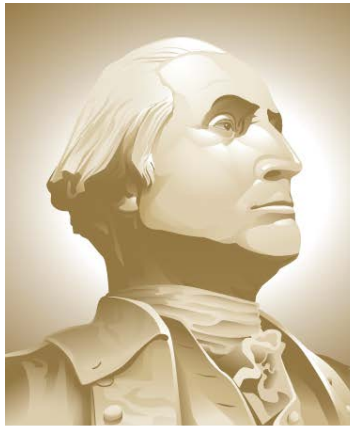


VTRA 2015 Calibration Case and VTRA 2010 Base Case Comparison



**THE GEORGE
WASHINGTON
UNIVERSITY**

WASHINGTON, DC

VCU

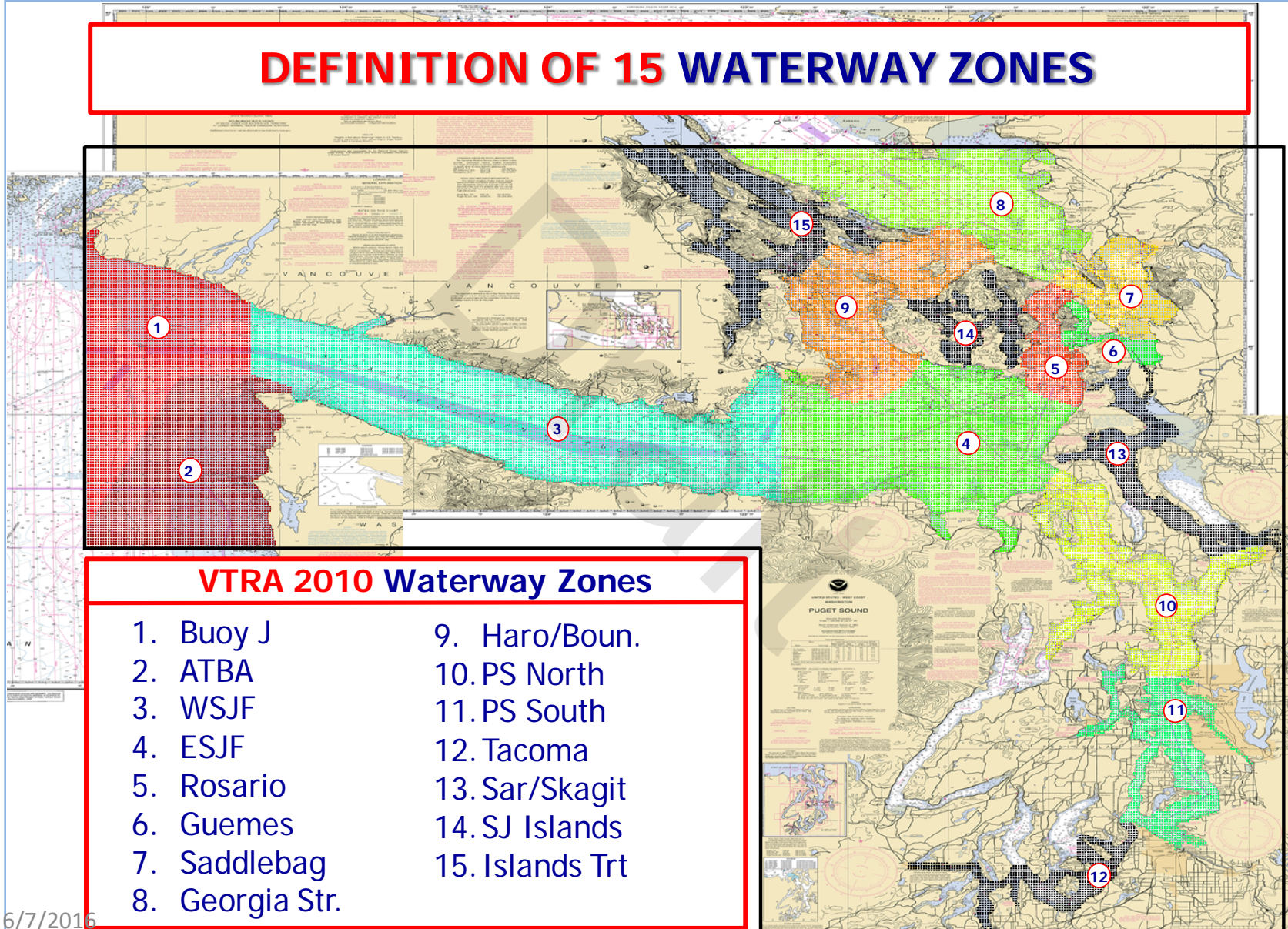
Jason R.W. Merrick (VCU) and J. Rene van Dorp (GW)

June 1st - 2nd, 2016

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



DEFINITION OF 15 WATERWAY ZONES



By Waterway Zone Risk Comparison

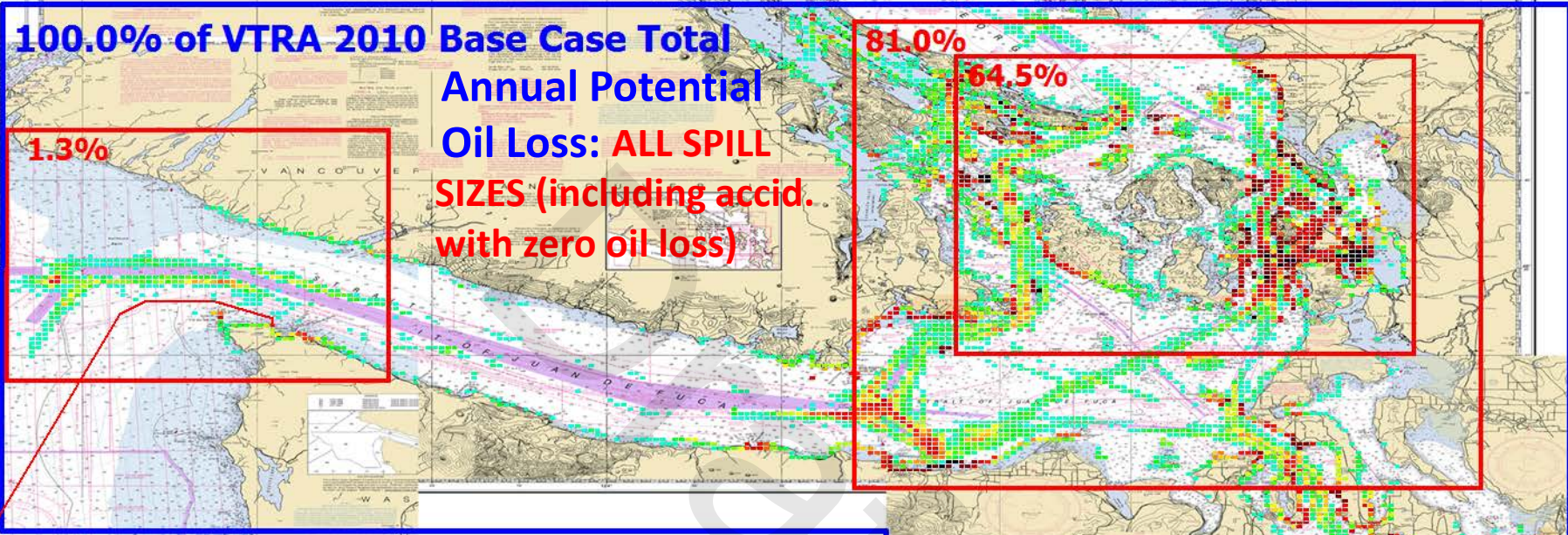
Oil Spill Size Category:

ALL SPILL SIZES

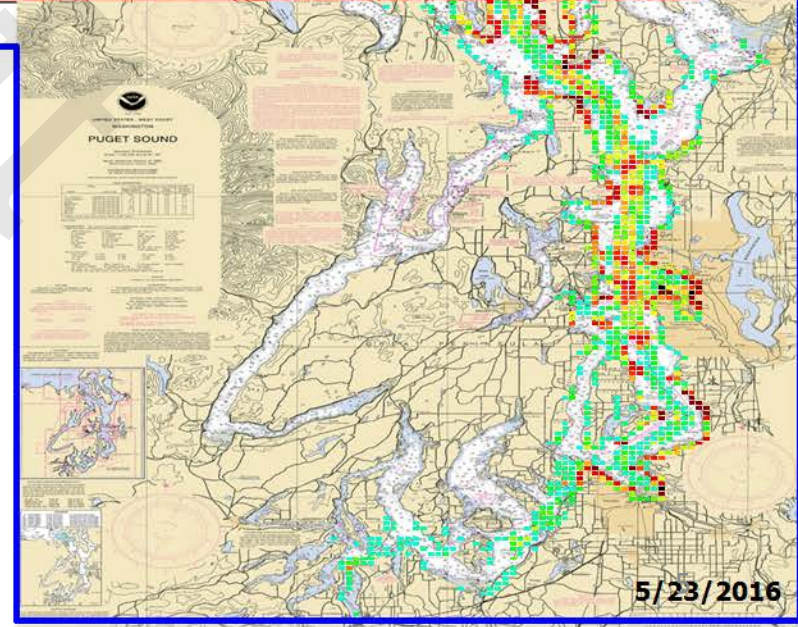
VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



VTRA 2010 BASE CASE - ALL FV



VTRA '10 Base Case
GEOGRAPHIC PROFILE
OF POTENTIAL ANNUAL
OIL LOSS OF ACCIDENTS
IN SPILL SIZE CATEGORY
ALL SPILL SIZES



6/7/2016

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

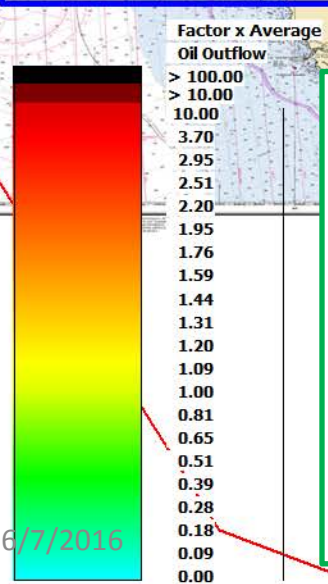


VTRA 2015 CALLIBRATION CASE - ALL FV

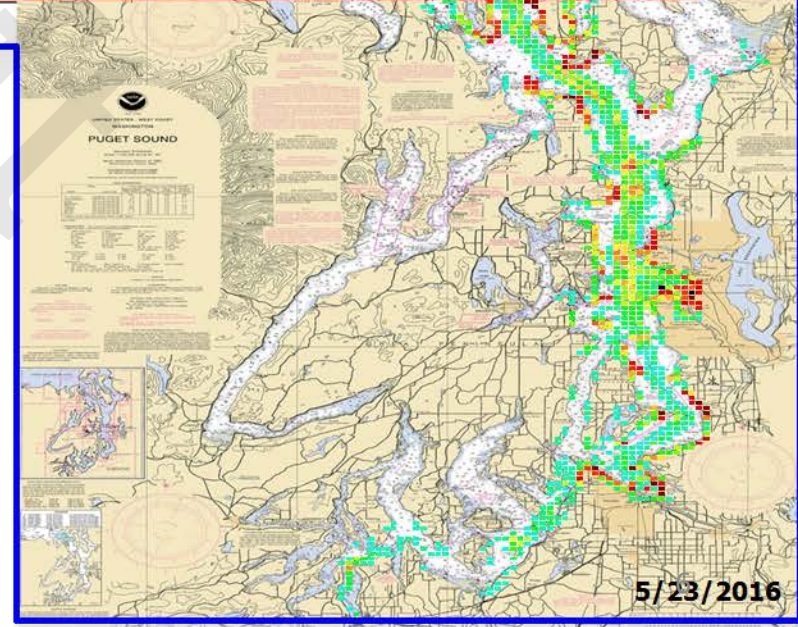
41.9% of VTRA 2010 Base Case Total Annual Potential Oil Loss: ALL SPILL SIZES (including accid. with zero oil loss)

