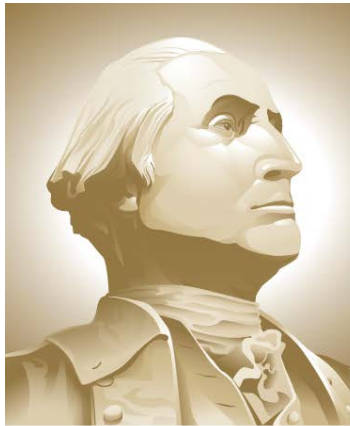


## VTRA 2015 Case T : GDK – 1503 and VTRA 2015 Calibration Case Comparison



**THE GEORGE  
WASHINGTON  
UNIVERSITY**

WASHINGTON, DC

**VCU**

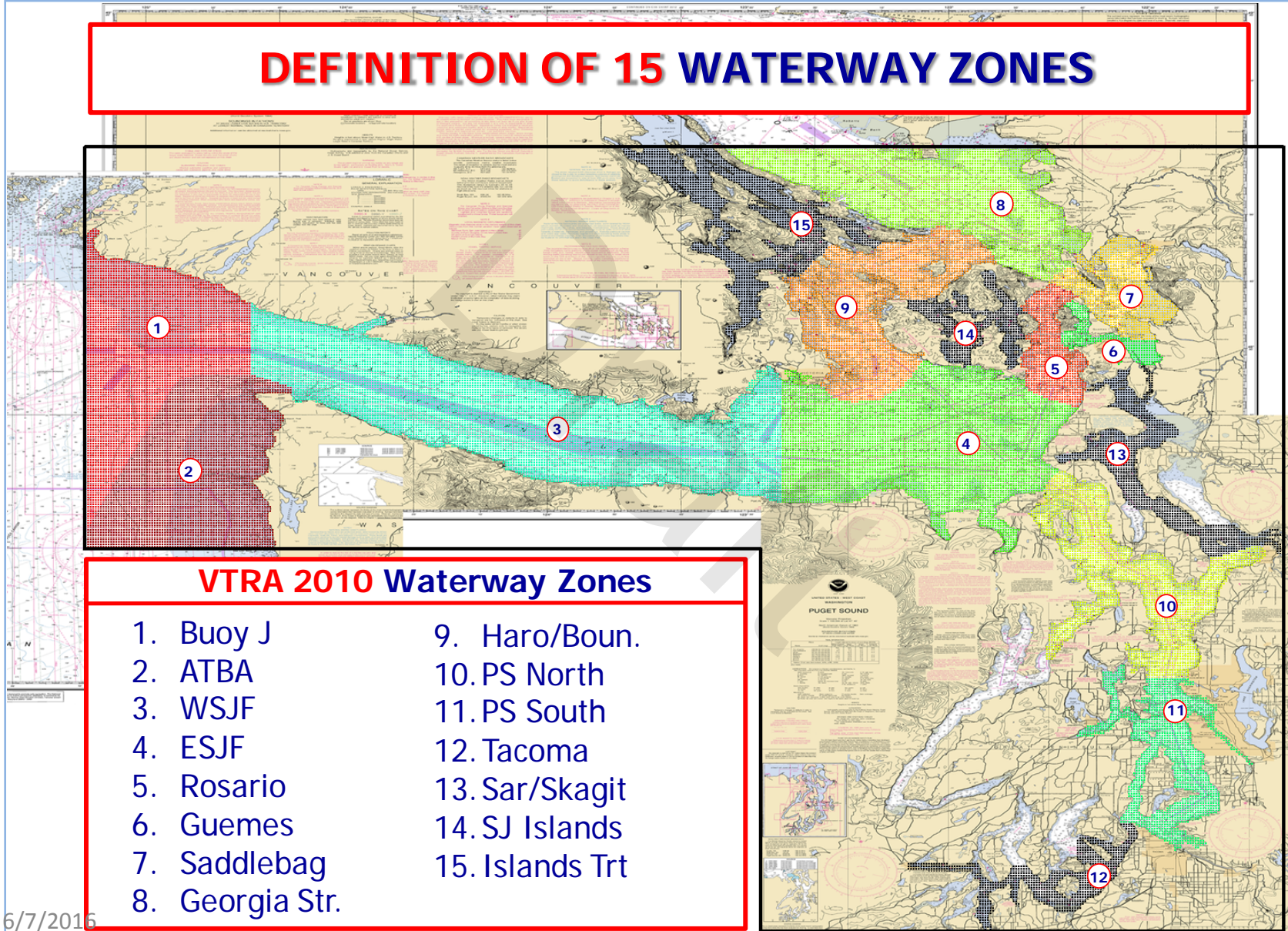
**Jason R.W. Merrick (VCU) and J. Rene van Dorp (GW)**

