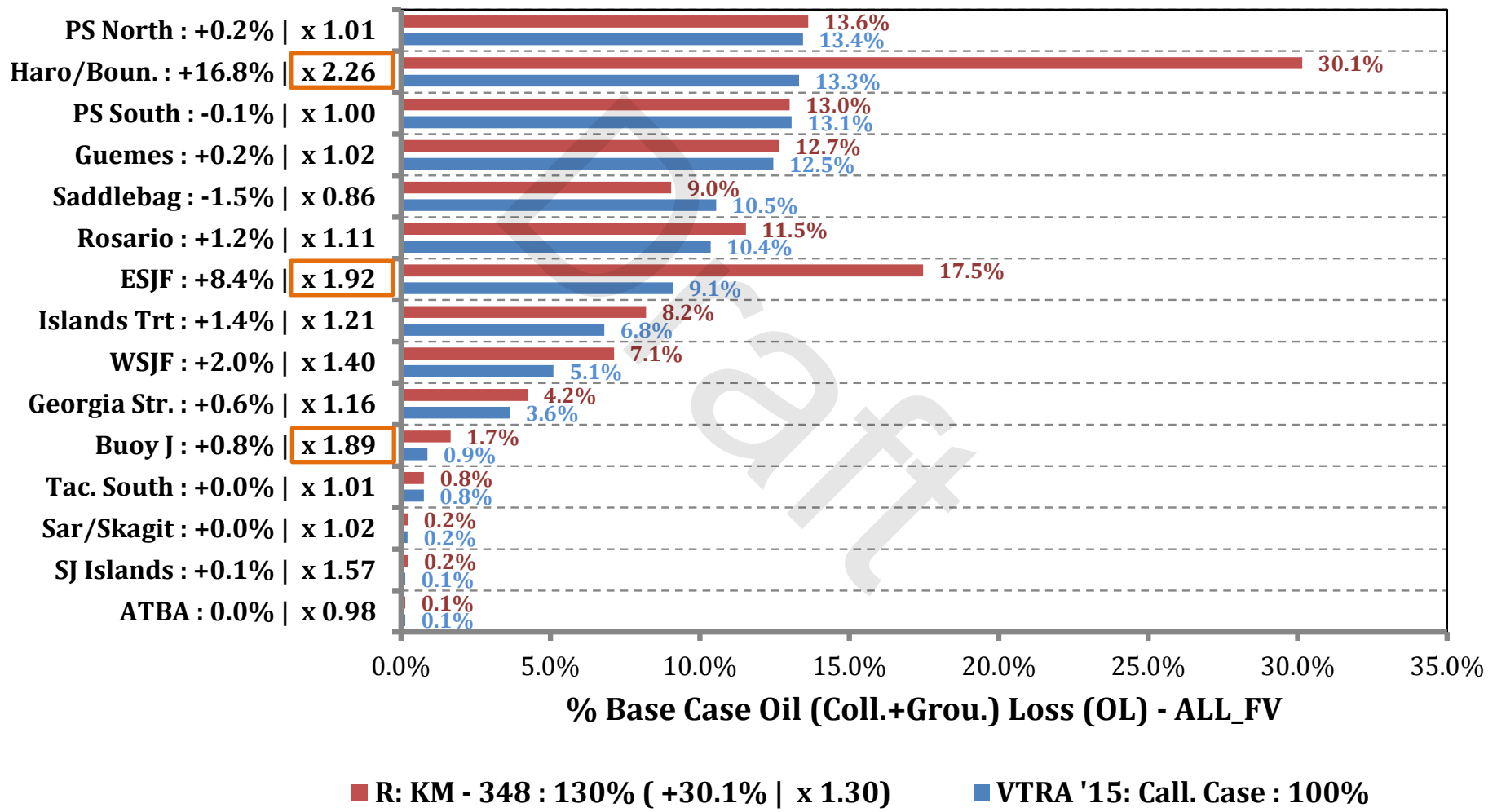


R: KM - 348 3D Risk Profile All FV - Pot.Grou+Coll+All.Oil Loss: 130% of Cal. Case POL



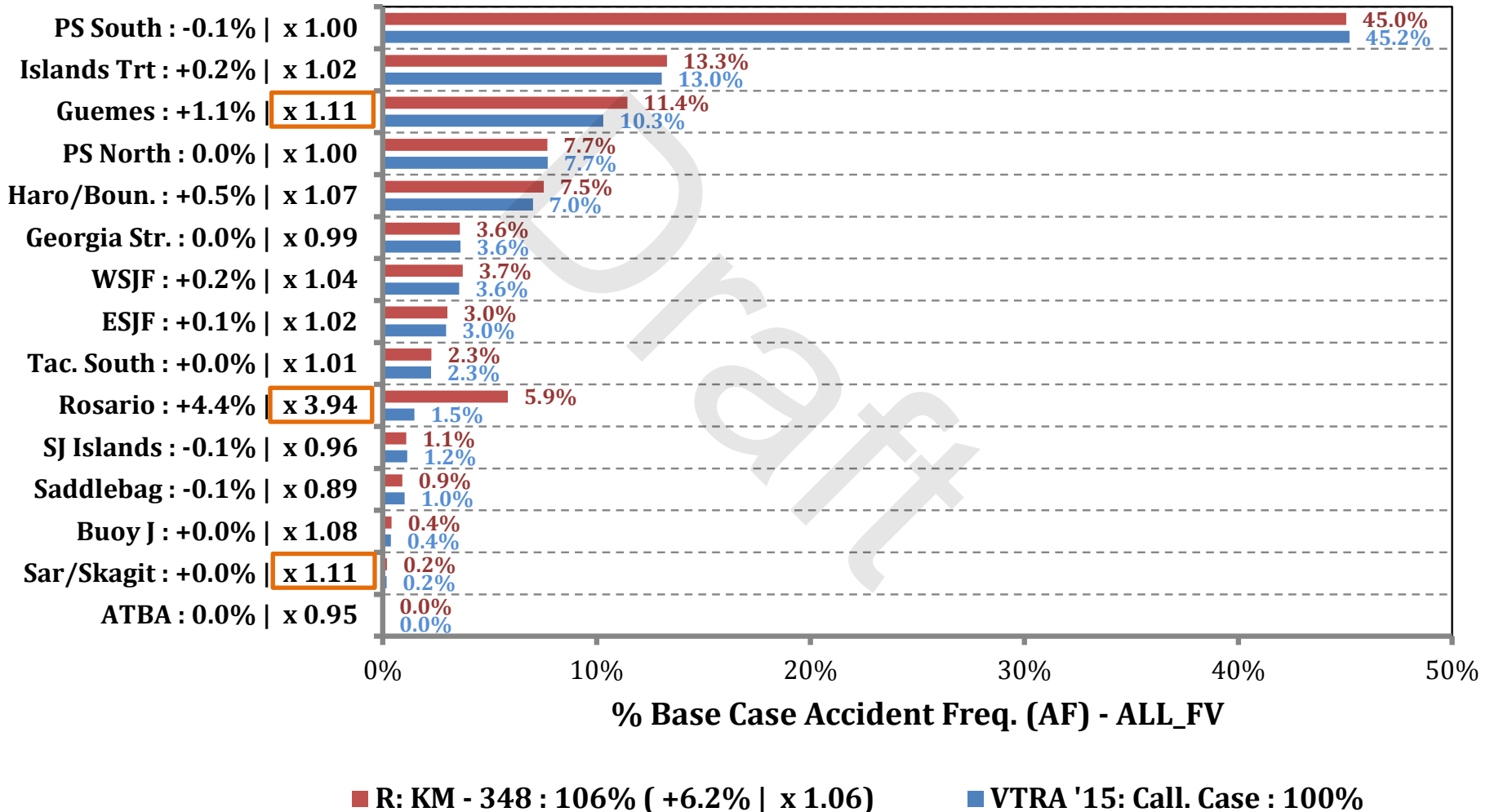
VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