30.9%
23.3%

0.7%



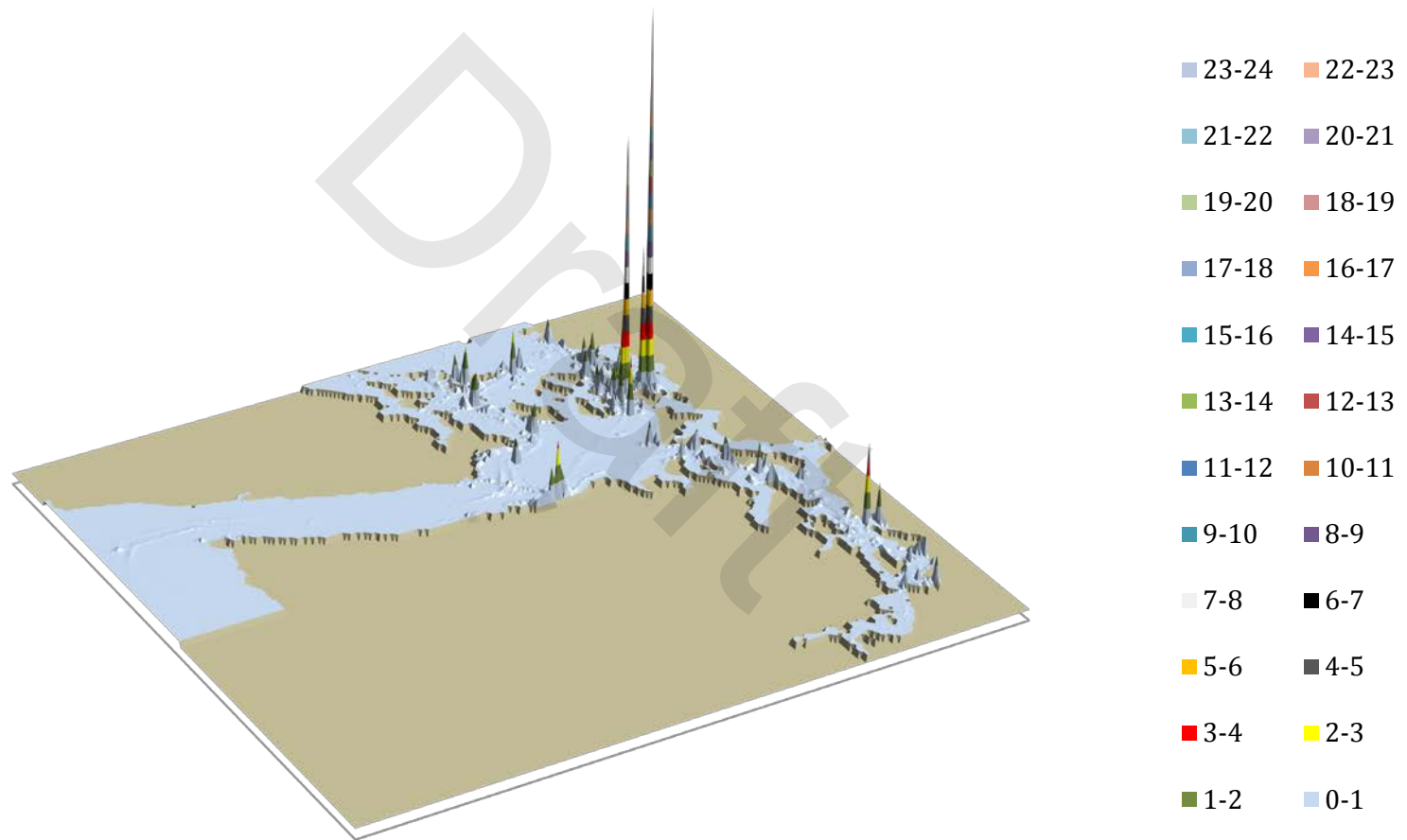
VTRA '15 Calibration Case
GEOGRAPHIC PROFILE OF POTENTIAL ANNUAL OIL LOSS OF ACCIDENTS IN SPILL SIZE CATEGORY **ALL SPILL SIZES**



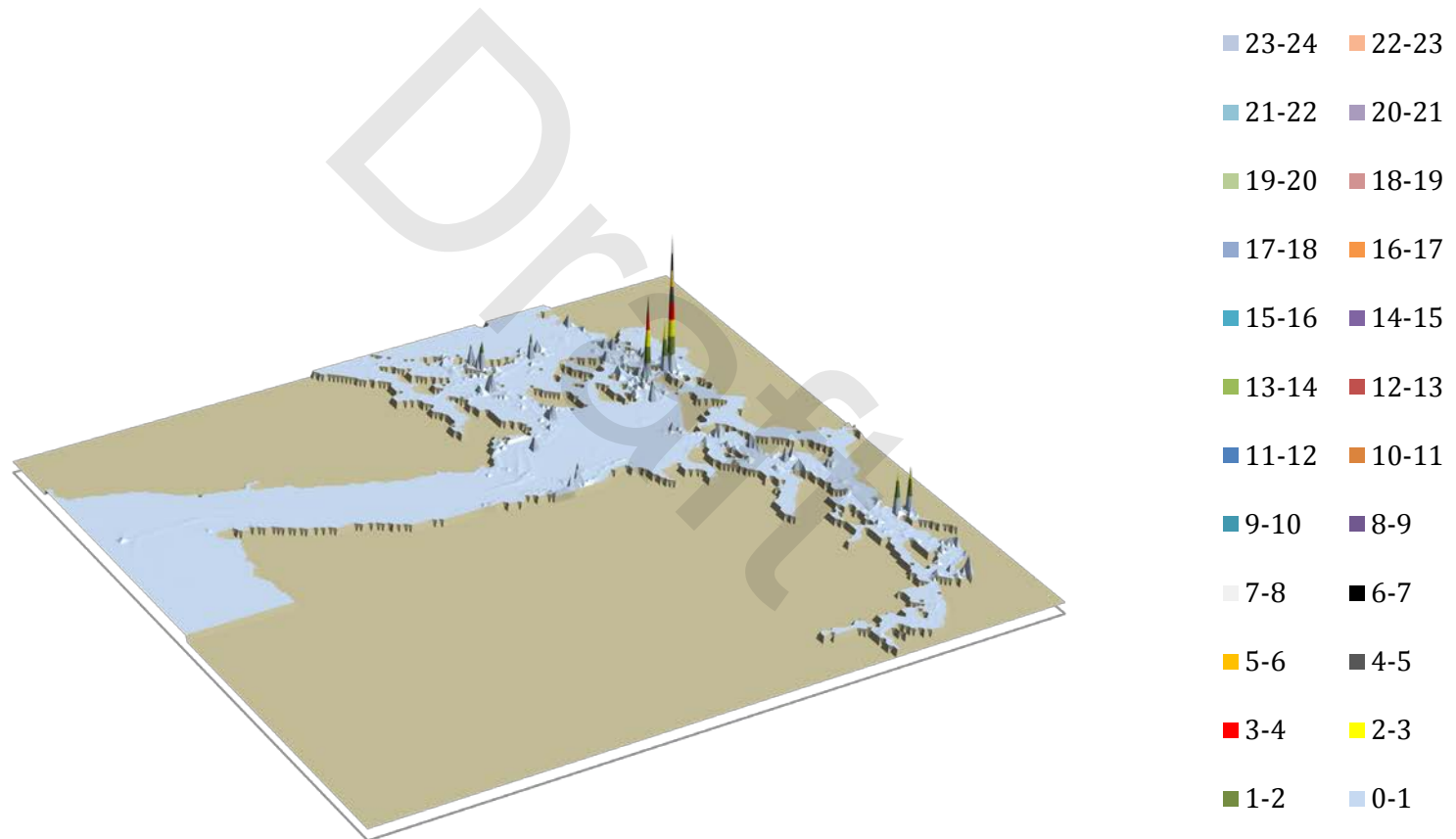
6/7/2016

5/23/2016

VTRA '10 Base Case 3D Risk Profile All FV - Pot. Grou+Coll.Oil Loss: 100% of Base Case POL

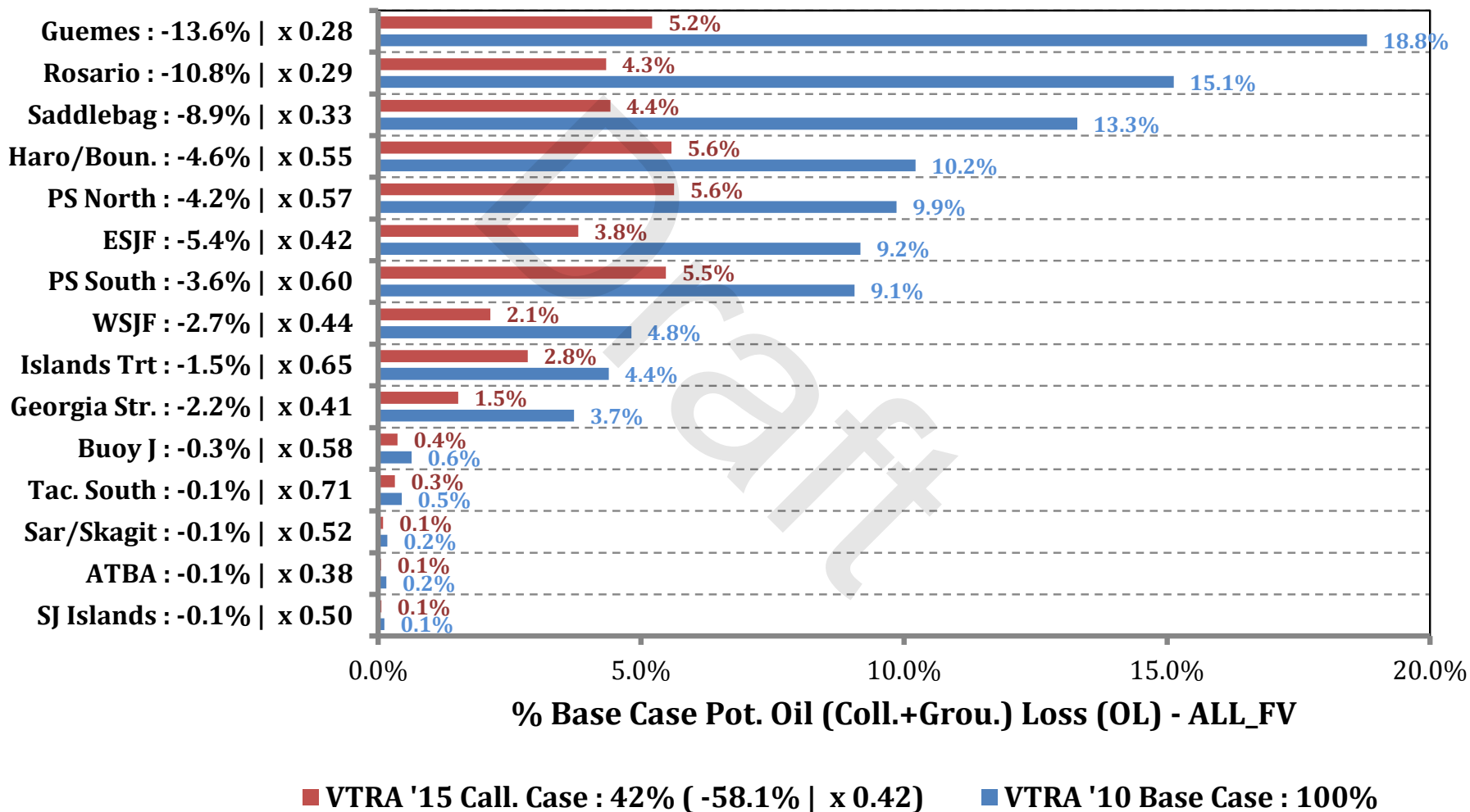


VTRA '15 Cal. Case 3D Risk Profile All FV - Pot. Grou+Coll.Oil Loss: 42% of Base Case POL



VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

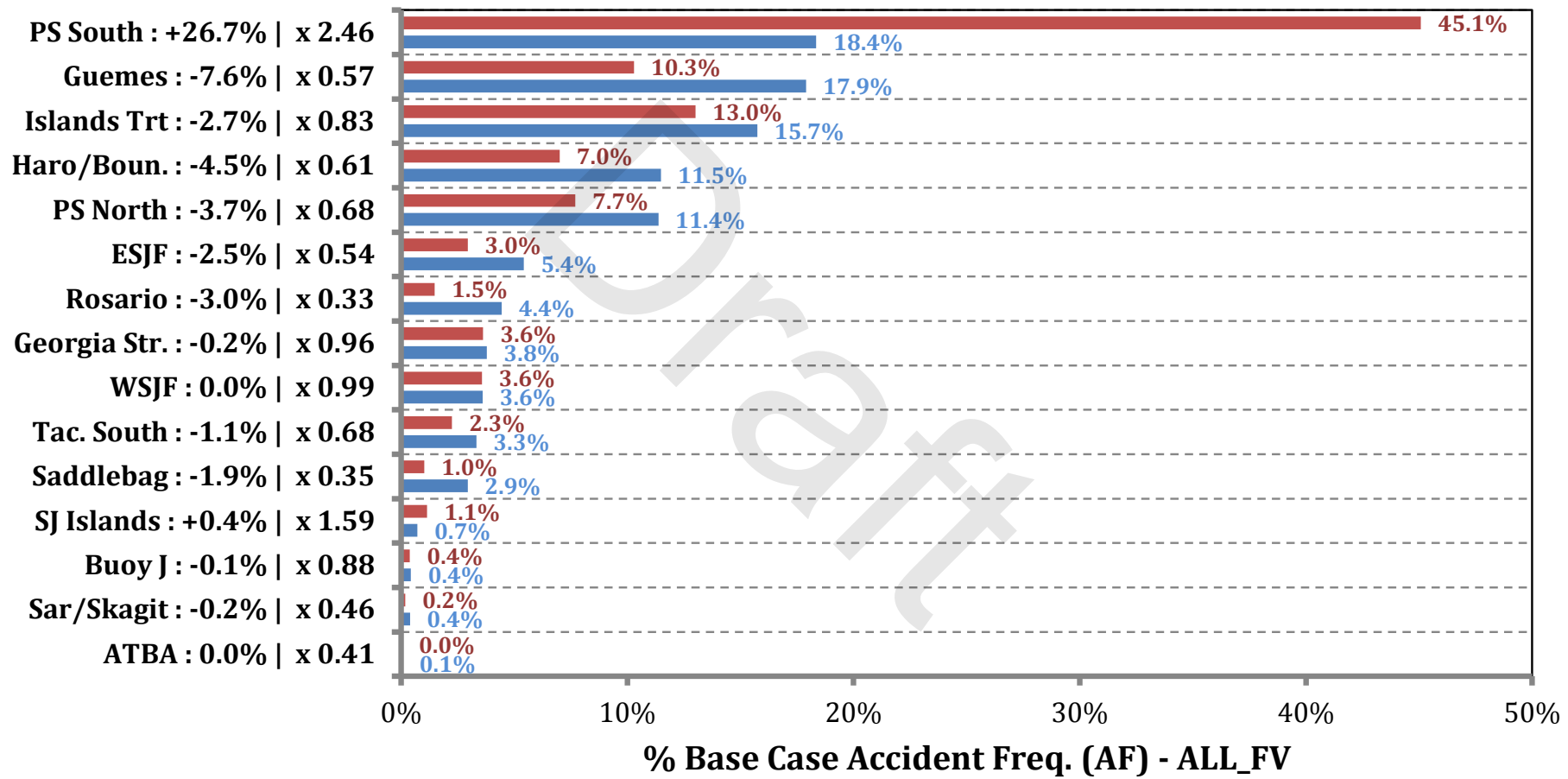
% Base Case Pot. Oil (Coll. + Grou. + All.) Loss - ALL_FV



VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



% Base Case Accident (Coll.+Grou.+All.) Freq. - ALL_FV



■ VTRA '15 Call. Case : 100% (-0.3% | x 1.00)
 ■ VTRA '10 Base Case : 100%

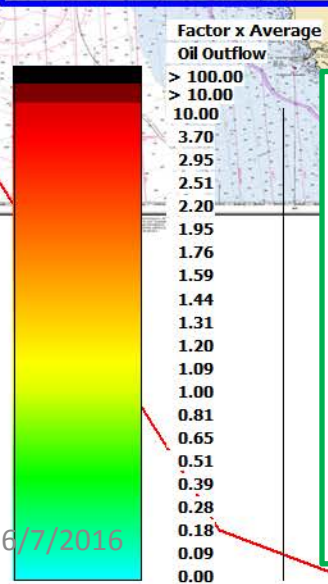
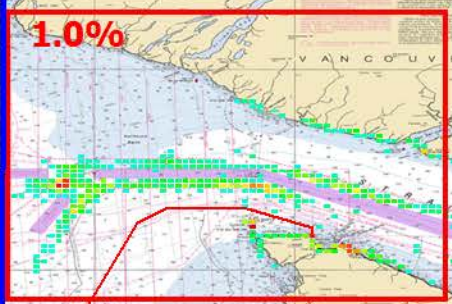
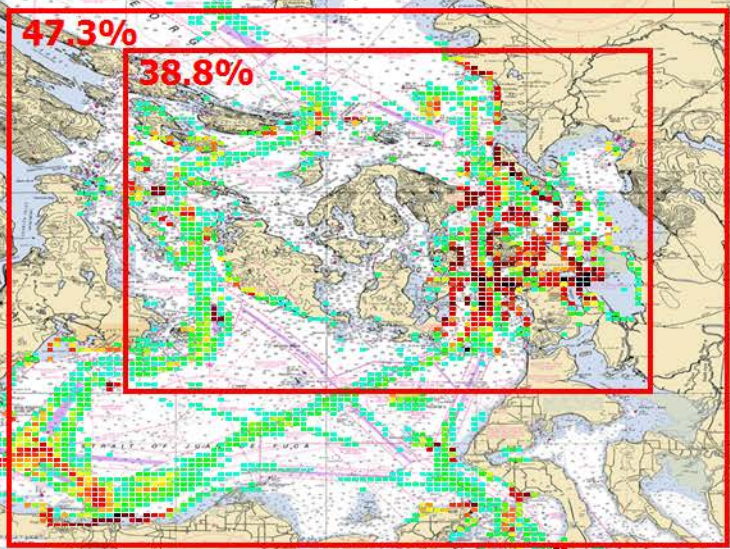
By Waterway Zone **Relative Risk** and **Absolute Risk** Comparison

Oil Spill Size Category:
2500 m³ or more

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

VTRA 2010 BASE CASE - ALL FV

54.4% of VTRA 2010 Base Case Total Annual Potential Oil Loss:
SPILL SIZES LARGER THAN 2,500 m³



VTRA '10: Base Case
GEOGRAPHIC PROFILE OF POTENTIAL ANNUAL OIL LOSS OF ACCIDENTS WITH SPILL SIZE **2,500 m³ or more**

≈ 1.43% Probability of Spill Occurrence in 10 years

Average of ≈ 6,073 m³ Per Potential Spill (≈ 5,223 Metric. Tons)

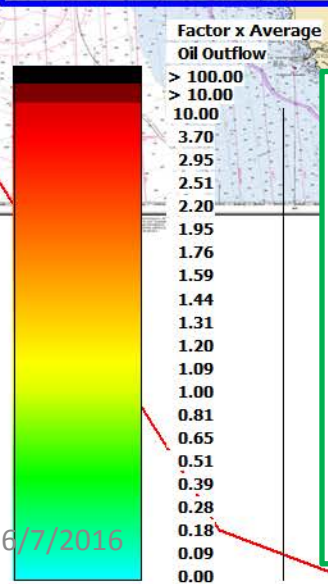
VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

VTRA 2015 CALIBRATION CASE - ALL FV

16.7% of VTRA 2010 Base Case Total Annual Potential Oil Loss:
SPILL SIZES LARGER THAN 2,500 m³