June 1<sup>st</sup> - 2<sup>nd</sup>, 2016

# VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



## DEFINITION OF 15 WATERWAY ZONES



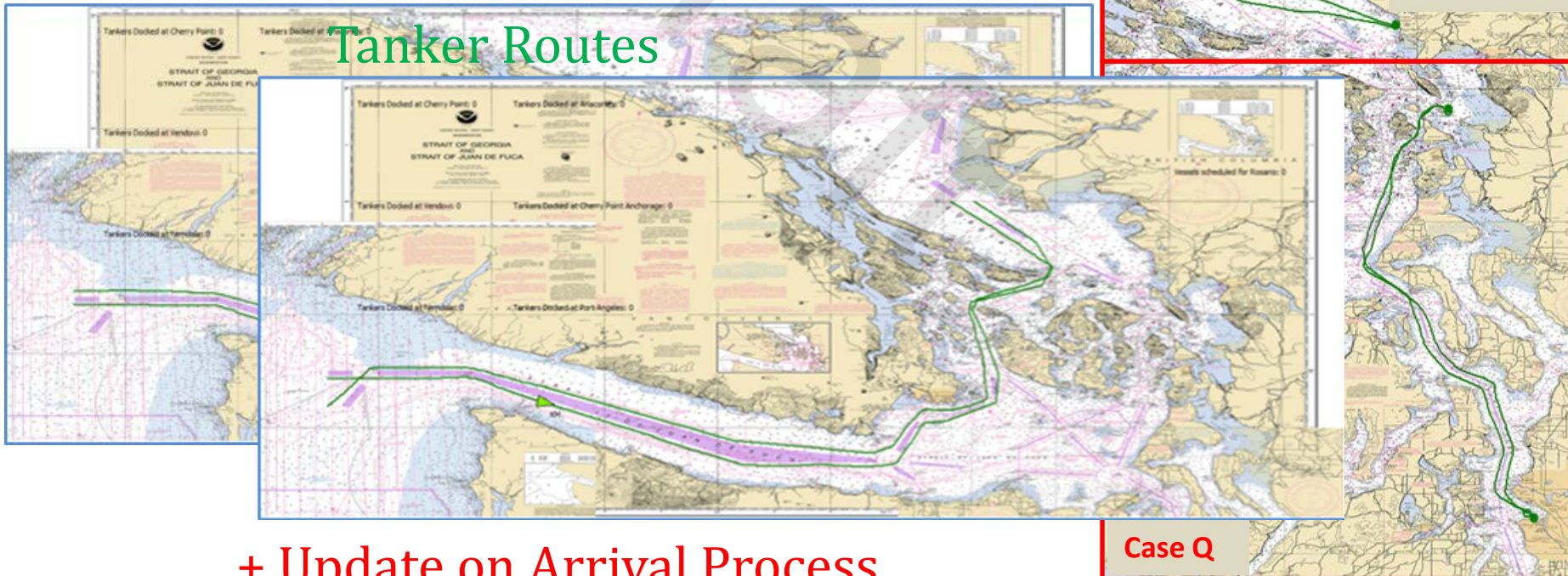
## VTRA '15 Case : T – GDK 1503

CASE T	VTRA 2010 Case R	VTRA 2015 Updated Case R
Tankers (Case R)	348	348
Bulk Carriers (Case Q + S)	835	787
Container Ships (Case S)	67	368
Sub Total	1250	1503
Bunkering Support (Q + R + S)	290	310
Total # Vessels	1540	1813

### Bunker Routes

### Container + Bulk Carrier Routes

### Tanker Routes



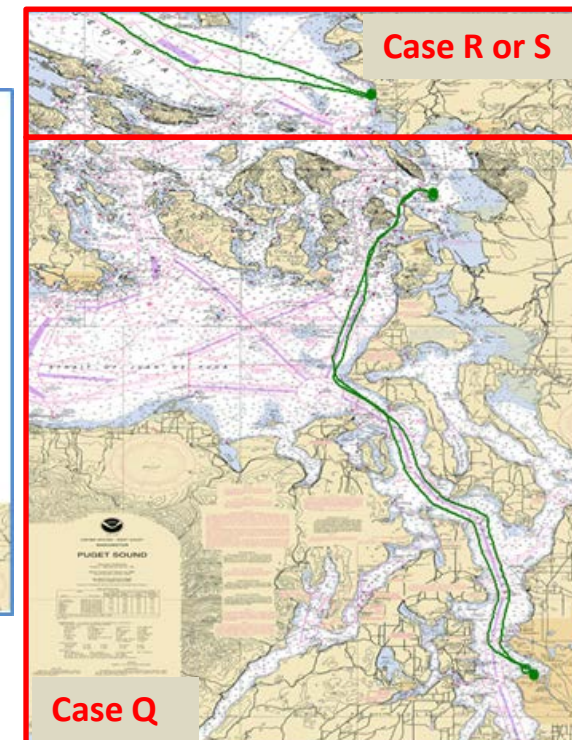
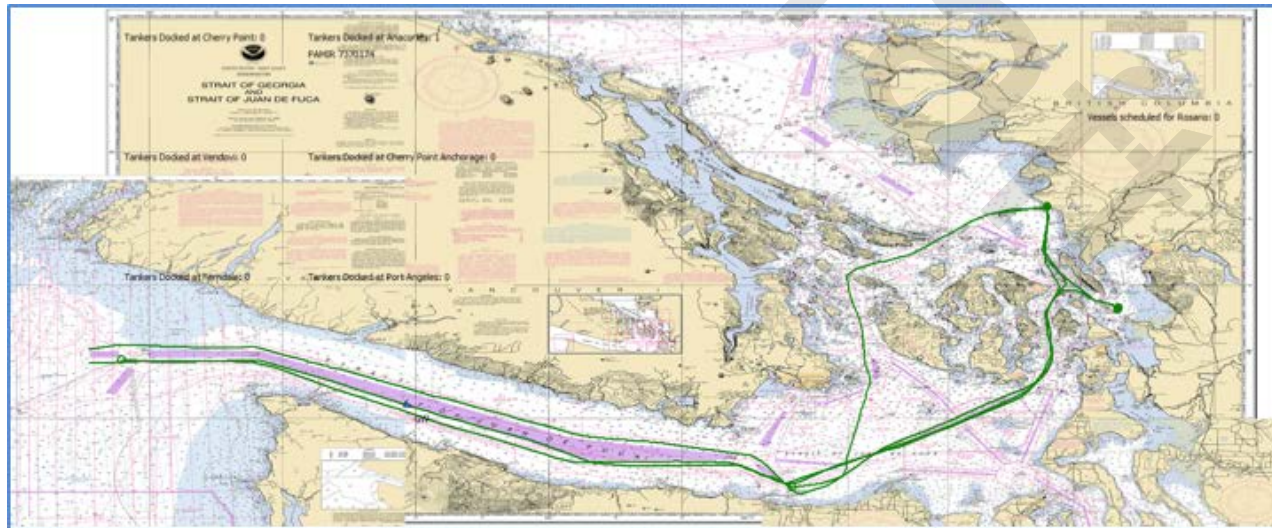
+ Update on Arrival Process

## VTRA '15 Case : T – GDK 1503

CASE T	VTRA 2010 Case R	VTRA 2015 Updated Case R
Tankers (Case R)	348	348
Bulk Carriers (Case Q + S)	835	787
Container Ships (Case S)	67	368
Sub Total	1250	1503
Bunkering Support (Q + R + S)	290	310
Total # Vessels	1540	1813