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



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

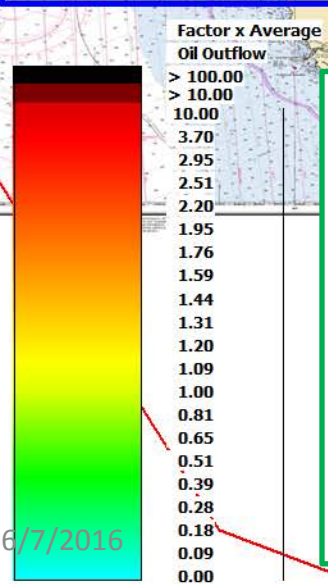
VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

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

33.9%
27.2%

1.0%



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

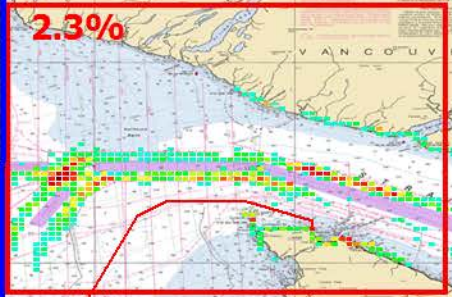
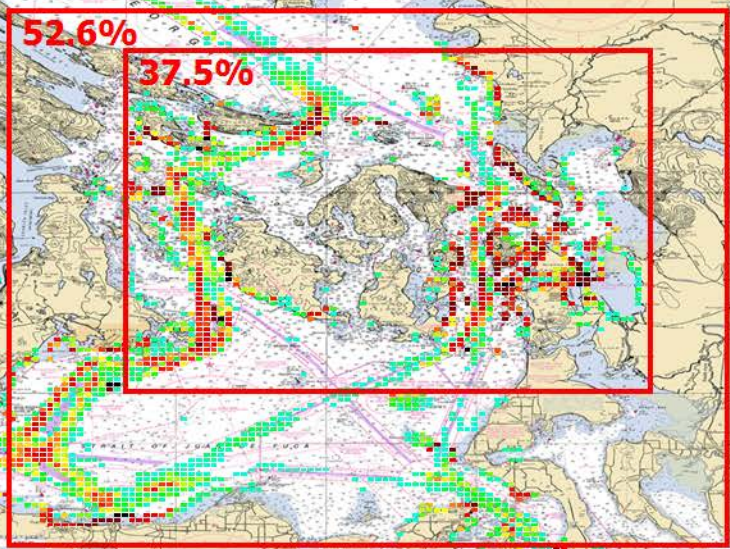
≈ 0.47% Probability of Spill Occurrence in 10 years

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

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

R: VTRA 2015 - Kinder Morgan 348 - ALL FV

60.1% of VTRA 2015 Cal. Case Total Annual Potential Oil Loss:
SPILL SIZES LARGER THAN 2,500 m³



VTRA '15 Case R: KM - 348
GEOGRAPHIC PROFILE OF POTENTIAL ANNUAL OIL LOSS OF ACCIDENTS WITH SPILL SIZE 2,500 m³ or more

≈ 0.90% Probability of Spill Occurrence in 10 years

Average of ≈ 4,465 m³ Per Potential Spill (≈ 3,840 Metric Tons)