14.2%
11.4%

0.4%



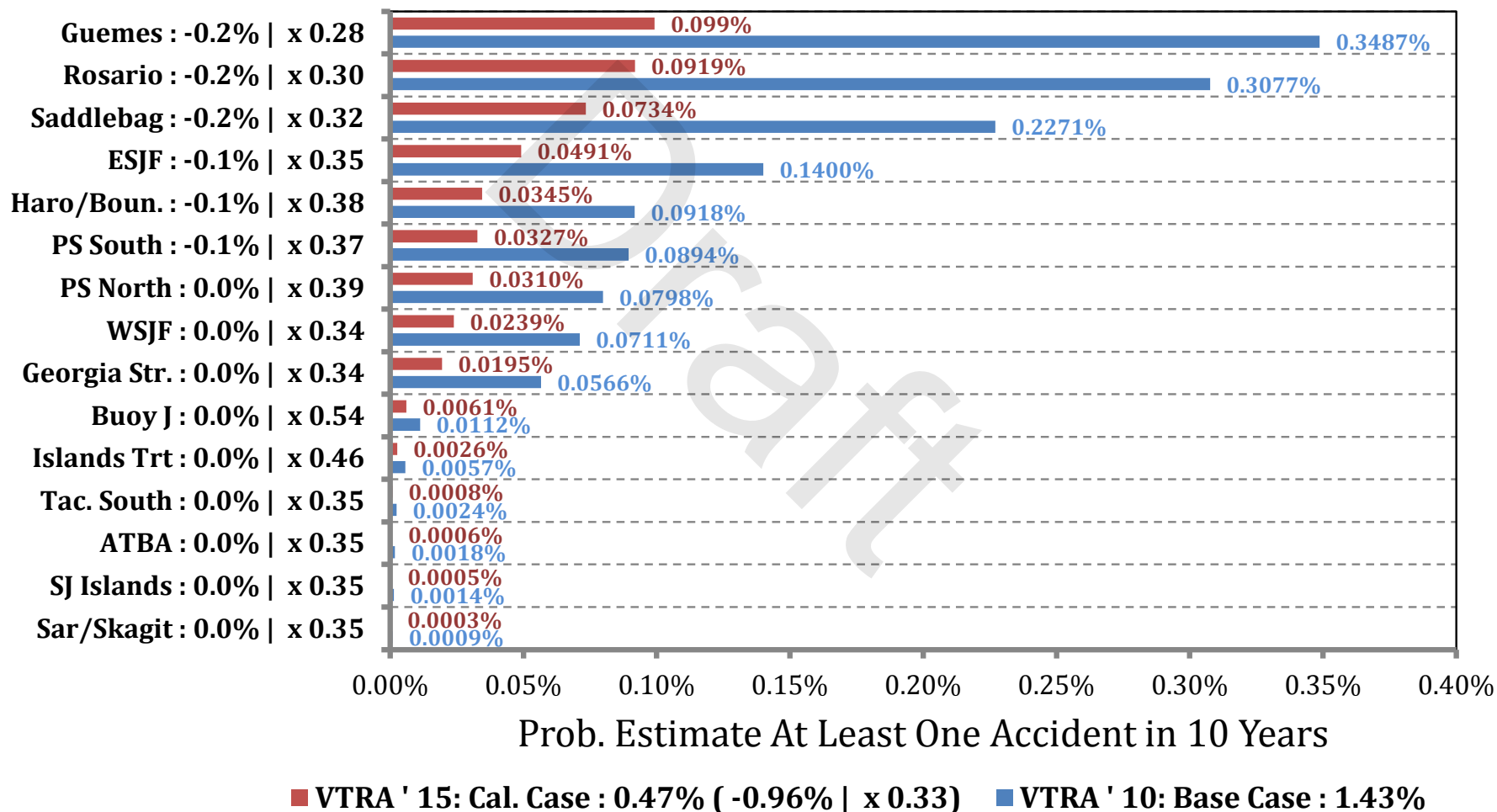
VTRA '15: Cal. Case
GEOGRAPHIC PROFILE OF POTENTIAL ANNUAL OIL LOSS OF ACCIDENTS WITH SPILL SIZE 2,500 m³ or more

≈ 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

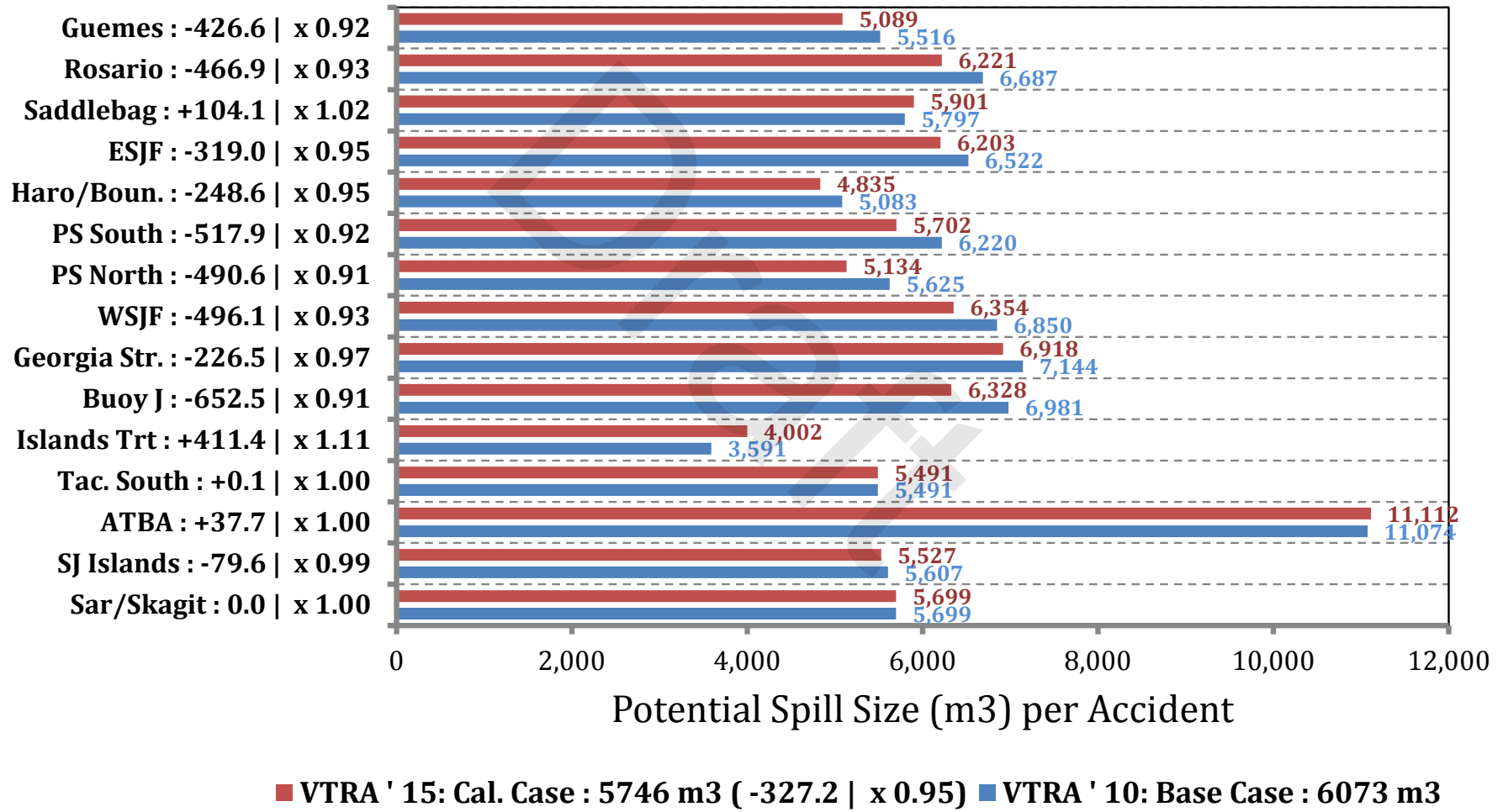
Prob. Estimate At Least One Accident in 10 Years - ALL_FV - Oil Spill Size Category: 2500 cubic meters or more



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 2010 BASE CASE - ALL FV

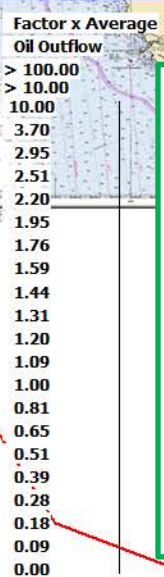
14.4% of VTRA 2010 Base Case Total Annual Potential Oil Loss:

0.1%

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

12.8%

11.1%



VTRA '10: Base Case
GEOGRAPHIC PROFILE
OF POTENTIAL
ANNUAL OIL LOSS
OF ACCIDENTS
WITH SPILL SIZE BETWEEN
1,000 m³ - 2,500 m³

≈ 1.39% Probability of Spill Occurrence in 10 years

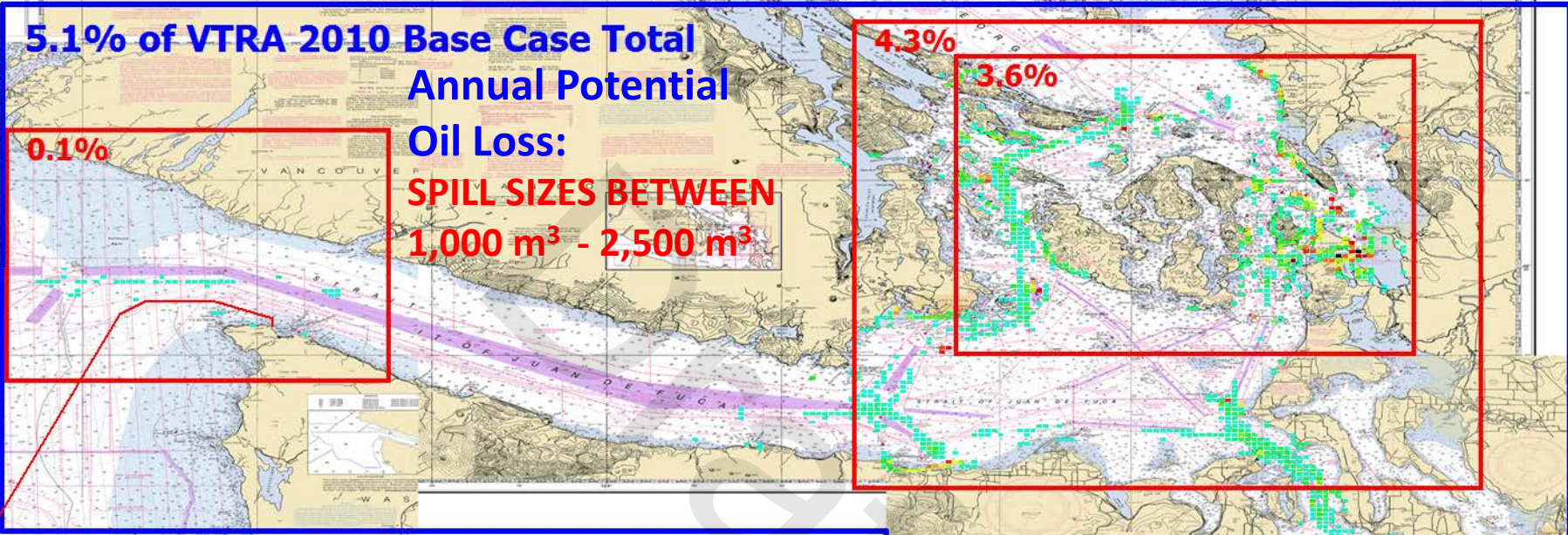
Average of ≈ 1,653 m³ Per Potential Spill (≈ 1,422 Metric Tons)

6/7/2016

5/23/2016

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
WITH SPILL SIZE **BETWEEN**
1,000 m³ - 2,500 m³