### Bunker Routes

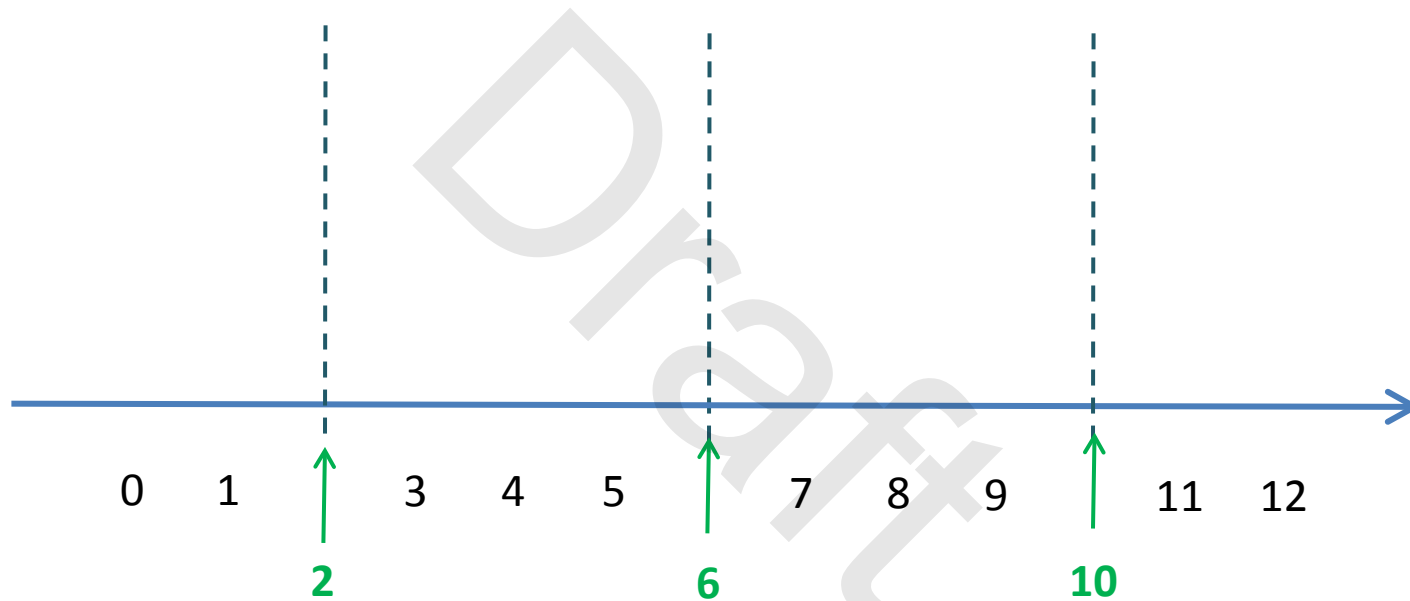
### Bulk Carrier Routes – Case Q



+ Update on Arrival Process

## NOT SELECTED

### VTRA 2010 – What If FV Scheduled Arrival Pattern Model



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

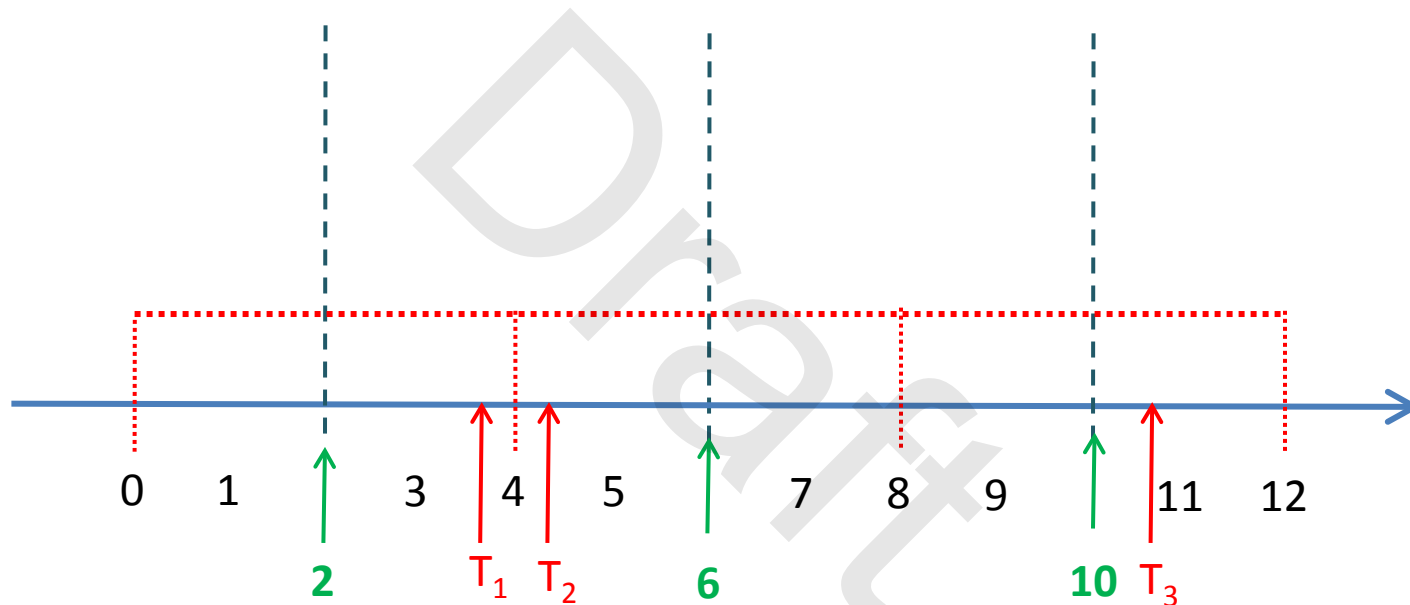
% OF VTRA '10 BASE CASE POTENTIAL TOTAL OIL LOSS: CASE T: GW - DP - KM : 1.68

% OF VTRA '15 BASE CASE POTENTIAL TOTAL OIL LOSS: CASE T: GKM - 1503 : 1.62

## NOT SELECTED

### VTRA 2015 – What If FV

#### Complete Random Arrival Pattern Model



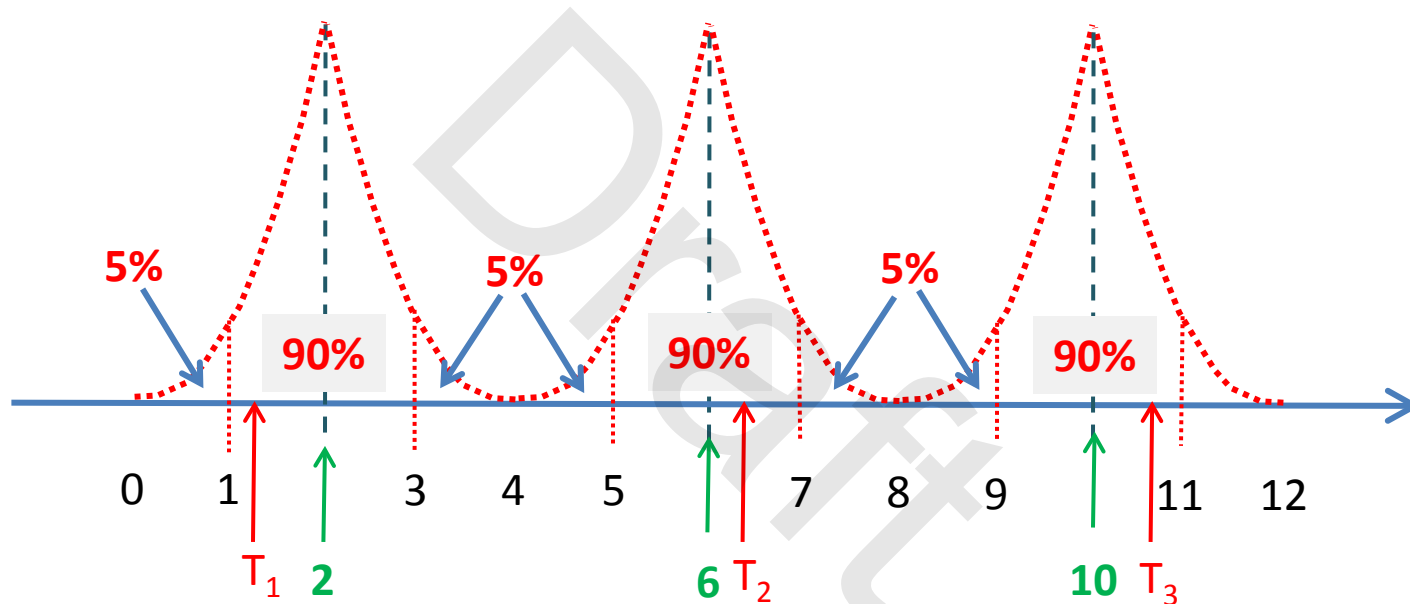
VTRA 2010 Equidistant Fixed Arrival Pattern (one every 4 days)