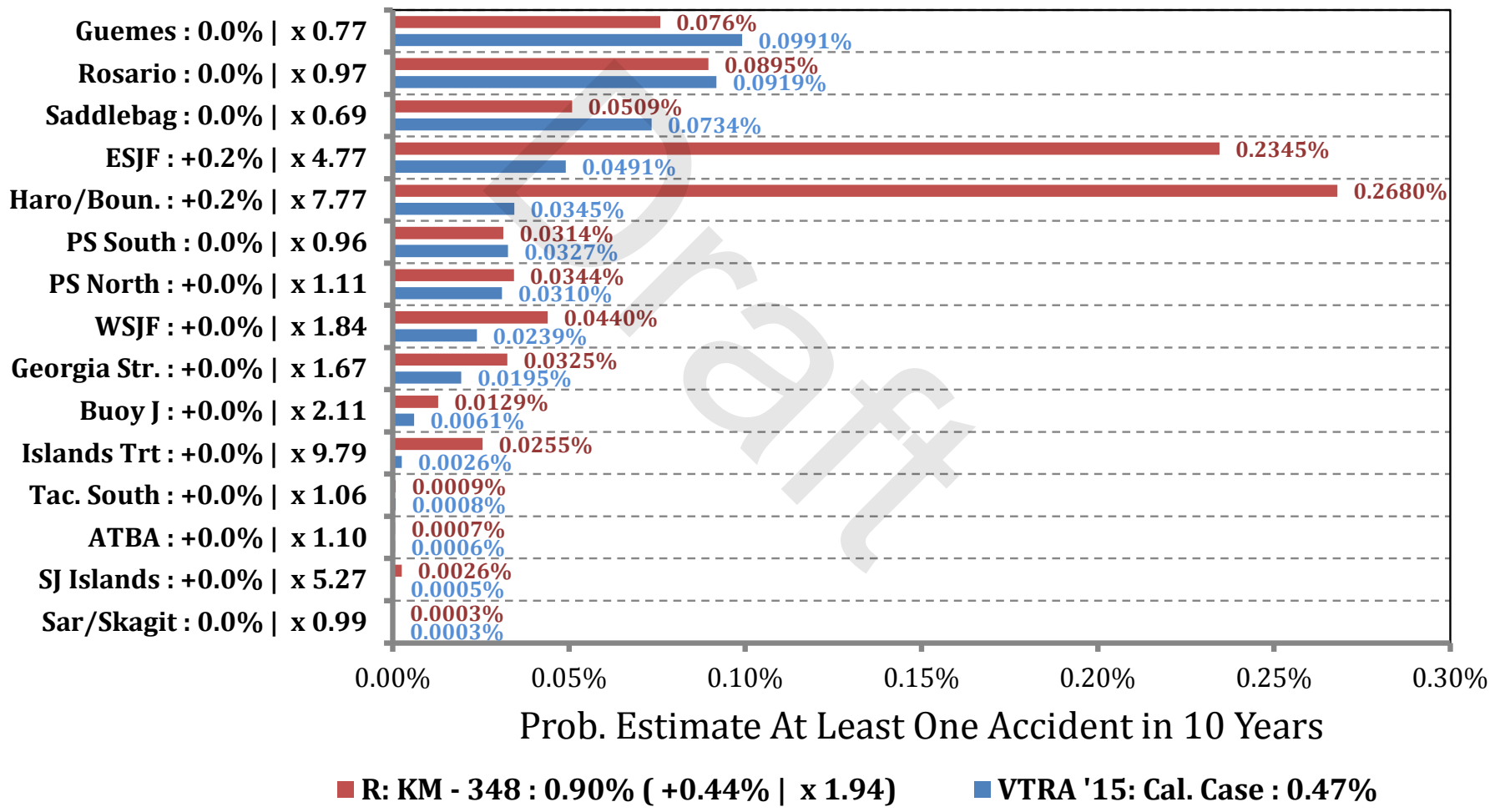
6/7/2016

5/27/2016

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

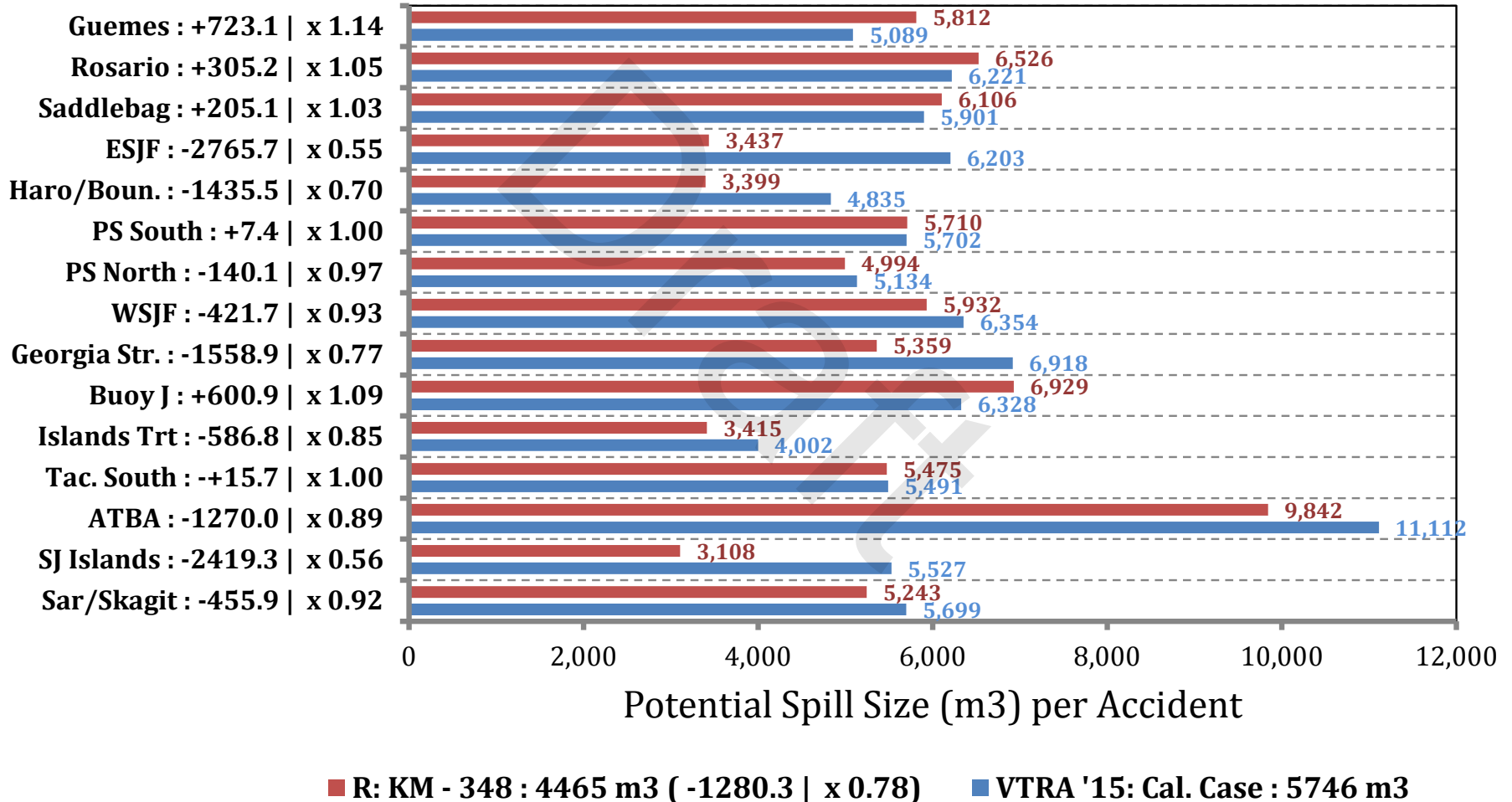


Prob. Estimate At Least One Accident in 10 Years - ALL_FV - Oil Spill Size Category: 2500 cubic meters or more



VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

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



By Waterway Zone Risk Comparison

Oil Spill Size Category:

1000 m³ - 2500 m³

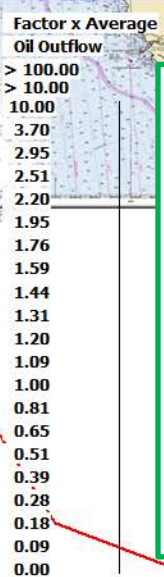
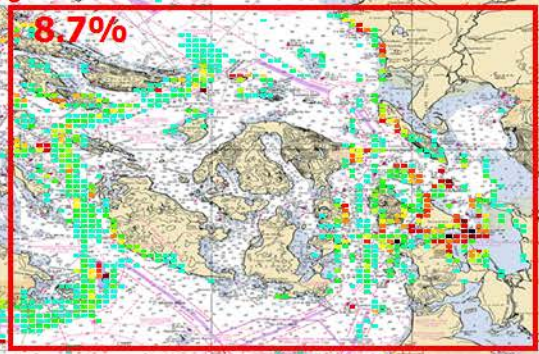
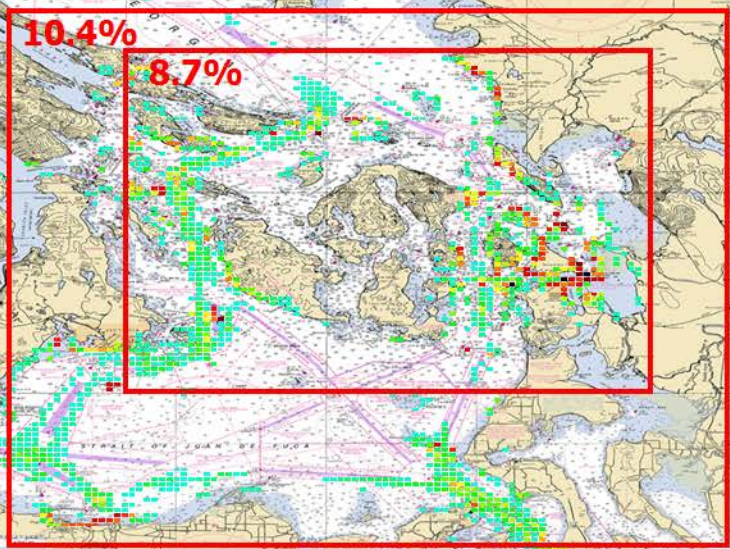
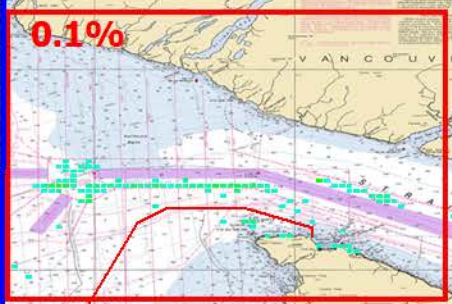
VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



VTRA 2015 CALIBRATION CASE - ALL FV

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

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)

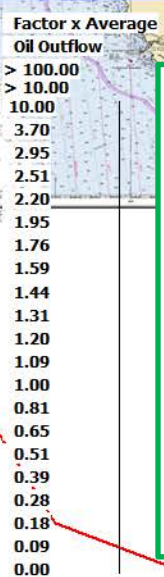
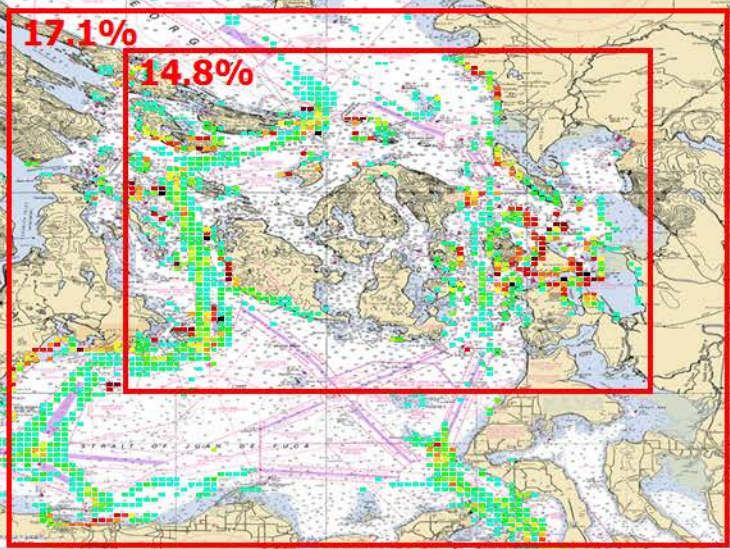
5/24/2016

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

R: VTRA 2015 - Kinder Morgan 348 - ALL FV

19.0% of VTRA 2015 Cal. Case Total Annual Potential Oil Loss:

0.2%
SPILL SIZES BETWEEN 1,000 m³ - 2,500 m³



VTRA '15 Case R: KM - 348
GEOGRAPHIC PROFILE OF POTENTIAL ANNUAL OIL LOSS OF ACCIDENTS WITH SPILL SIZE BETWEEN 1,000 m³ - 2,500 m³