≈ 0.50% Probability
of Spill Occurrence
in 10 years

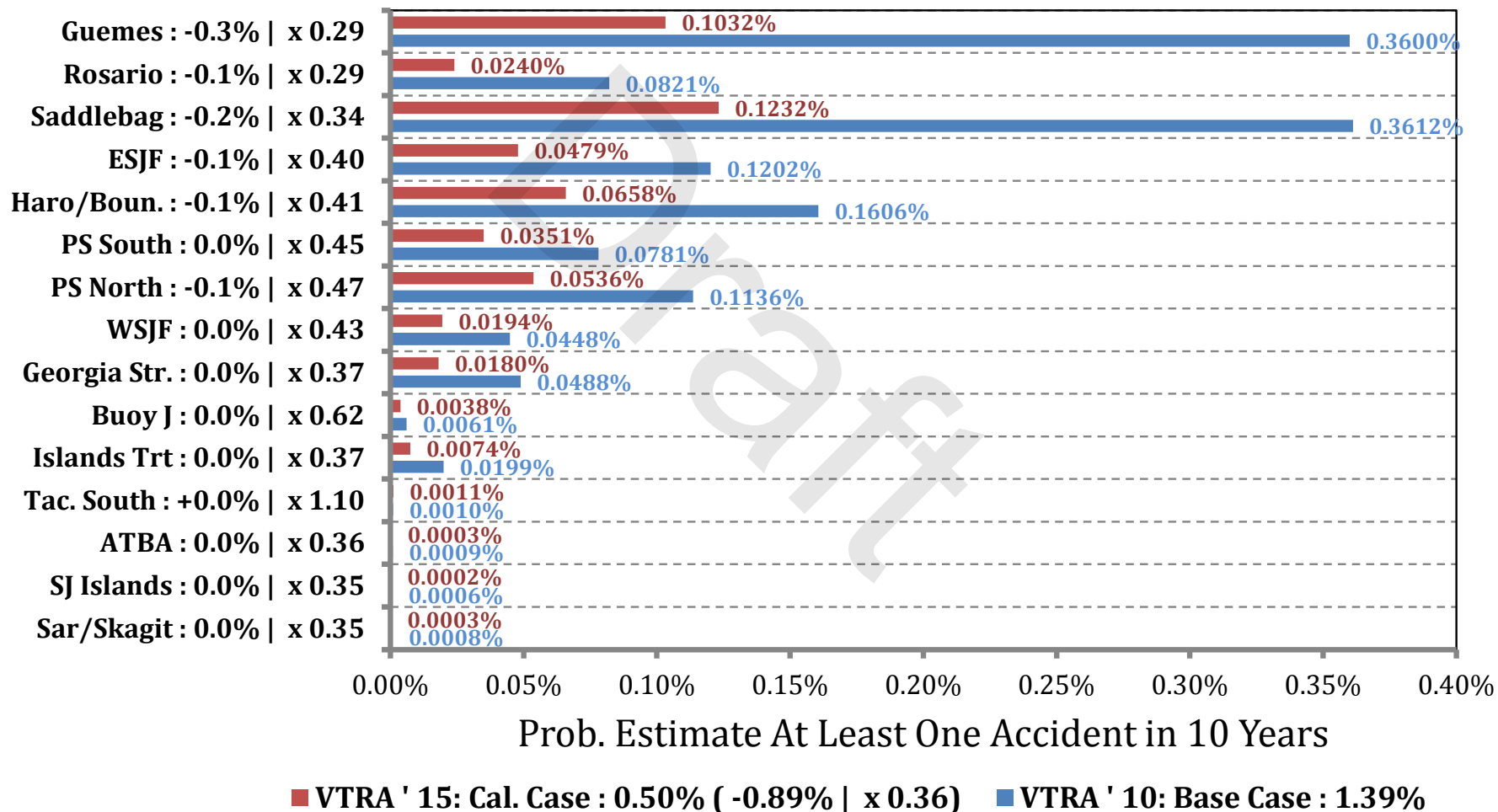
Average of ≈ 1,628 m³
Per Potential Spill
(≈ 1,400 Metric Tons)

6/7/2016

5/26/2016

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

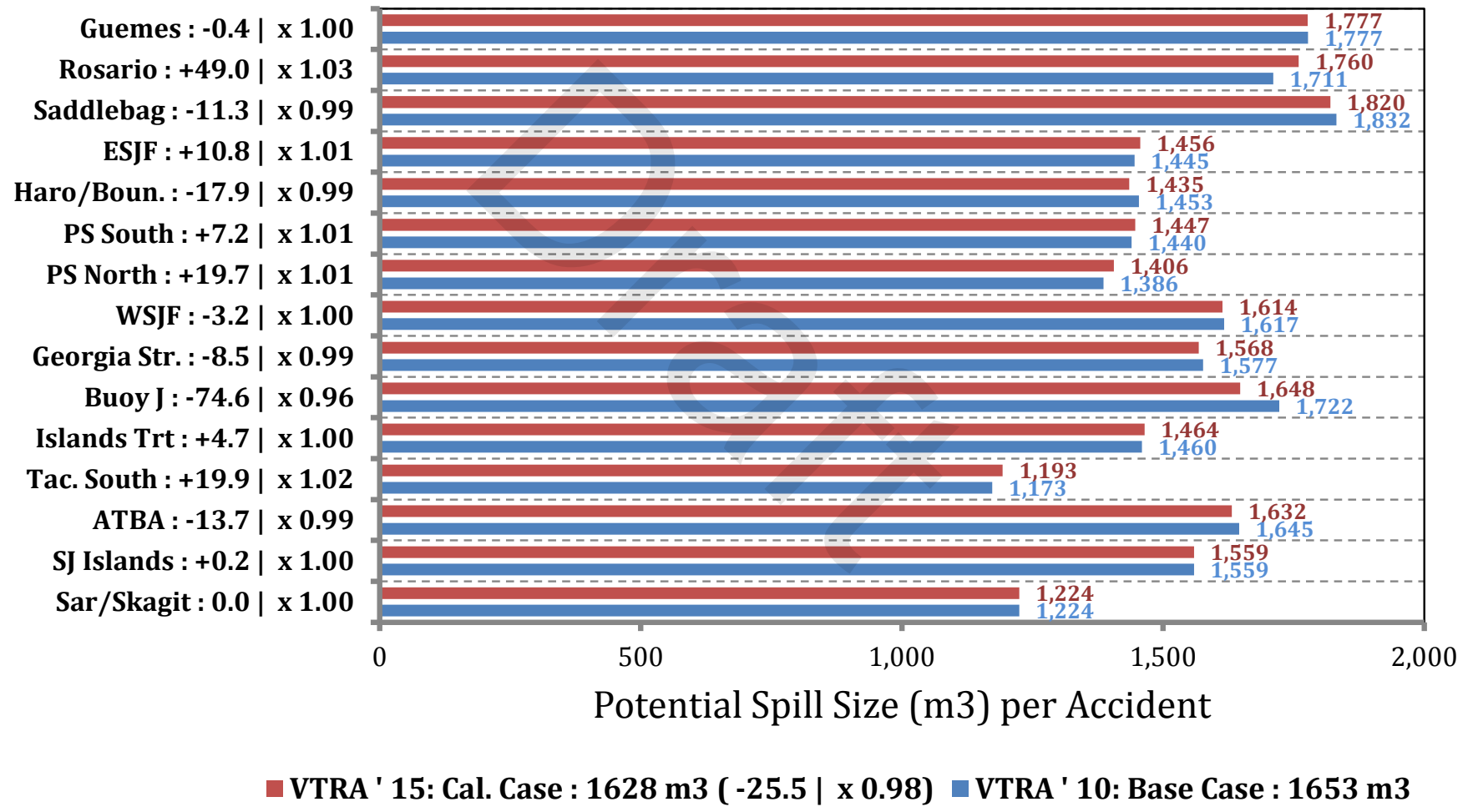
Prob. Estimate At Least One Accident in 10 Years - ALL_FV - Oil Spill Size Category: 1000 - 2500 m3



VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



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



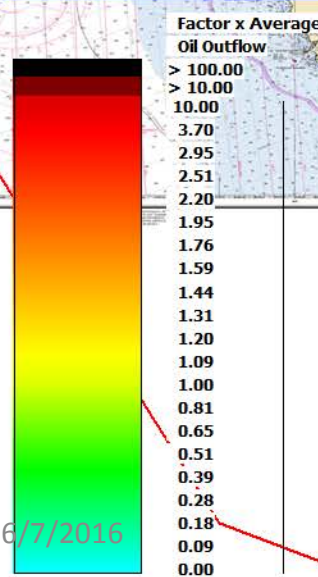
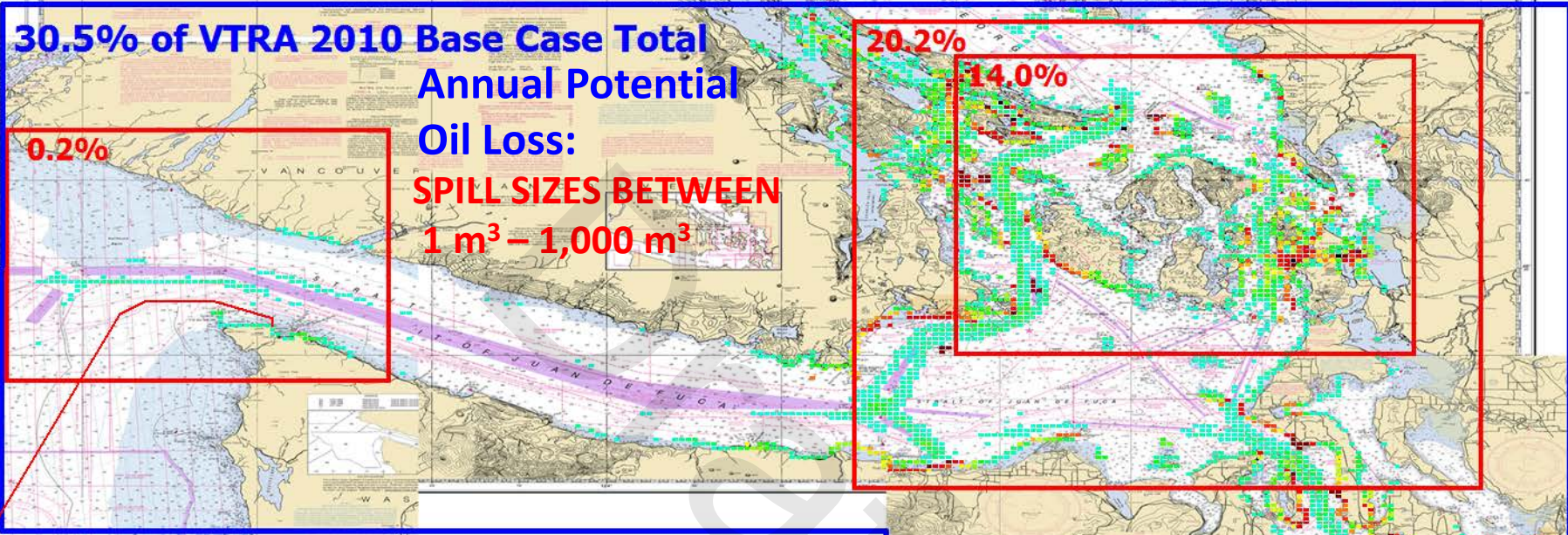
By Waterway Zone Risk Comparison

Oil Spill Size Category:

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

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

VTRA 2010 BASE CASE - ALL FV



VTRA '10: Base Case
GEOGRAPHIC PROFILE
OF ANNUAL
POTENTIAL OIL LOSS
OF ACCIDENTS
WITH SPILL SIZE
BETWEEN 1 m³ - 1000 m³

≈ 52.2% Probability
of Spill Occurrence
in 10 years

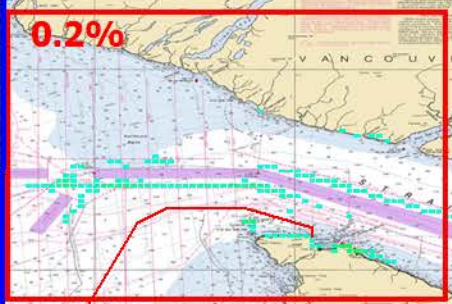
Average of ≈ 66.0 m³
Per Potential Spill
(≈ 416 barrels)