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

% OF VTRA '10 BASE CASE POTENTIAL TOTAL OIL LOSS: CASE T: GW - DP - KM : 1.68

% OF VTRA '15 BASE CASE POTENTIAL TOTAL OIL LOSS: CASE T: GKM - 1503 : 1.57

## 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 T: GW - DP - KM : 1.68

% OF VTRA '15 BASE CASE POTENTIAL TOTAL OIL LOSS: CASE T: GKM - 1503 : 1.60



# By Waterway Zone Risk Comparison

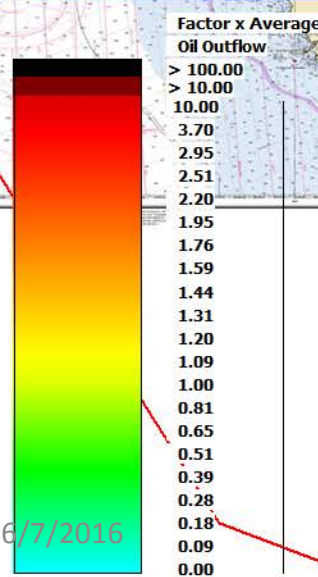
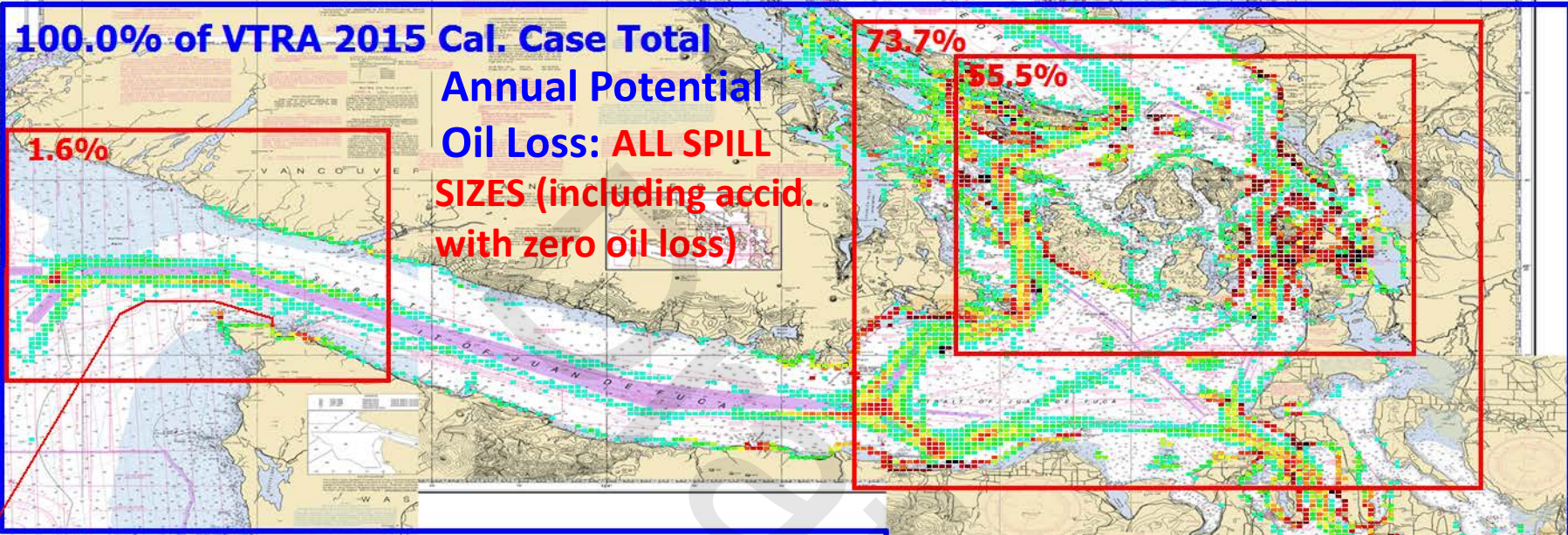
Oil Spill Size Category:

**ALL SPILL SIZES**

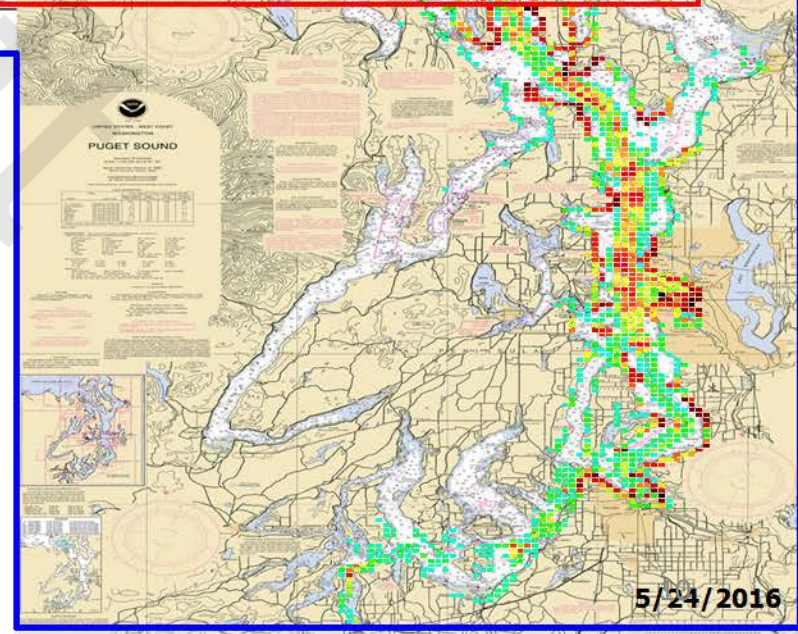
# VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



## 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**



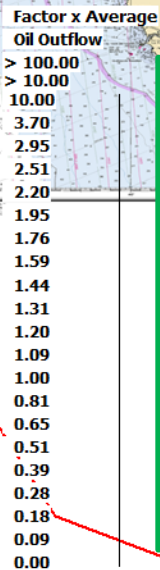
# VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