≈ 0.75% Probability of Spill Occurrence in 10 years

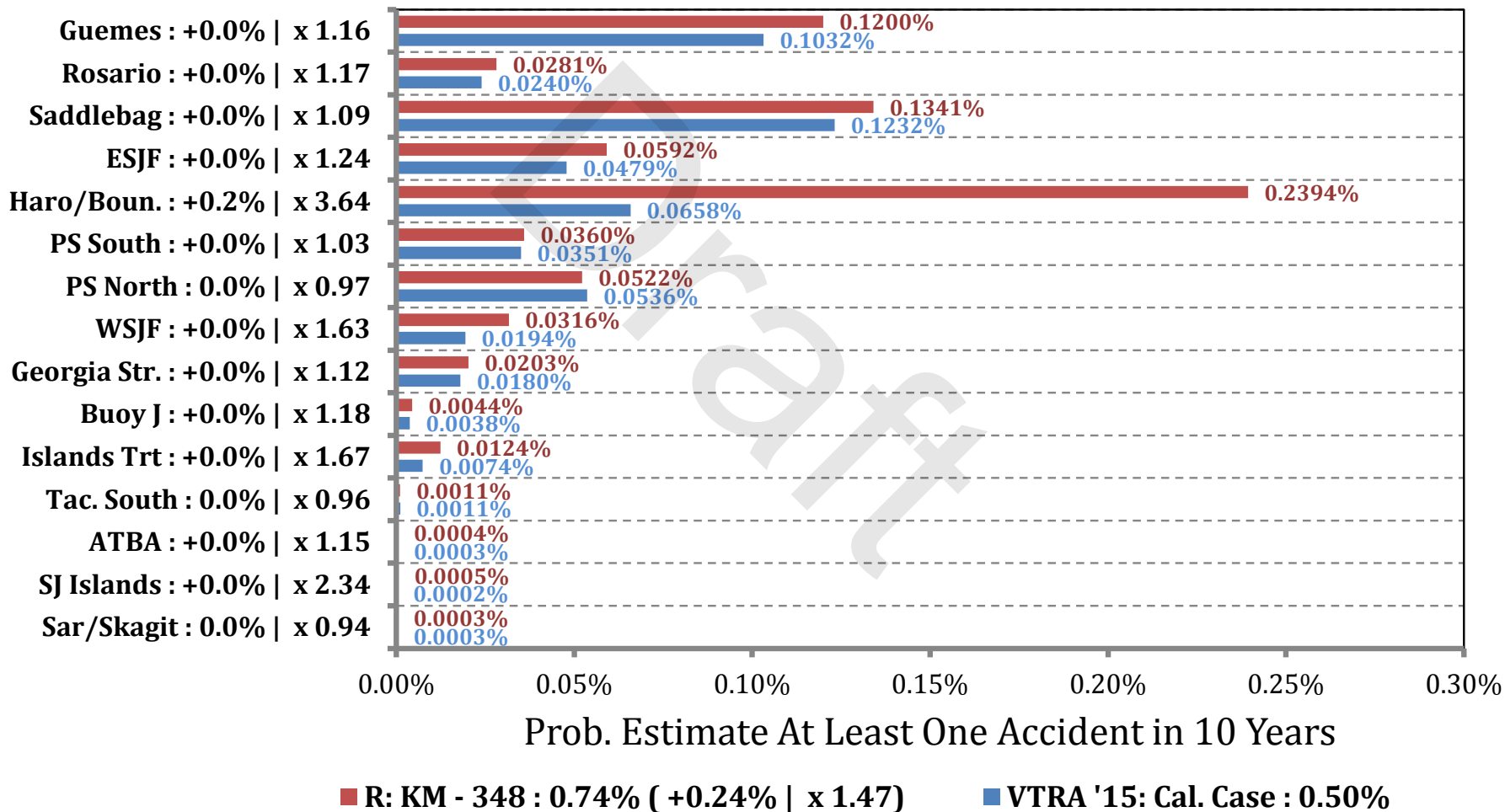
Average of ≈ 1,727 m³ Per Potential Spill (≈ 1,485 Metric Tons)

6/7/2016

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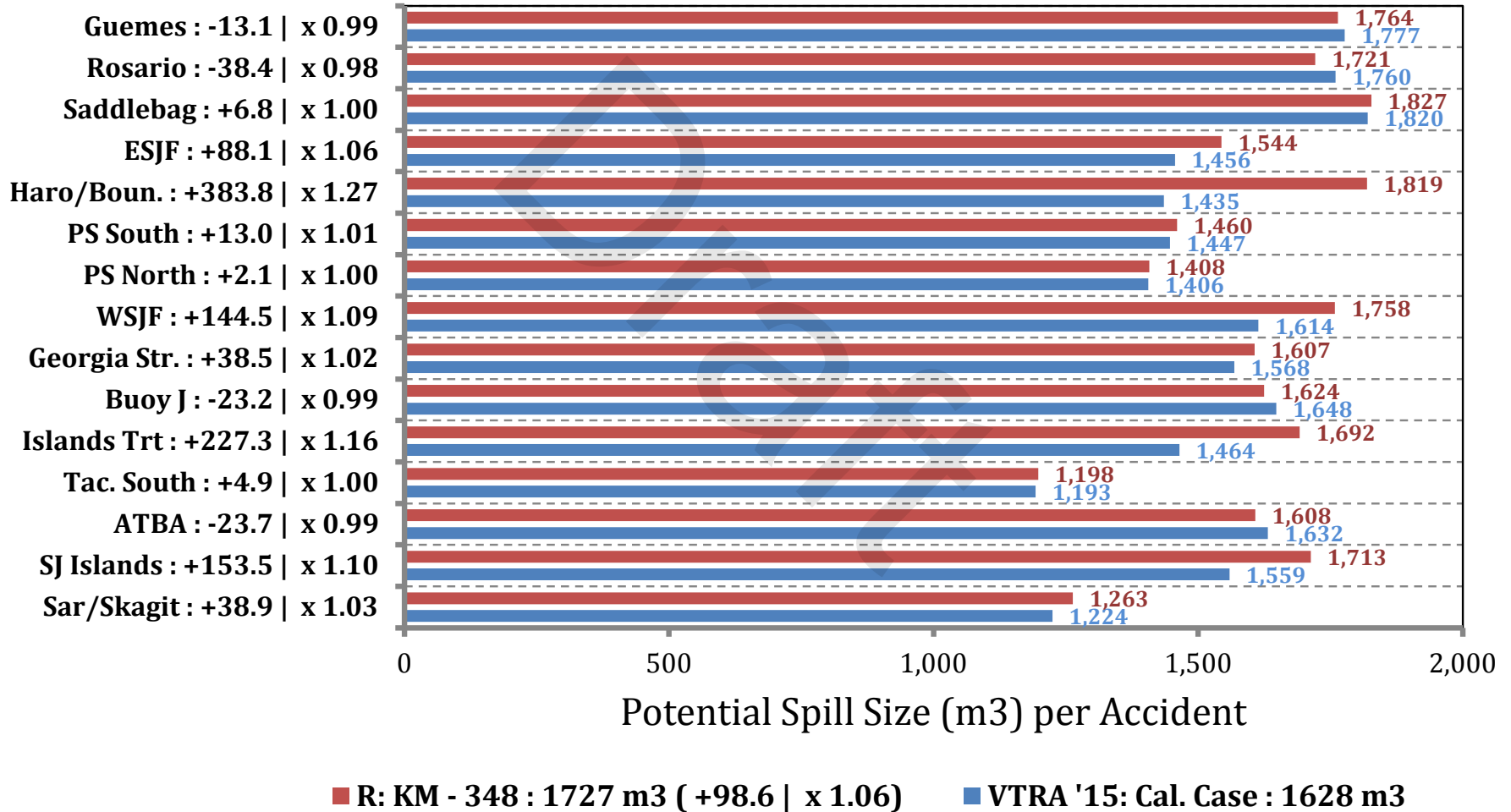
VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

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

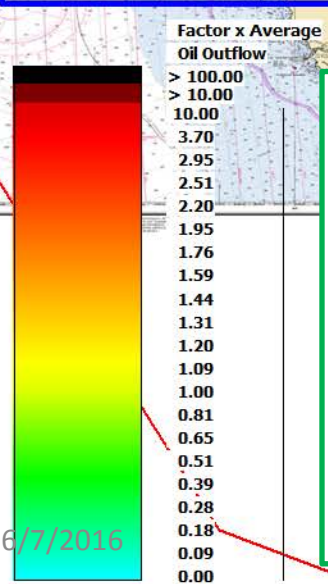


VTRA 2015 CALIBRATION CASE - ALL FV

47.4% of VTRA 2015 Cal. Case Total Annual Potential Oil Loss:

0.4%
SPILL SIZES BETWEEN 1 m³ - 1,000 m³

28.9%
19.1%



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 ≈ 42.0 m³
Per Potential Spill
(≈ 265 Barrels)

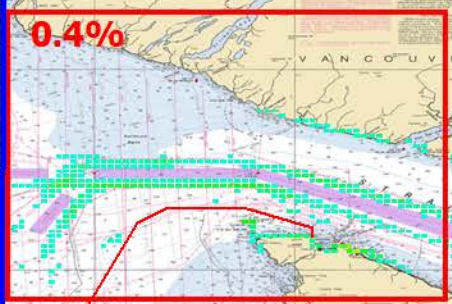
6/7/2016

5/24/2016

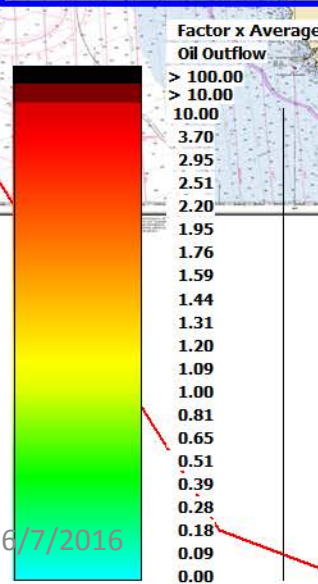
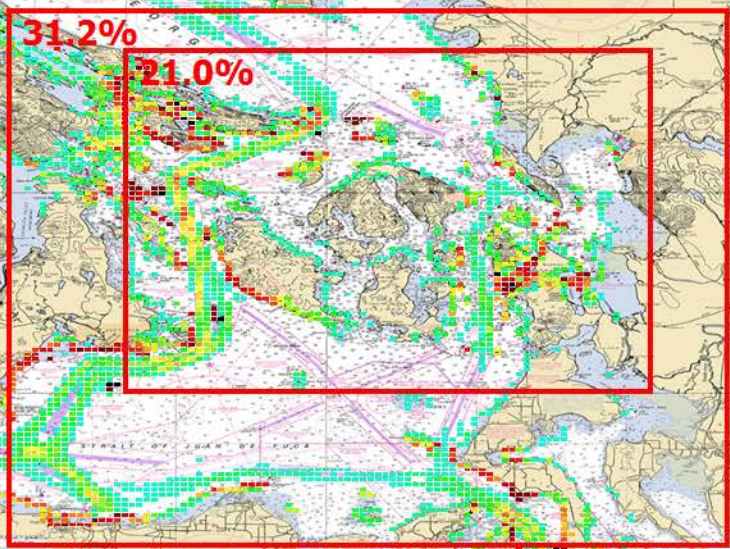
VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

R: VTRA 2015 - Kinder Morgan 348 - ALL FV

49.8% of VTRA 2015 Cal. Case Total Annual Potential Oil Loss:



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



VTRA '15 Case R: KM - 348
GEOGRAPHIC PROFILE
OF ANNUAL
POTENTIAL OIL LOSS
OF ACCIDENTS
WITH SPILL SIZE
BETWEEN 1 m³ - 1000 m³

≈ 54.9% Probability
of Spill Occurrence
in 10 years

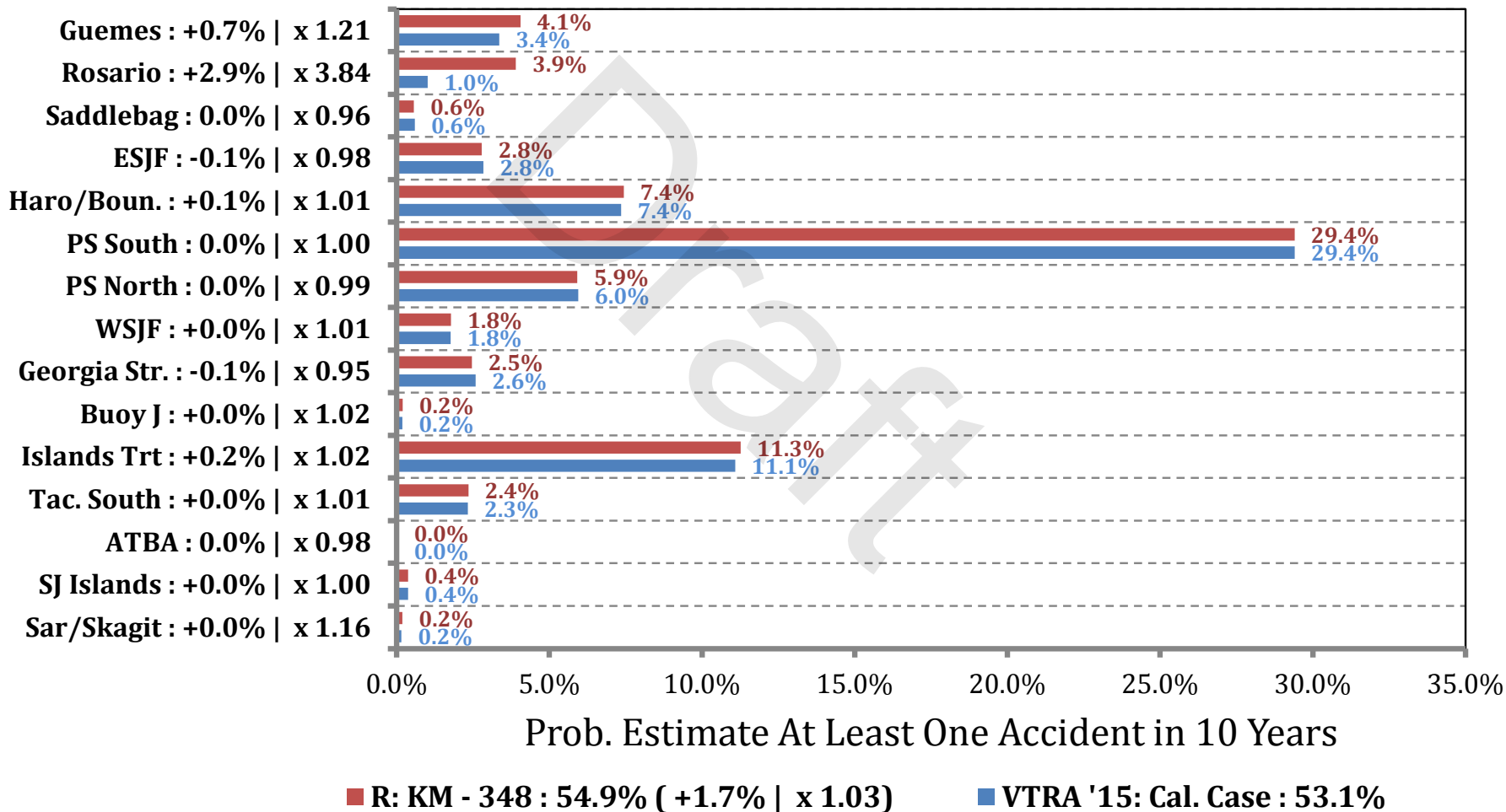
Average of ≈ 42.0 m³
Per Potential Spill
(≈ 265 Barrels)