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

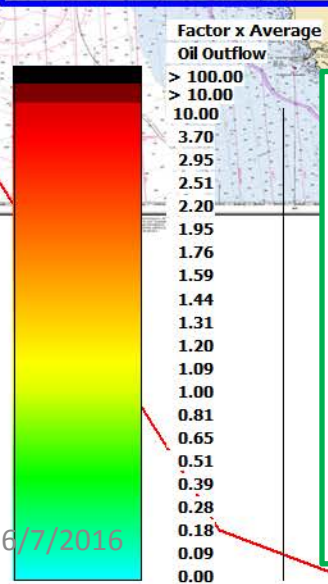
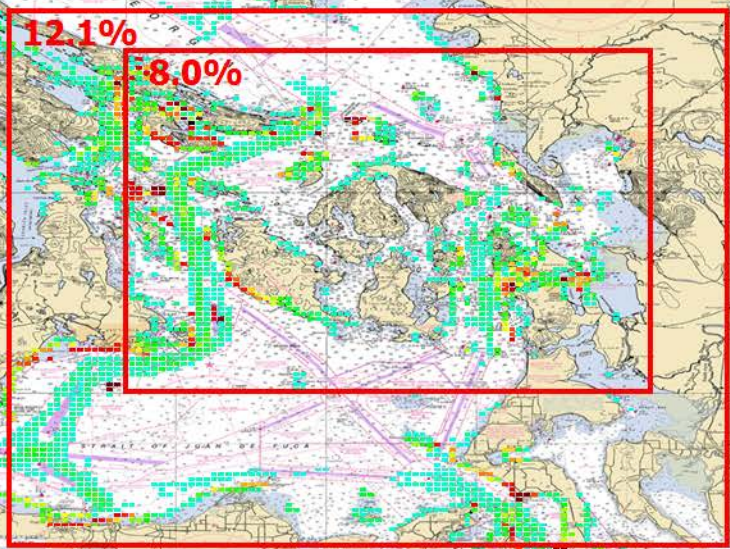


VTRA 2015 CALIBRATION CASE - ALL FV

19.9% of VTRA 2010 Base Case Total Annual Potential Oil Loss:



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



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

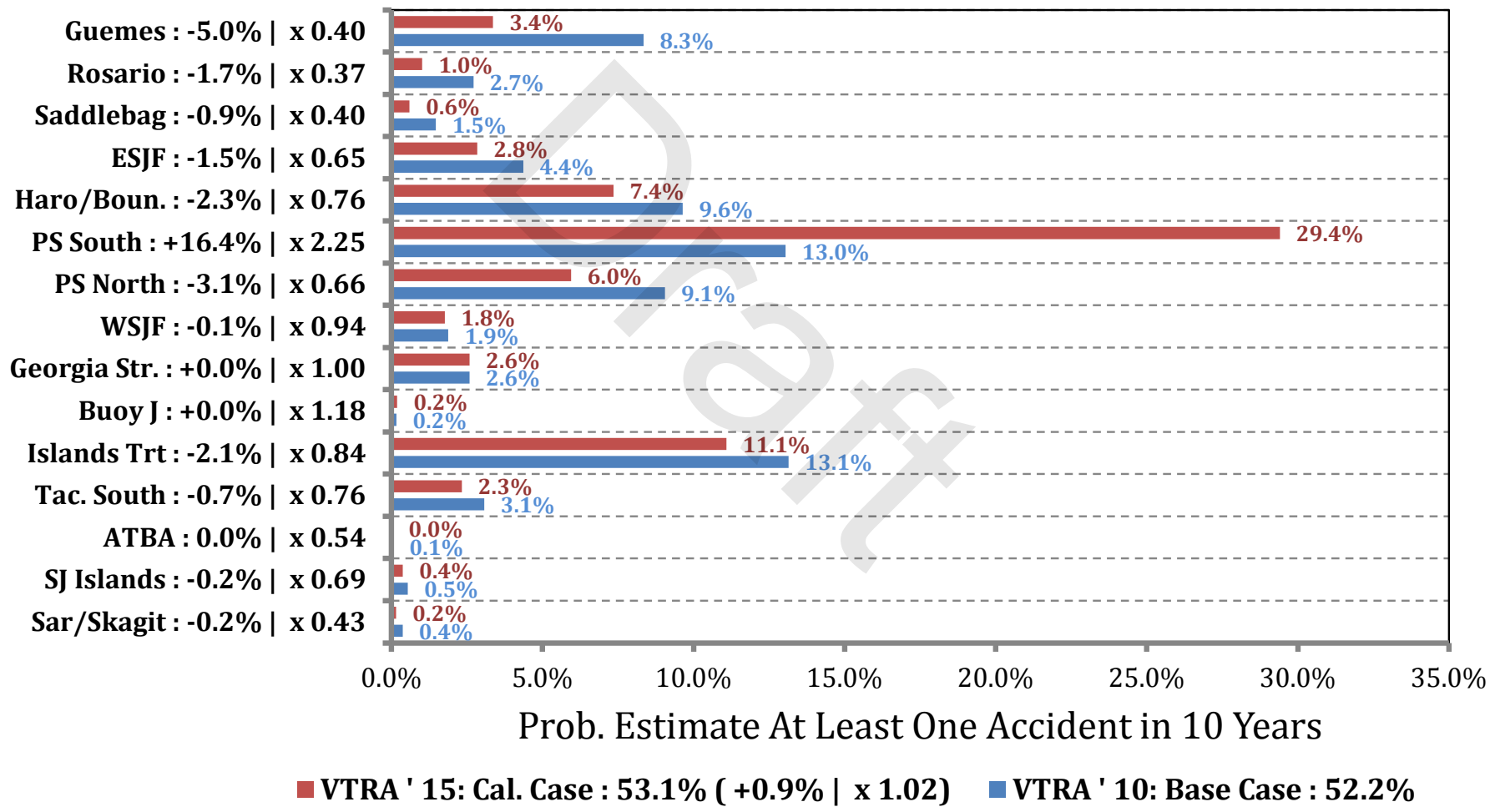
≈ 53.1% Probability of Spill Occurrence in 10 years

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

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

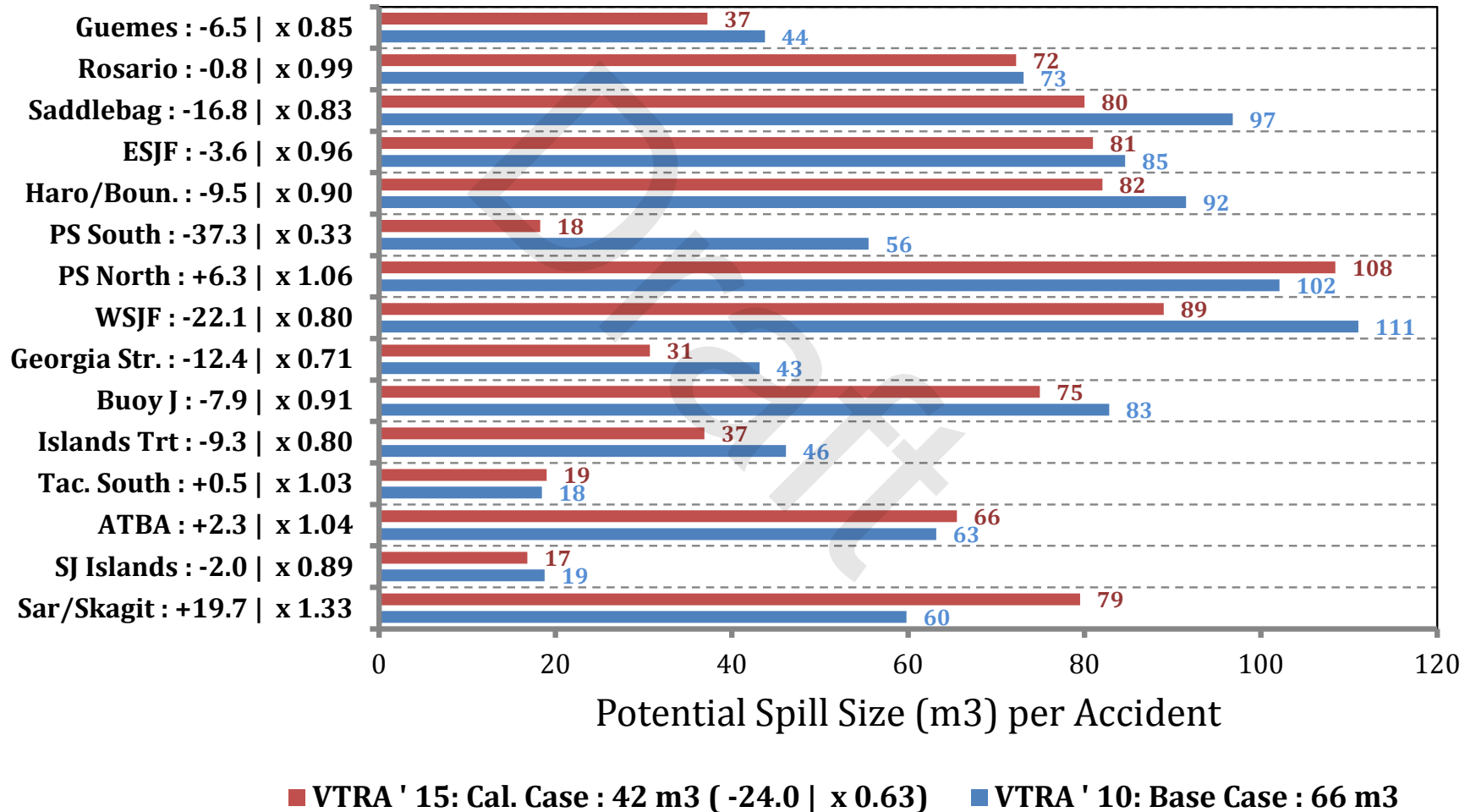


Prob. Estimate At Least One Accident in 10 Years - ALL_FV - Oil Spill Size Category: 1 - 1000 m3



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

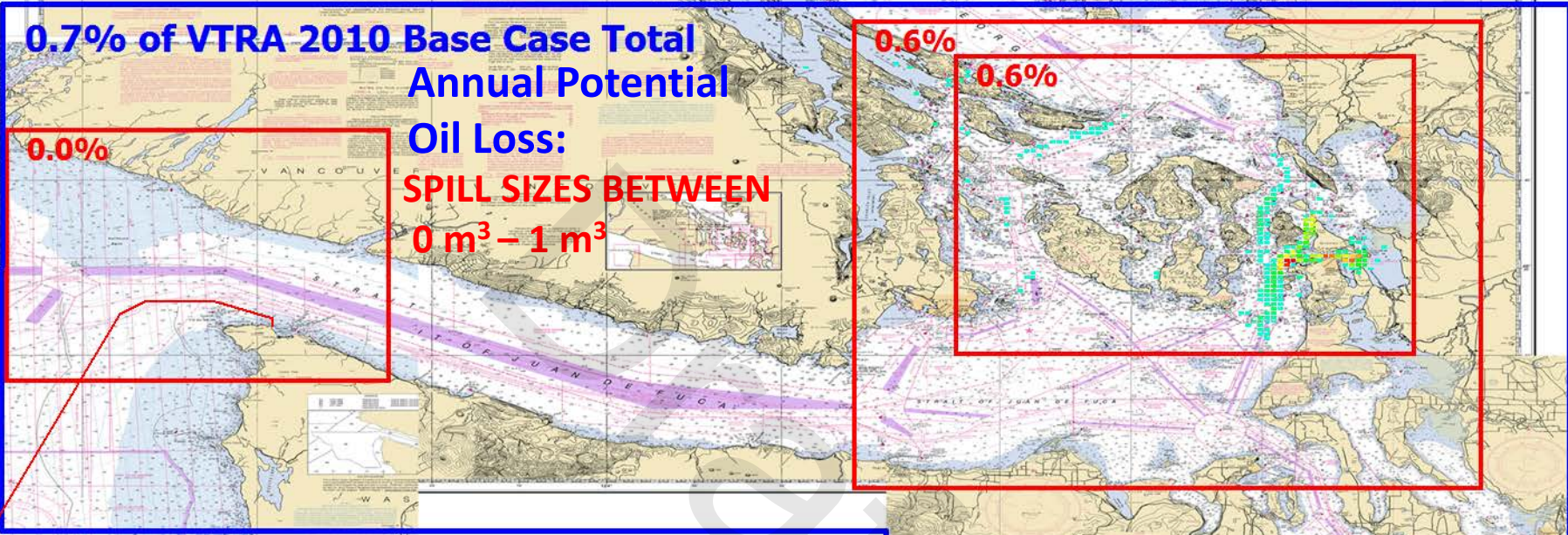
Oil Spill Size Category:

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

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

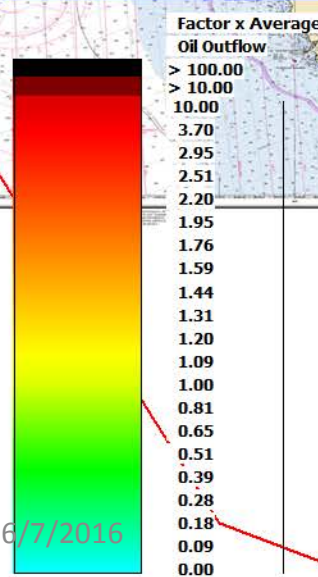


VTRA 2010 BASE CASE - ALL FV



0.7% of VTRA 2010 Base Case Total Annual Potential Oil Loss:
SPILL SIZES BETWEEN $0 \text{ m}^3 - 1 \text{ m}^3$

0.6%
0.6%



VTRA '10: Base 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 ≈ 0.03 m^3
Per Potential Spill
(≈ 6.7 gallons)

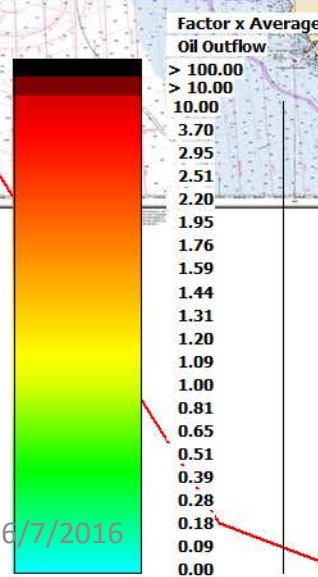
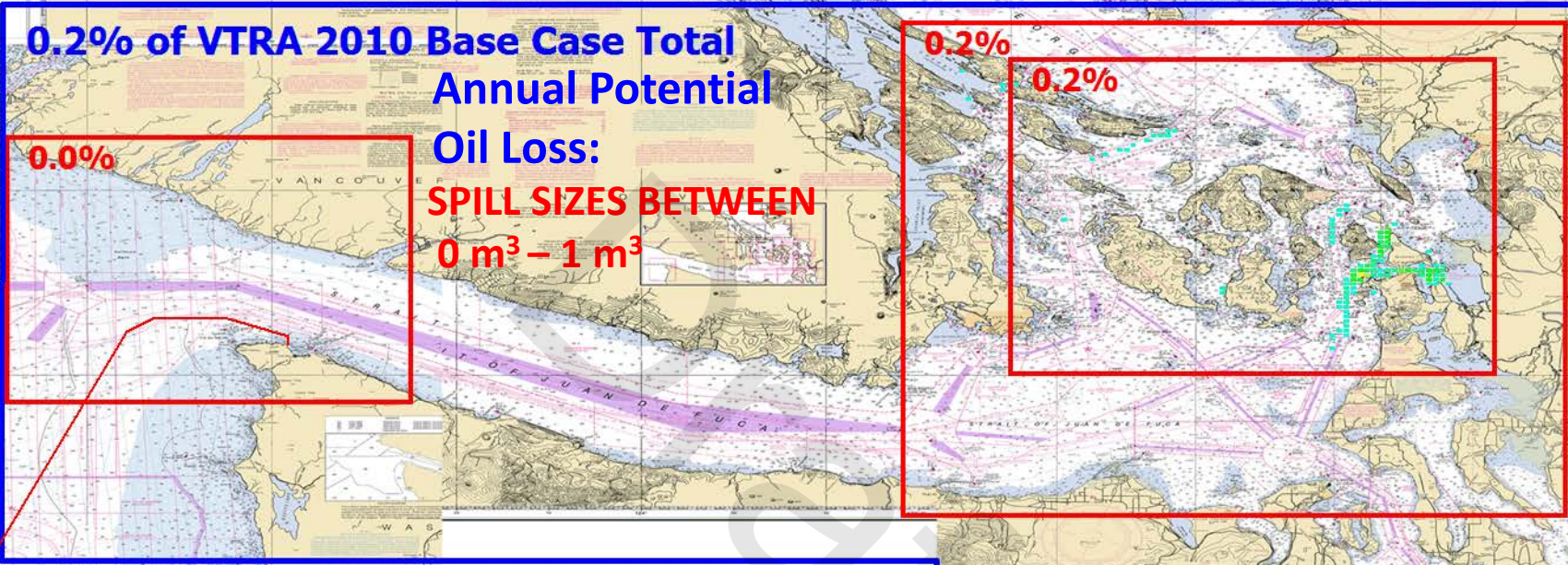
6/7/2016

5/23/2016

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

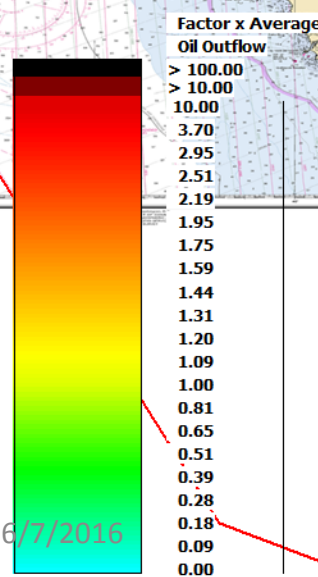
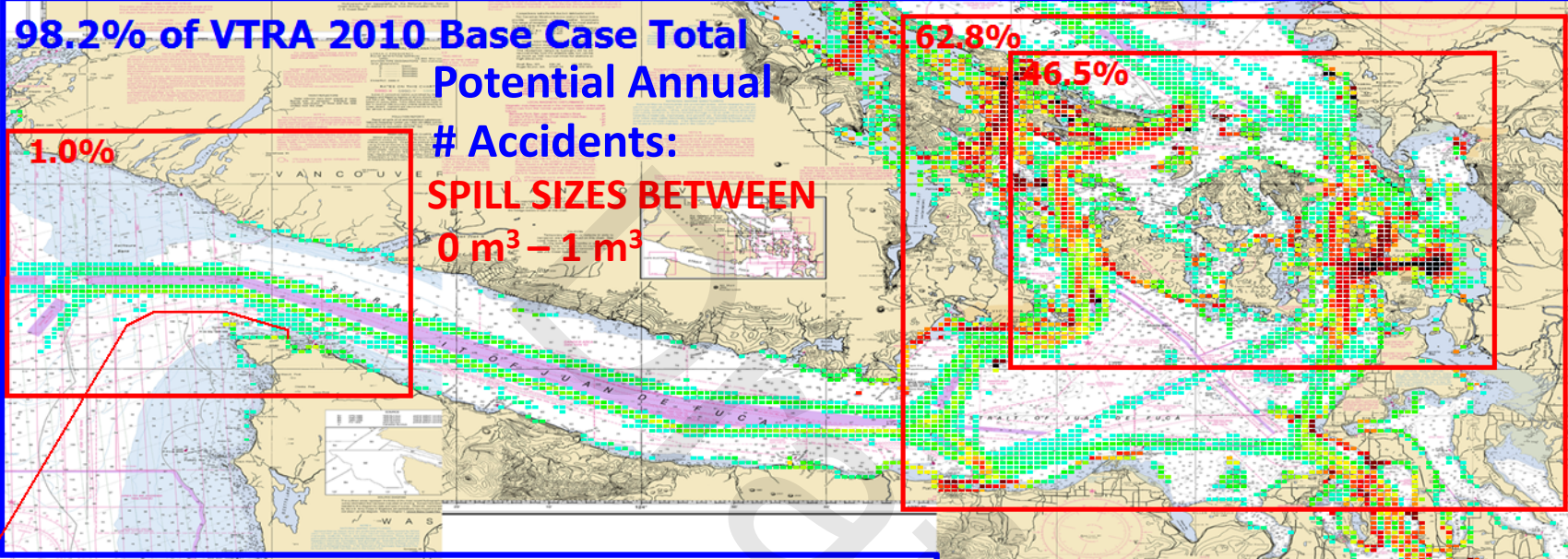
≈ 100% Probability
of Spill Occurrence
in 10 years

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

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



VTRA 2010 BASE CASE - ALL FV



Factor x Average
Oil Outflow
> 100.00
> 10.00
10.00
3.70
2.95
2.51
2.19
1.95
1.75
1.59
1.44
1.31
1.20
1.09
1.00
0.81
0.65
0.51
0.39
0.28
0.18
0.09
0.00

VTRA '10: Base Case
GEOGRAPHIC PROFILE
OF ANNUAL
POTENTIAL OIL LOSS
OF ACCIDENTS
WITH SPILL SIZE
BETWEEN 0 m³ - 1 m³

≈ 100% Probability
of Spill Occurrence
in 25 years

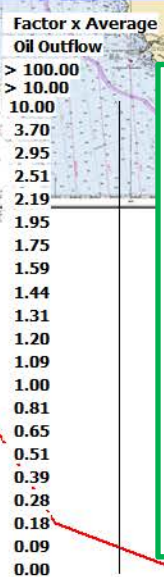
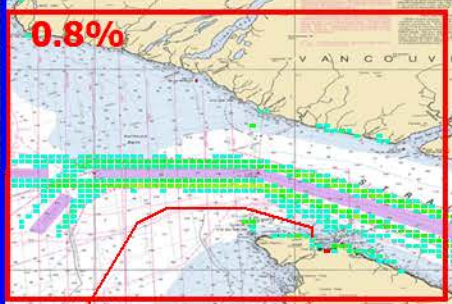
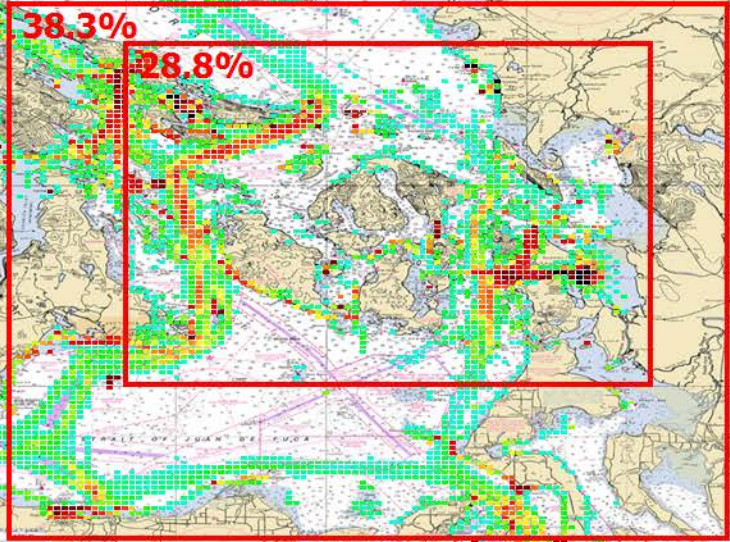
Average of ≈ 0.03 m³
Per Potential Spill
(≈ 6.7 gallons)