**T: VTRA 2015 - GW 487- KM 348 - DP Cont. 368 and Bulk 300 - ALL FV**

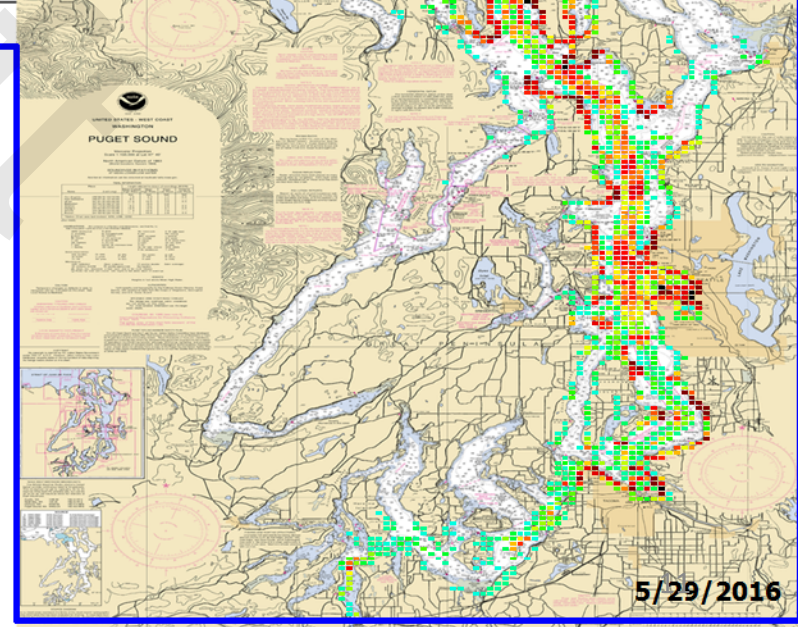
**160.5% of VTRA 2015 Cal. Case Total Annual Potential Oil Loss: ALL SPILL SIZES (including accid. with zero oil loss)**