6/7/2016

5/27/2016

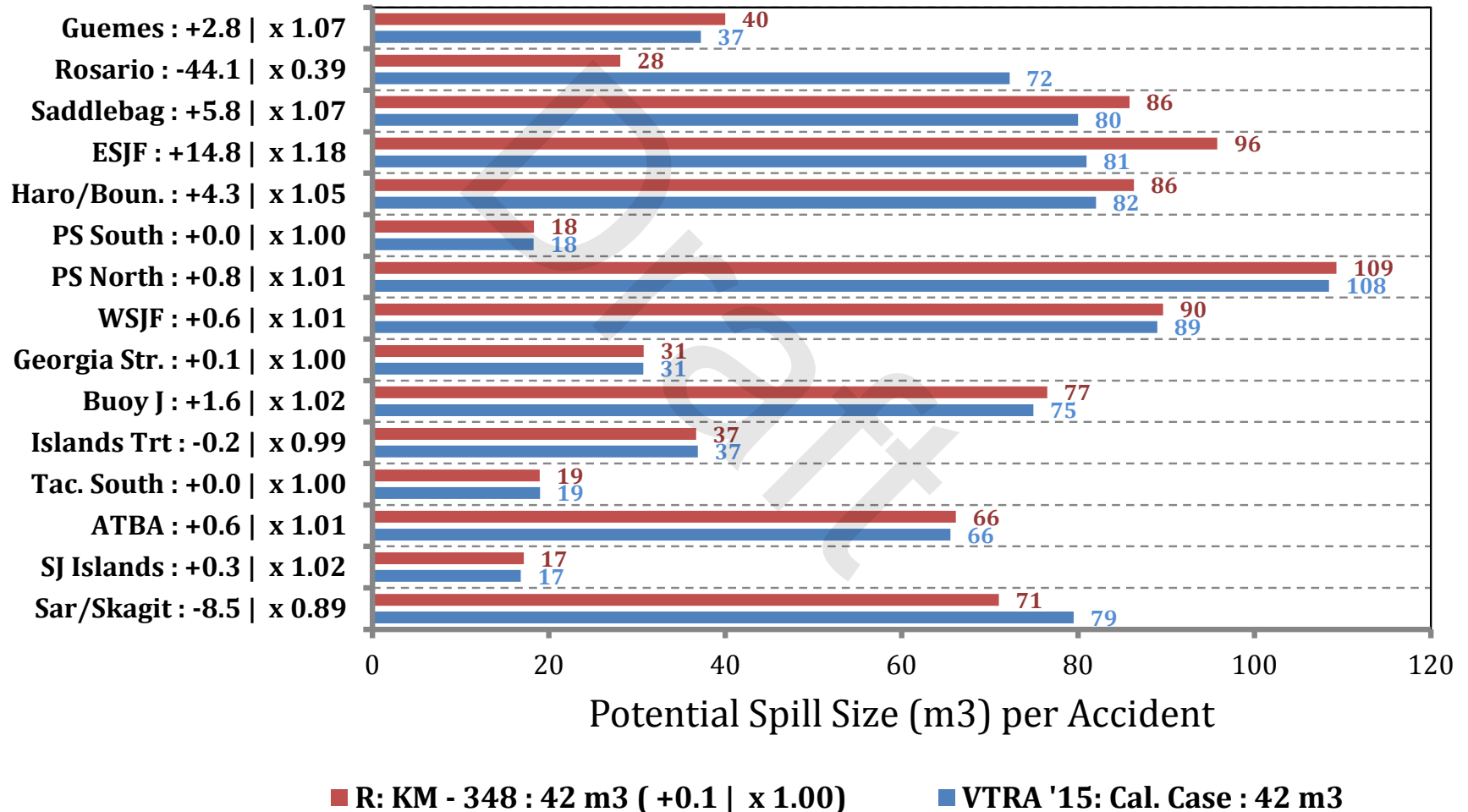
VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

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

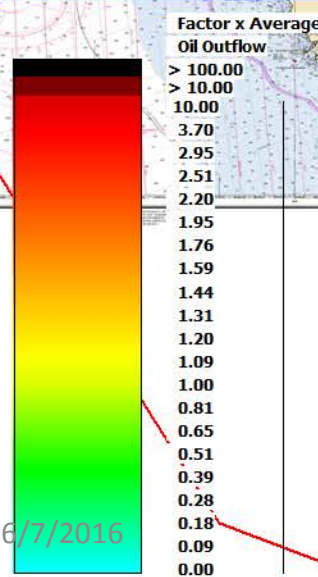
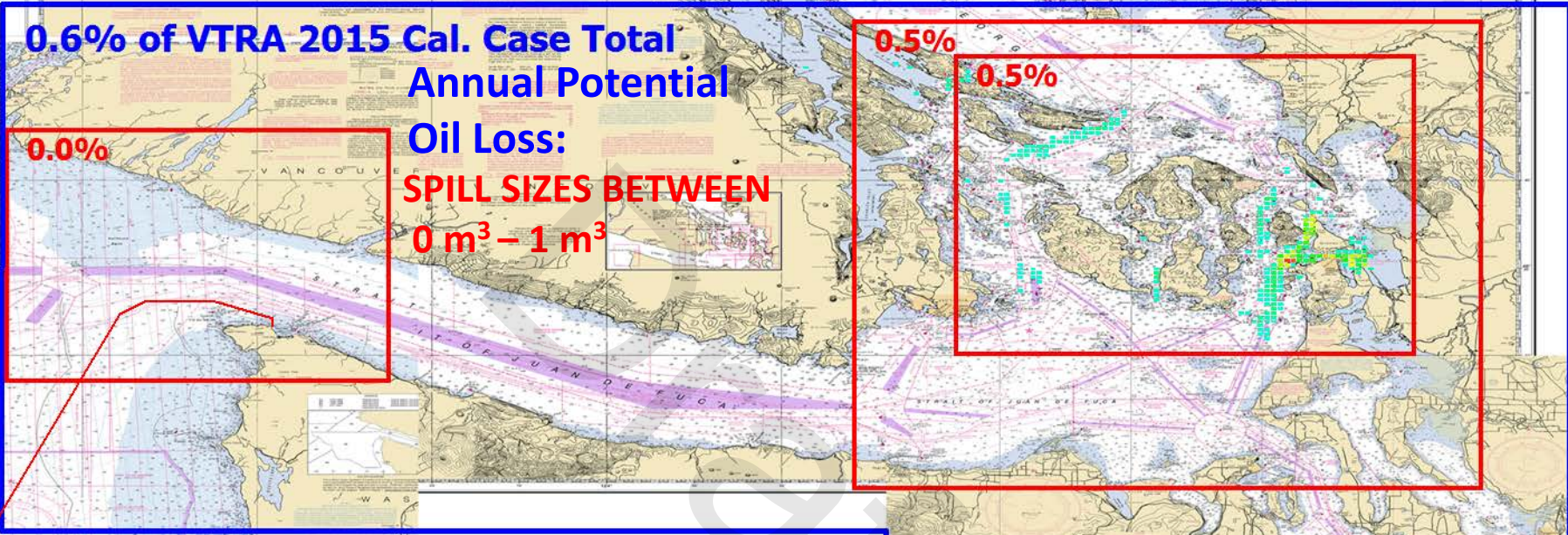
Oil Spill Size Category:

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

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)

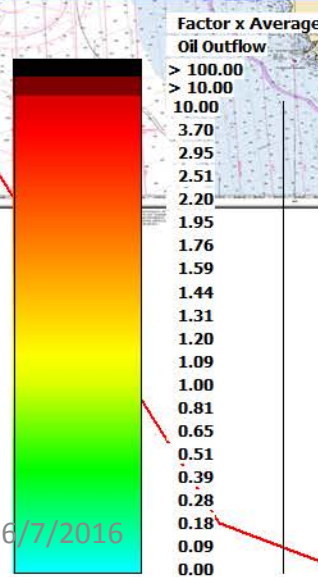
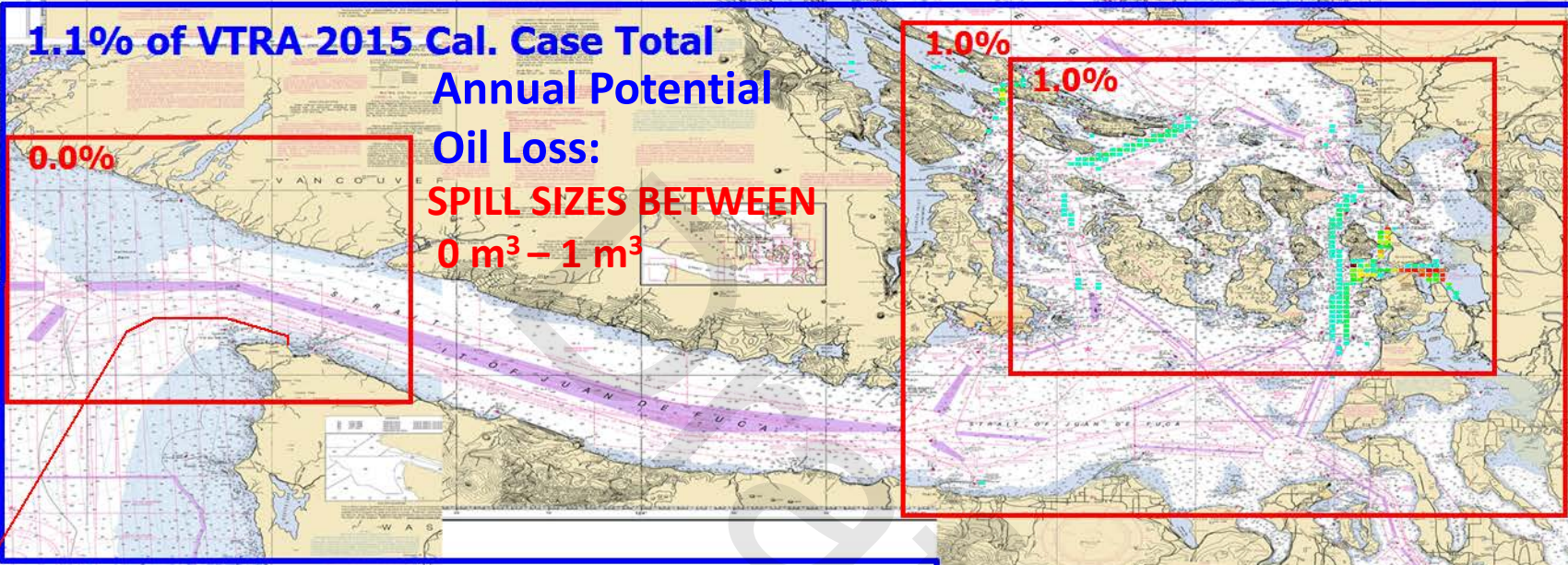
6/7/2016