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

VTRA 2015 CALIBRATION CASE - ALL FV

98.0% of VTRA 2010 Base Case Total Potential Annual # Accidents:

SPILL SIZES BETWEEN 0 m³ - 1 m³



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 25 years

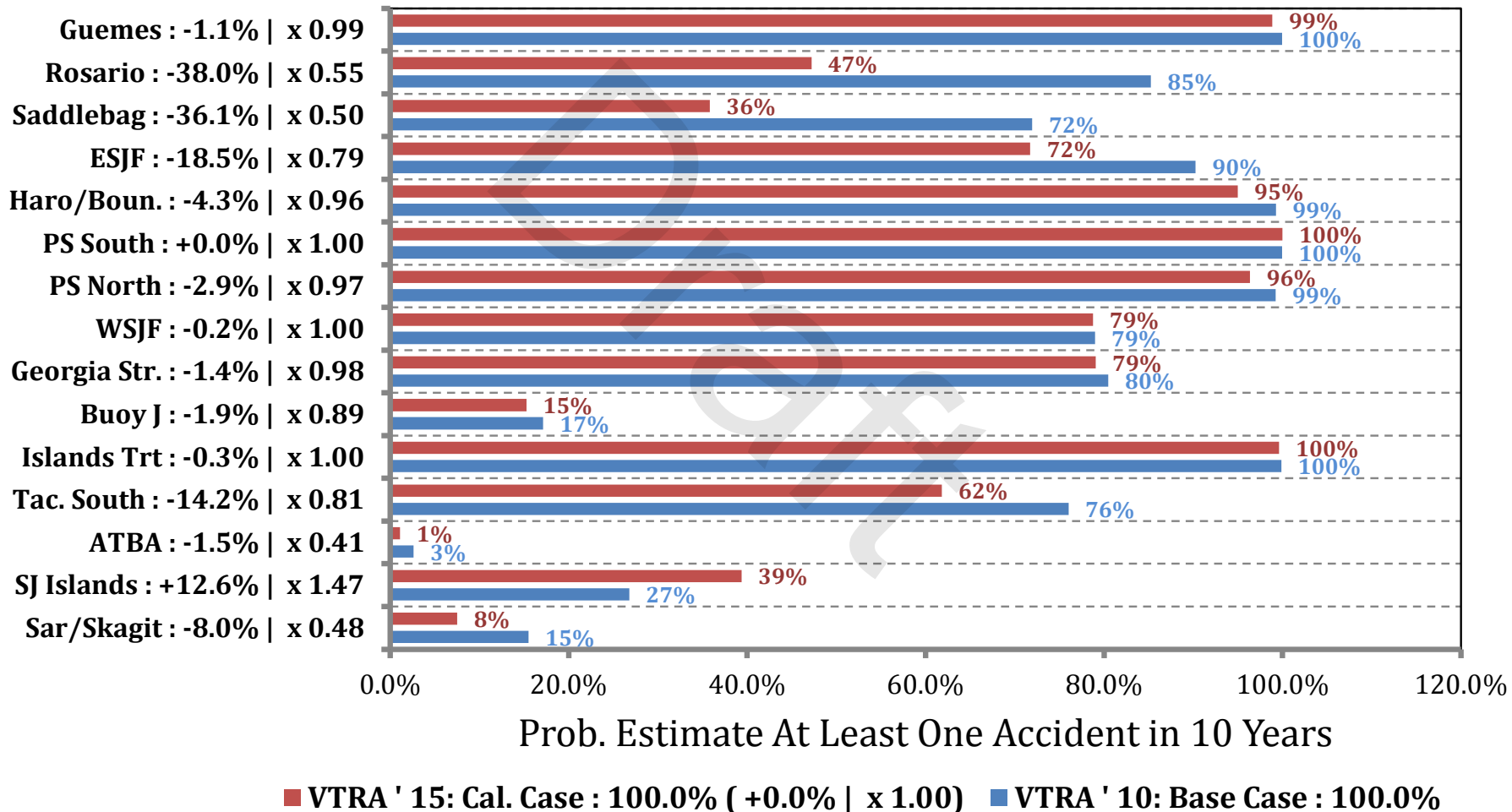
Average of 0.01 m³
Per Potential Spill
(= 2.4 gallons)

6/7/2016

5/26/2016

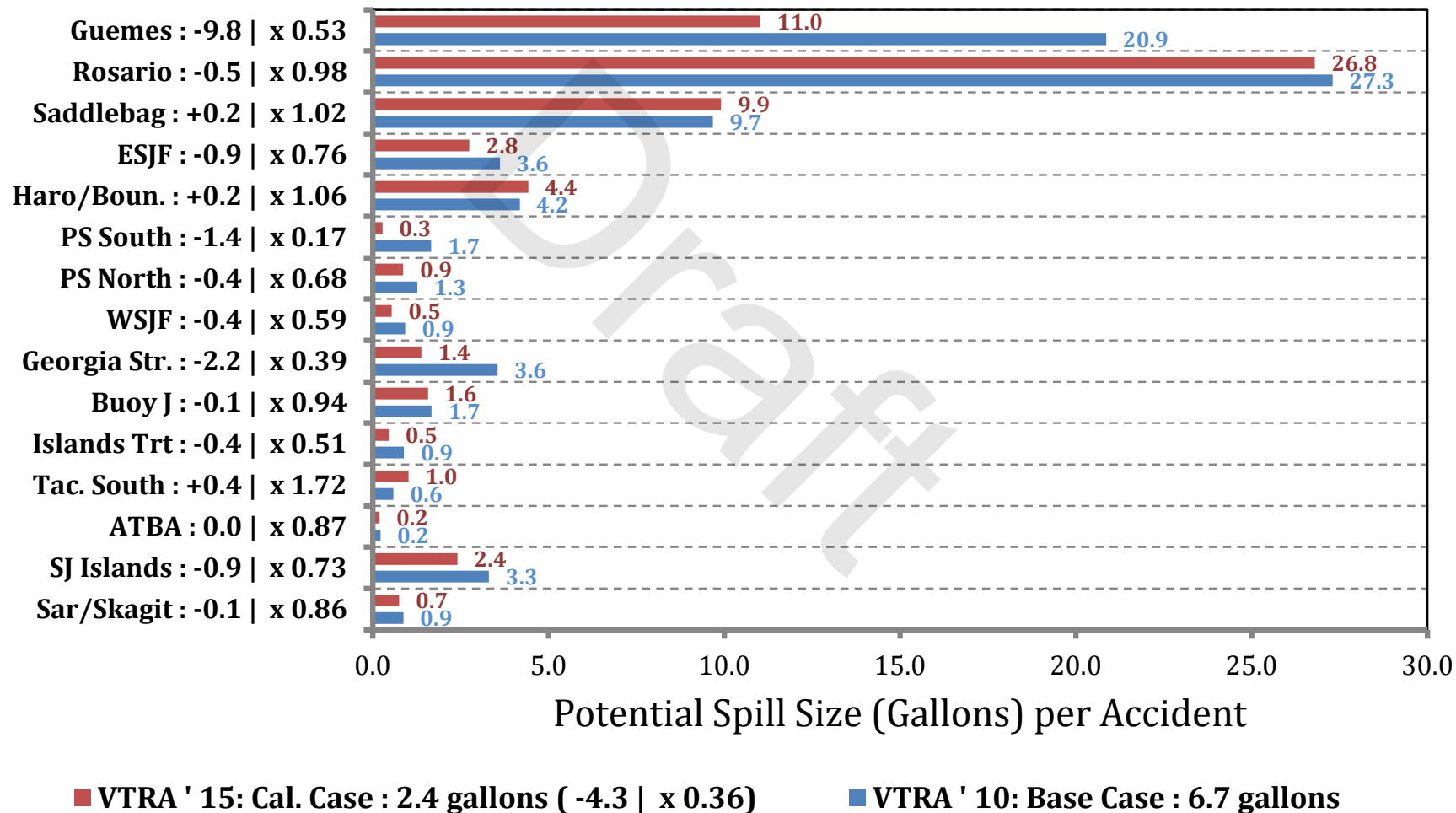
VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

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



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 ' 10: Base Case	Base Case % Potential Annual Oil Loss	54.4%	14.4%	30.5%	0.7%	100.0%
	Base Case % Potential Annual Accident Frequency	0.03%	0.03%	1.7%	98.2%	100.0%
	Average potential spill size per accident (in m^3)	6,072	1,653	66.0	0.03	3.7
	Probability of at least one accident in 1 year by spill size	0.14%	0.14%	7.1%	98.7%	98.8%
	Probability of at least one accident in 10 years by spill size	1.43%	1.39%	52.3%	100.0%	100.0%
	Probability of at least one accident in 25 years by spill size	3.53%	3.44%	84.3%	100.0%	100.0%
		OIL_2500_MORE	OIL_1000_2500	OIL_1_1000	OIL_0_1	ANY SIZE
VTRA ' 15: Cal. Case	Base Case % Potential Annual Oil Loss	16.7% (-37.7% x0.31)	5.1% (-9.3% x0.35)	19.9% (-10.6% x0.65)	0.2% (-0.44% x0.36)	41.9% (-58.1% x0.42)
	Base Case % Potential Annual Accident Frequency	0.01% (-0.02% x0.32)	0.01% (-0.02% x0.36)	1.7% (+0.0% x1.03)	98.0% (-0.2% x1.00)	99.8% (-0.2% x1.00)
	Average potential spill size per accident (in m^3)	5745 (-327.0 x0.95)	1627 (-25.5 x0.98)	42.0 (-24.1 x0.64)	0.01 (0.0 x0.36)	1.5 (-2.1 x0.42)
	Probability of at least one accident in 1 year by spill size	0.05% (-0.10% x0.32)	0.05% (-0.09% x0.36)	7.3% (+0.2% x1.02)	98.7% (0.0% x1.00)	98.8% (0.0% x1.00)
	Probability of at least one accident in 10 years by spill size	0.47% (-0.96% x0.33)	0.50% (-0.89% x0.36)	53.2% (+0.9% x1.02)	100.0% (0.0% x1.00)	100.0% (0.0% x1.00)
	Probability of at least one accident in 25 years by spill size	1.16% (-2.37% x0.33)	1.25% (-2.19% x0.36)	85.0% (+0.7% x1.01)	100.0% (0.0% x1.00)	100.0% (0.0% x1.00)