**129.6%**  
**97.9%**

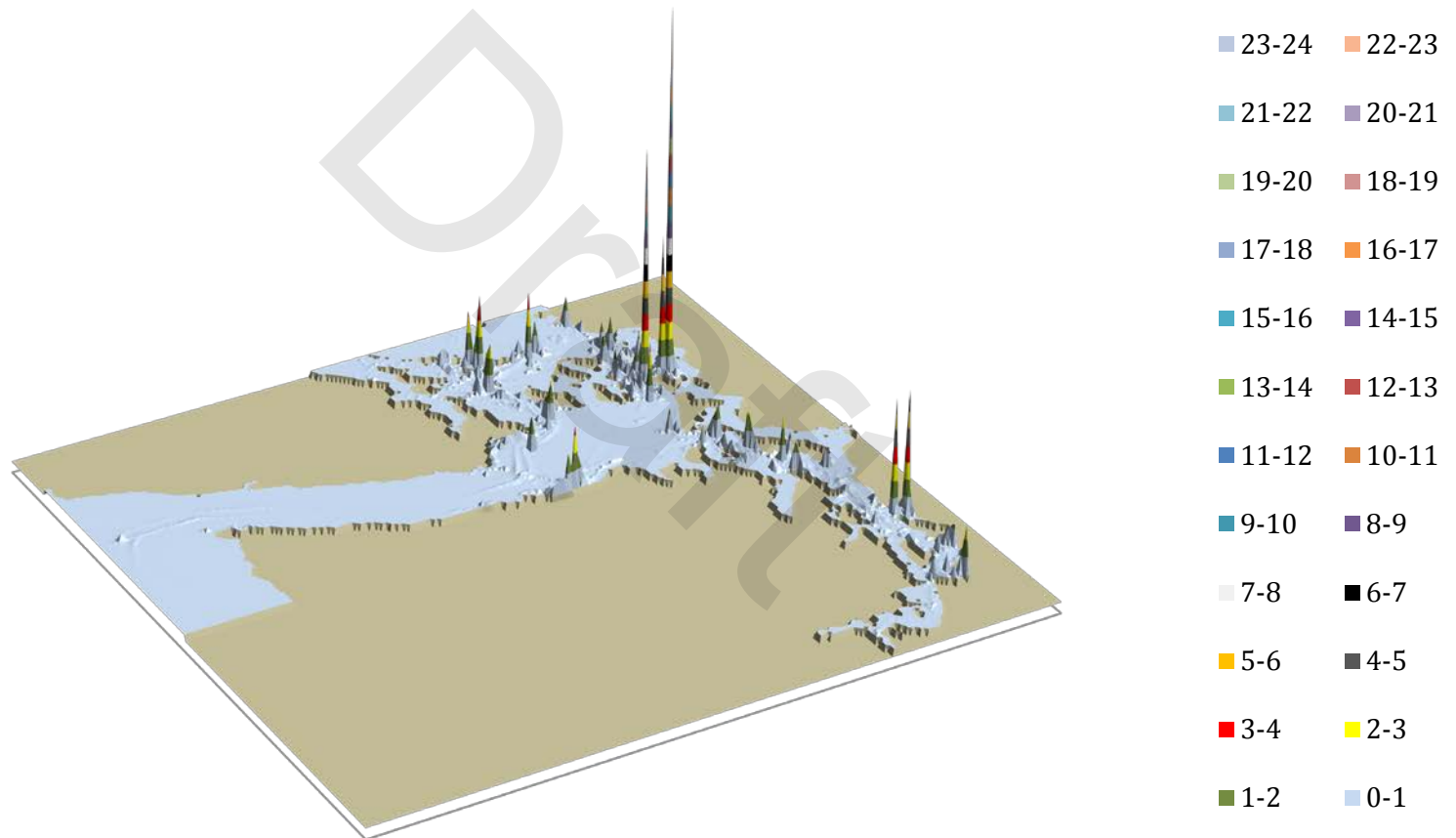
**4.6%**



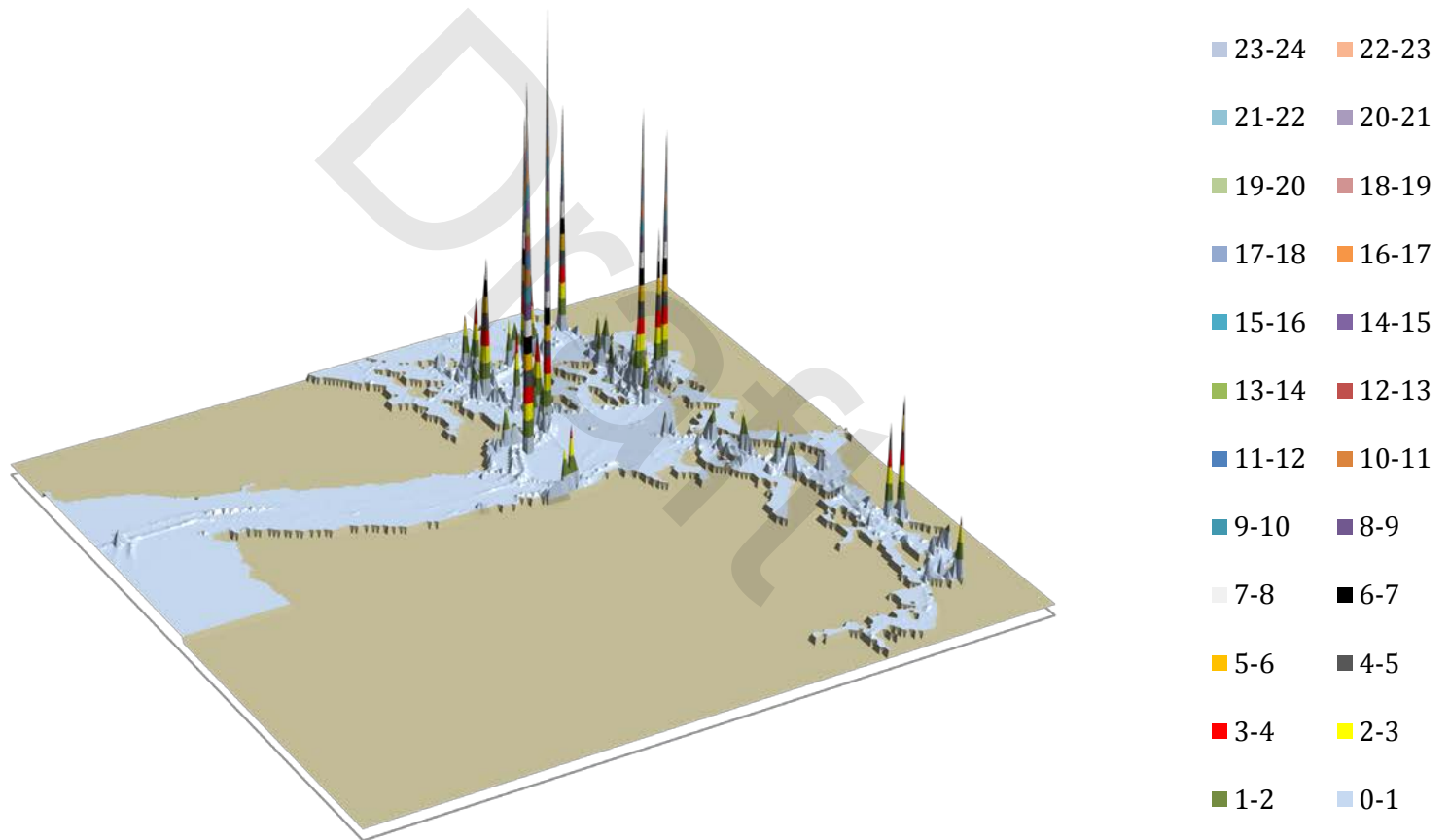
**VTRA '15 Case T: GDK - 1503**  
GEOGRAPHIC PROFILE OF POTENTIAL ANNUAL OIL LOSS OF ACCIDENTS IN SPILL SIZE CATEGORY **ALL SPILL SIZES**