5/24/2016

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



R: VTRA 2015 - Kinder Morgan 348 - ALL FV



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

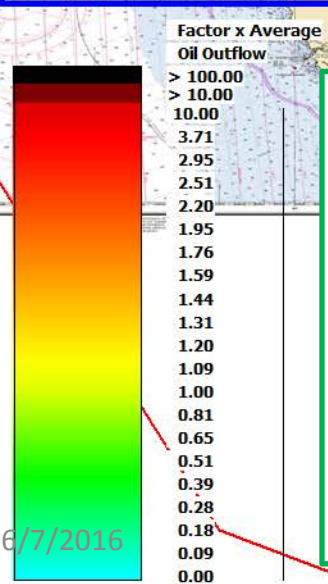
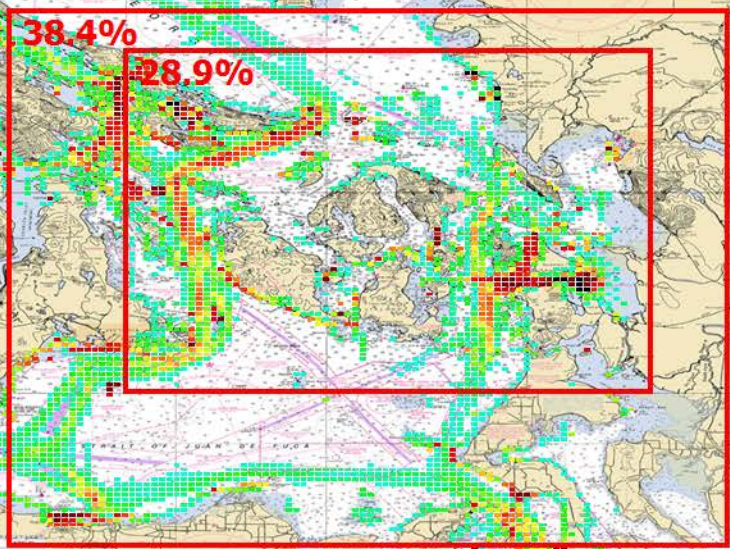
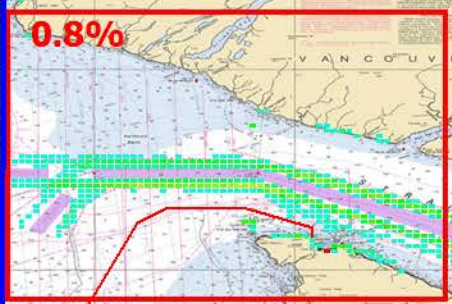
Average of ≈ 0.02 m³
Per Potential Spill
(≈ 4.2 gallons)

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: Cal. Case
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

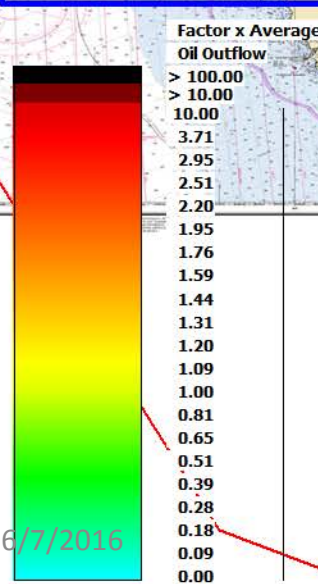
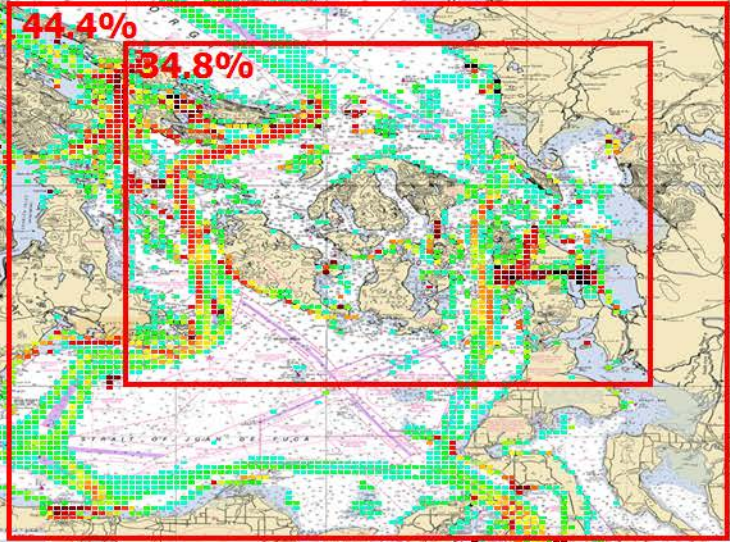
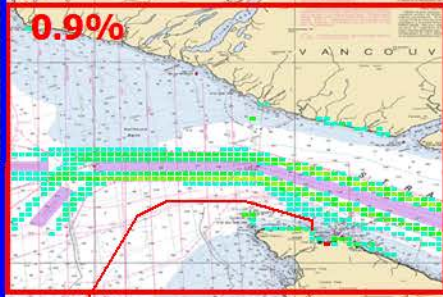
Average of ≈ 0.01 m^3
Per Potential Spill
(≈ 2.4 gallons)

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

R: VTRA 2015 - Kinder Morgan 348 - ALL FV

104.3% of VTRA 2015 Cal. Case Total Potential Annual # Accidents:

SPILL SIZES BETWEEN 0 m³ - 1 m³



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

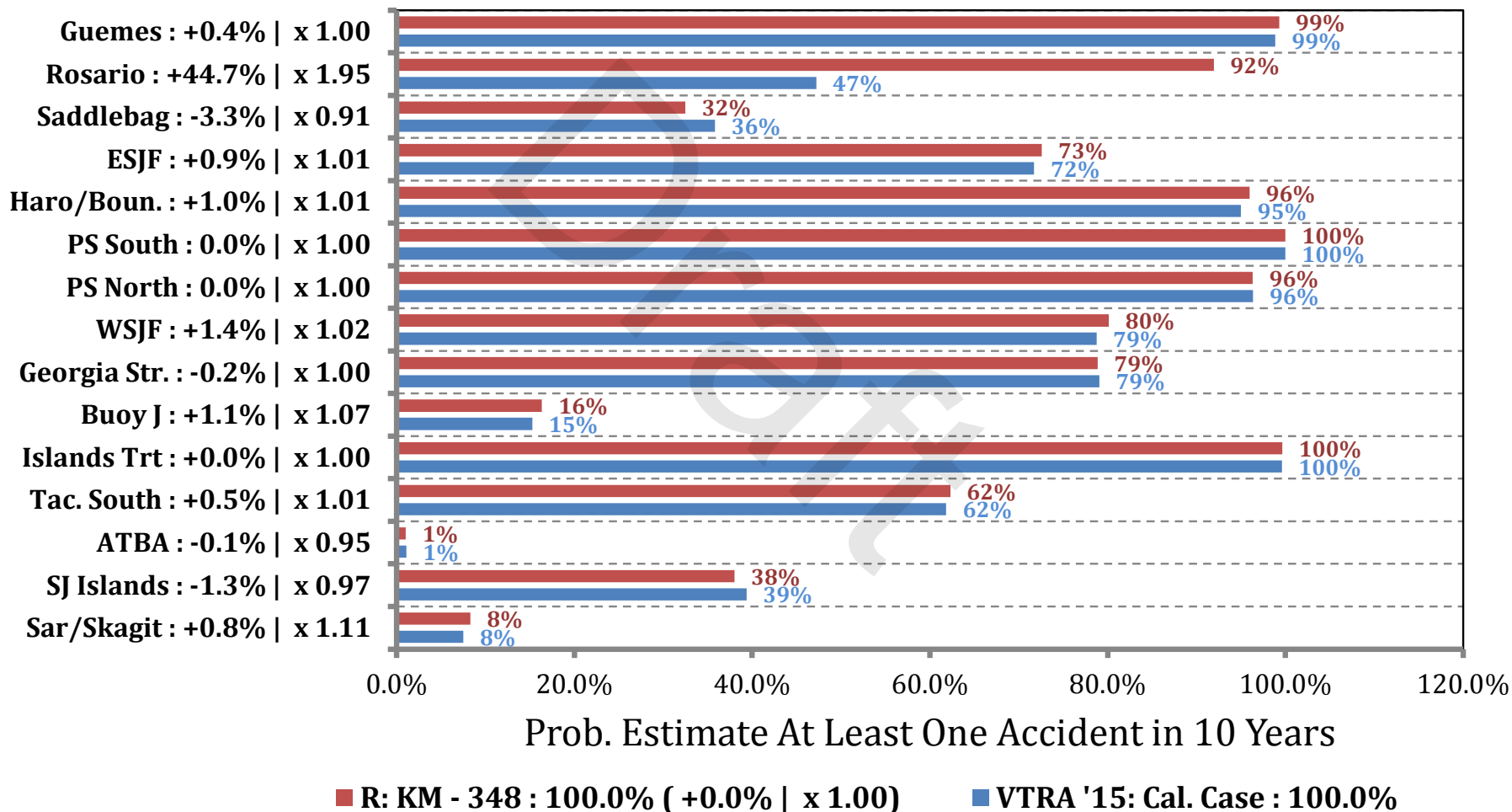
Average of ≈ 0.02 m³ Per Potential Spill (= 4.2 gallons)

6/7/2016

5/27/2016

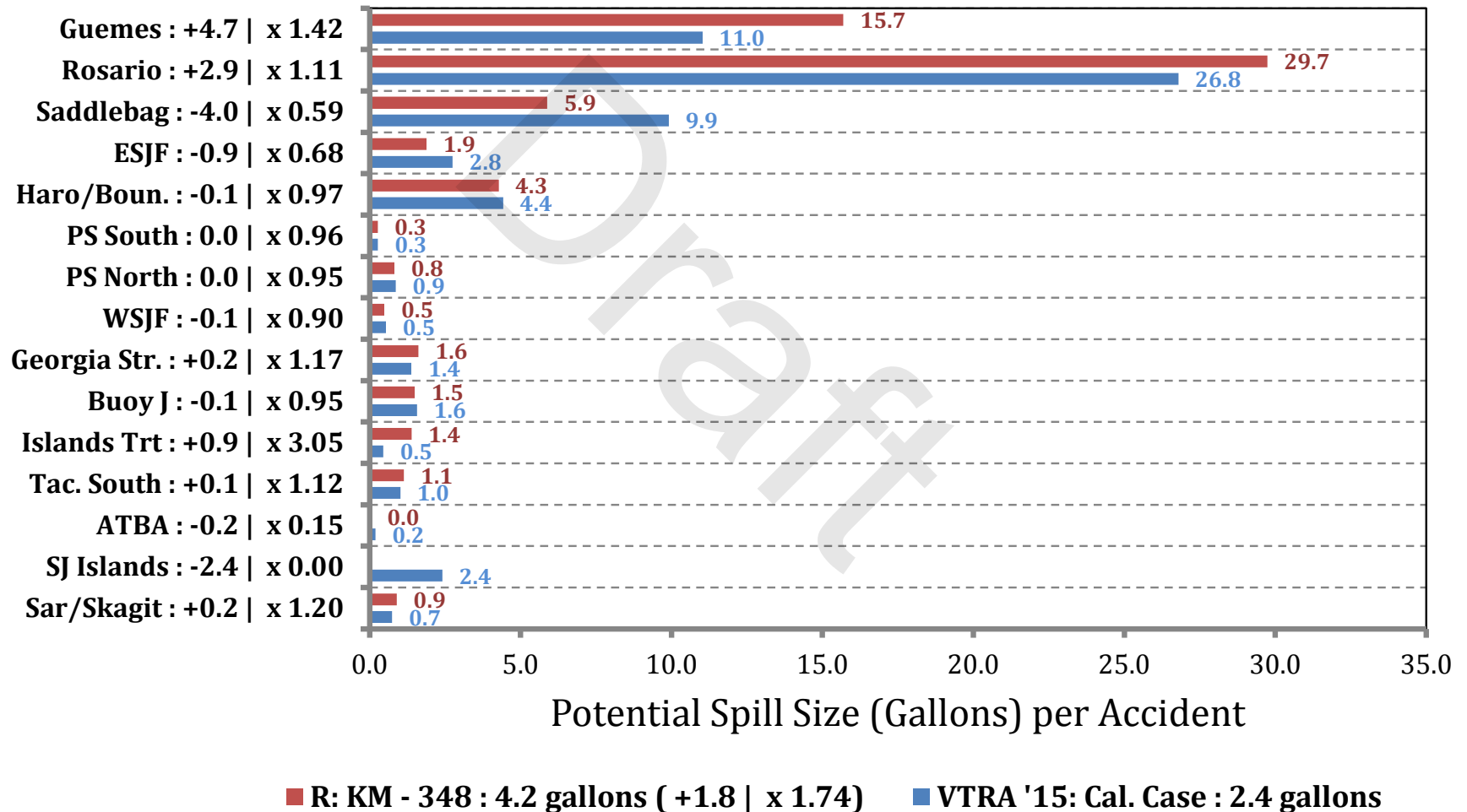
VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

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



By Waterway Zone 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 R: KM - 348	Base Case % Potential Annual Oil Loss	60.1% (+20.2% x1.51)	19.0% (+6.8% x1.56)	49.8% (+2.4% x1.05)	1.1% (+0.49% x1.84)	130.0% (+30.0% x1.30)
	Base Case % Potential Annual Accident Frequency	0.02% (+0.01% x1.94)	0.02% (+0.01% x1.47)	1.8% (+0.1% x1.05)	104.3% (+6.0% x1.06)	106.1% (+6.1% x1.06)
	Average potential spill size per accident (in m ³)	4466 (-1278.9 x0.78)	1726 (+98.7 x1.06)	42.0 (+0.1 x1.00)	0.02 (+0.0 x1.73)	1.9 (+0.3 x1.22)
	Probability of at least one accident in 1 year by spill size	0.09% (+0.04% x1.94)	0.07% (+0.02% x1.47)	7.7% (+0.3% x1.05)	99.0% (+0.3% x1.00)	99.0% (+0.3% x1.00)
	Probability of at least one accident in 10 years by spill size	0.90% (+0.44% x1.94)	0.74% (+0.24% x1.47)	54.9% (+1.7% x1.03)	100.0% (0.0% x1.00)	100.0% (0.0% x1.00)
	Probability of at least one accident in 25 years by spill size	2.24% (+1.08% x1.93)	1.83% (+0.58% x1.47)	86.4% (+1.3% x1.02)	100.0% (0.0% x1.00)	100.0% (0.0% x1.00)