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

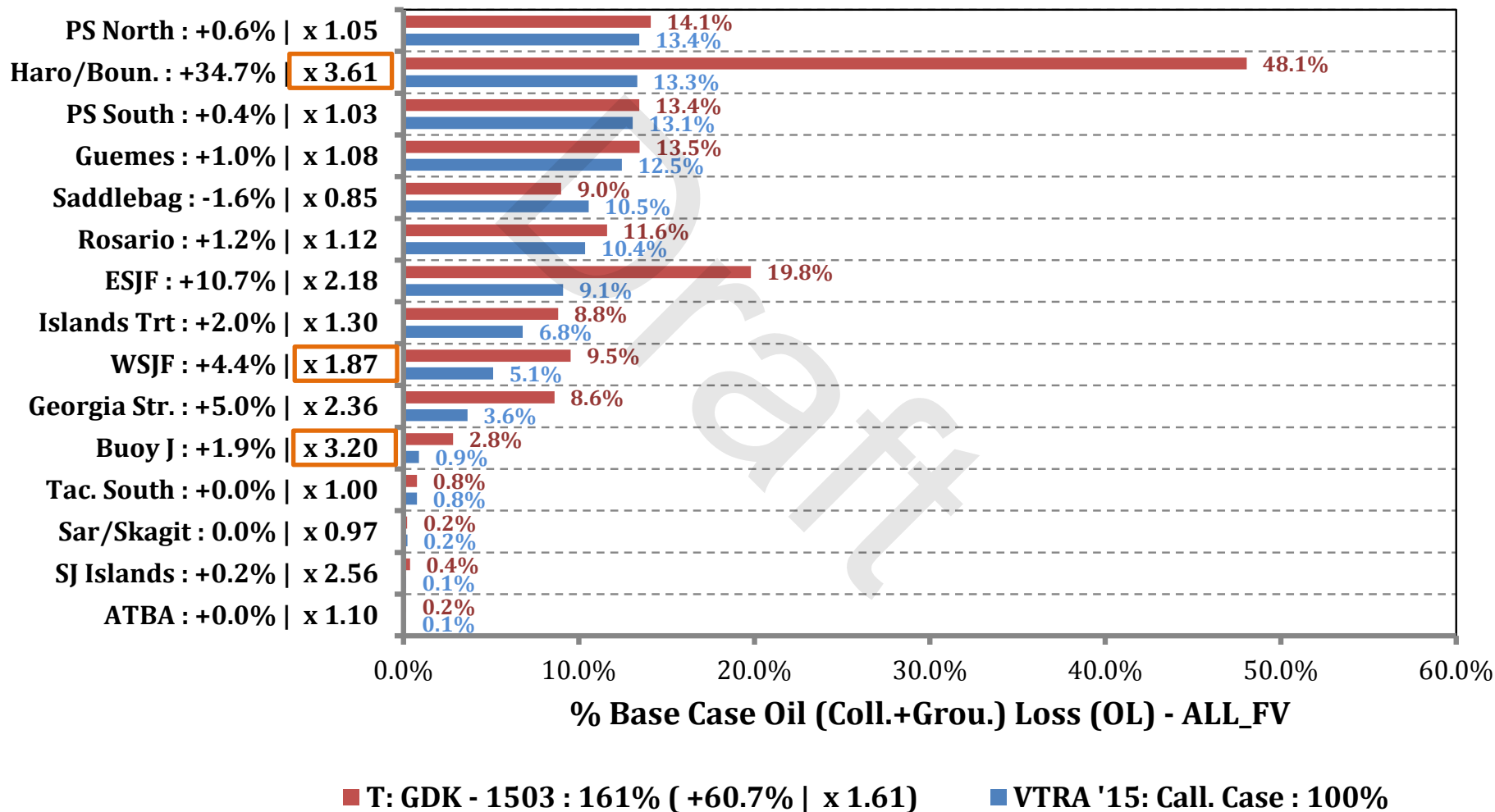


## T: GDK - 1503 3D Risk Profile All FV - Pot.Grou+Coll+All.Oil Loss: 160% of Cal. Case POL



# VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

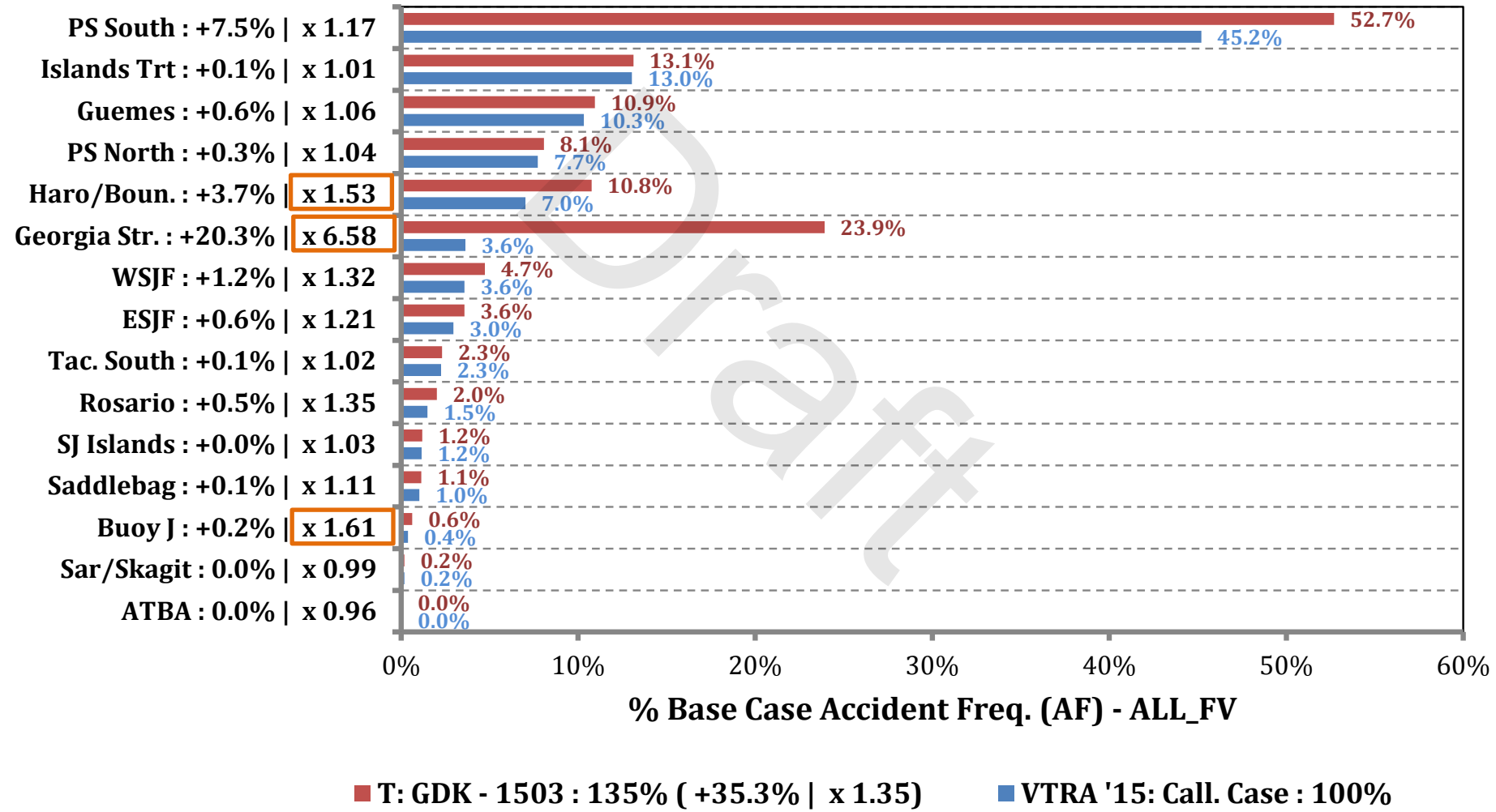
## % Base Case Oil (Coll. + Grou. + All.) Loss - ALL\_FV



# 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 m<sup>3</sup> or more**



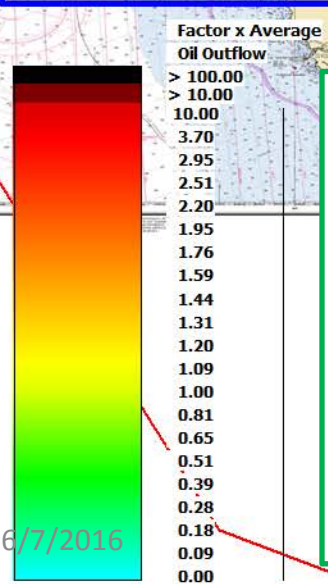
# VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

## VTRA 2015 CALIBRATION CASE - ALL FV

**39.8% of VTRA 2015 Cal. Case Total Annual Potential Oil Loss:**  
**SPILL SIZES LARGER THAN 2,500 m<sup>3</sup>**

**33.9%**  
**27.2%**

**1.0%**



**VTRA '15: Cal. Case**  
**GEOGRAPHIC PROFILE OF POTENTIAL ANNUAL OIL LOSS OF ACCIDENTS WITH SPILL SIZE 2,500 m<sup>3</sup> or more**

≈ 0.47% Probability of Spill Occurrence in 10 years

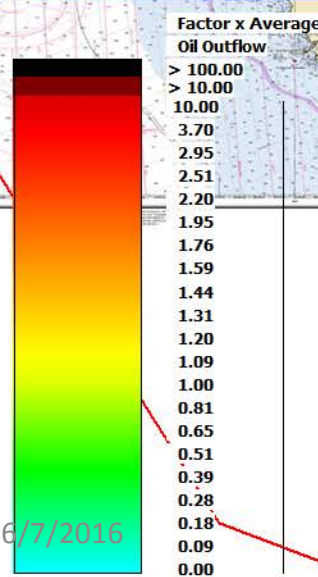
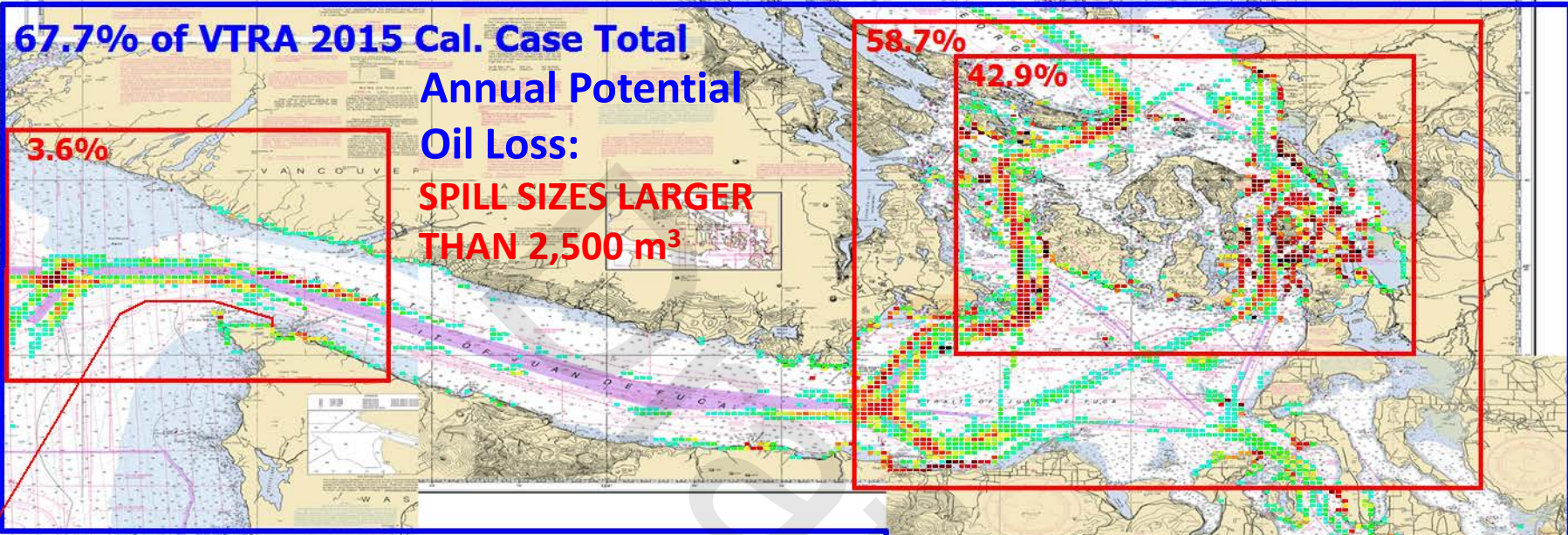
Average of ≈ 5,746 m<sup>3</sup> Per Potential Spill (≈ 4,942 Metric. Tons)

6/7/2016

5/24/2016

# VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

**T: VTRA 2015 - GW 487- KM 348 - DP Cont. 368 and Bulk 300 - ALL FV**



**VTRA '15 Case T: GDK - 1503**  
GEOGRAPHIC PROFILE OF POTENTIAL ANNUAL OIL LOSS OF ACCIDENTS WITH SPILL SIZE **2,500 m<sup>3</sup> or more**

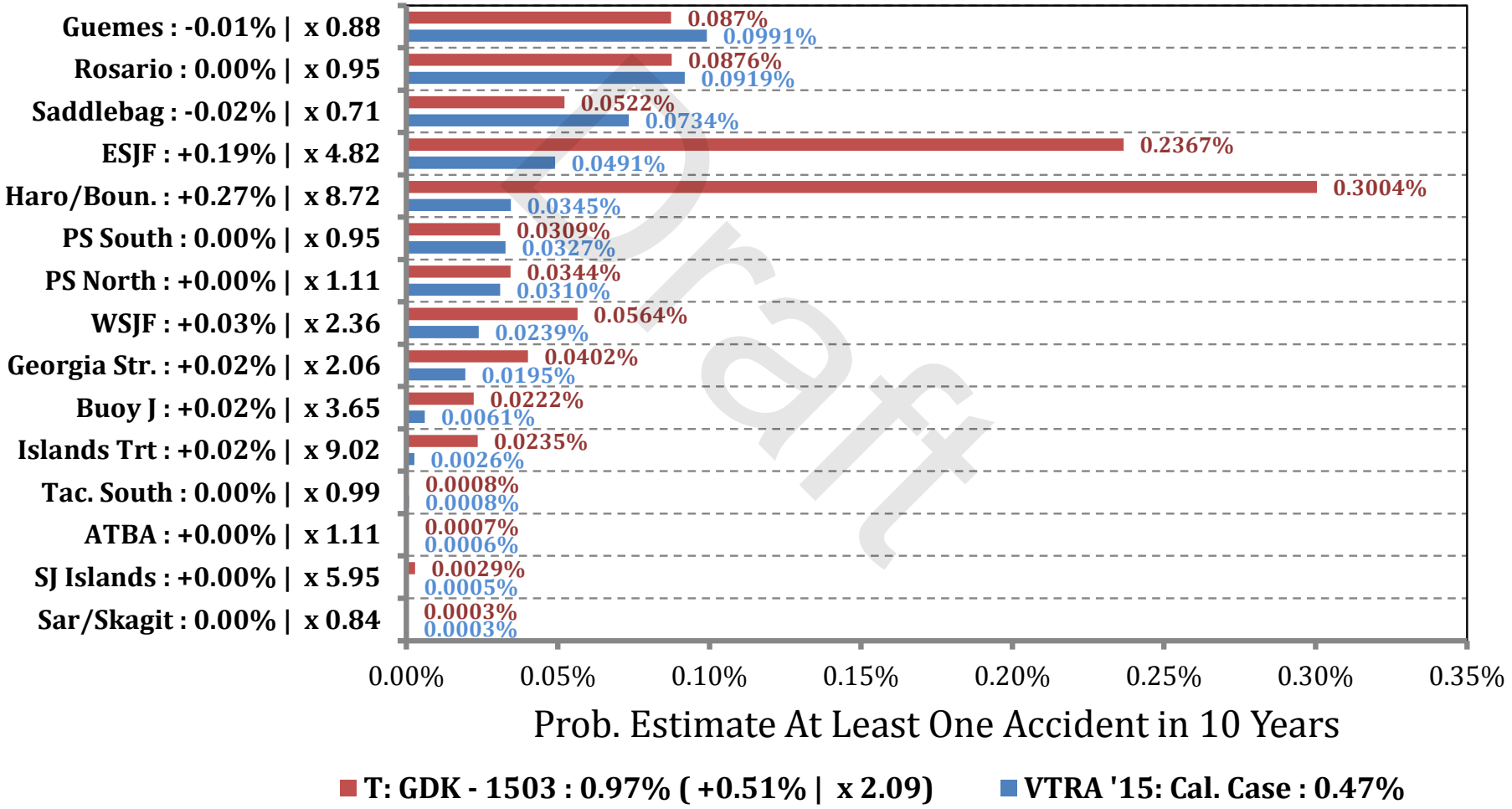
≈ 0.97% Probability of Spill Occurrence in 10 years

Average of ≈ 4,659 m<sup>3</sup> Per Potential Spill (≈ 4,007 Metric Tons)

# VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

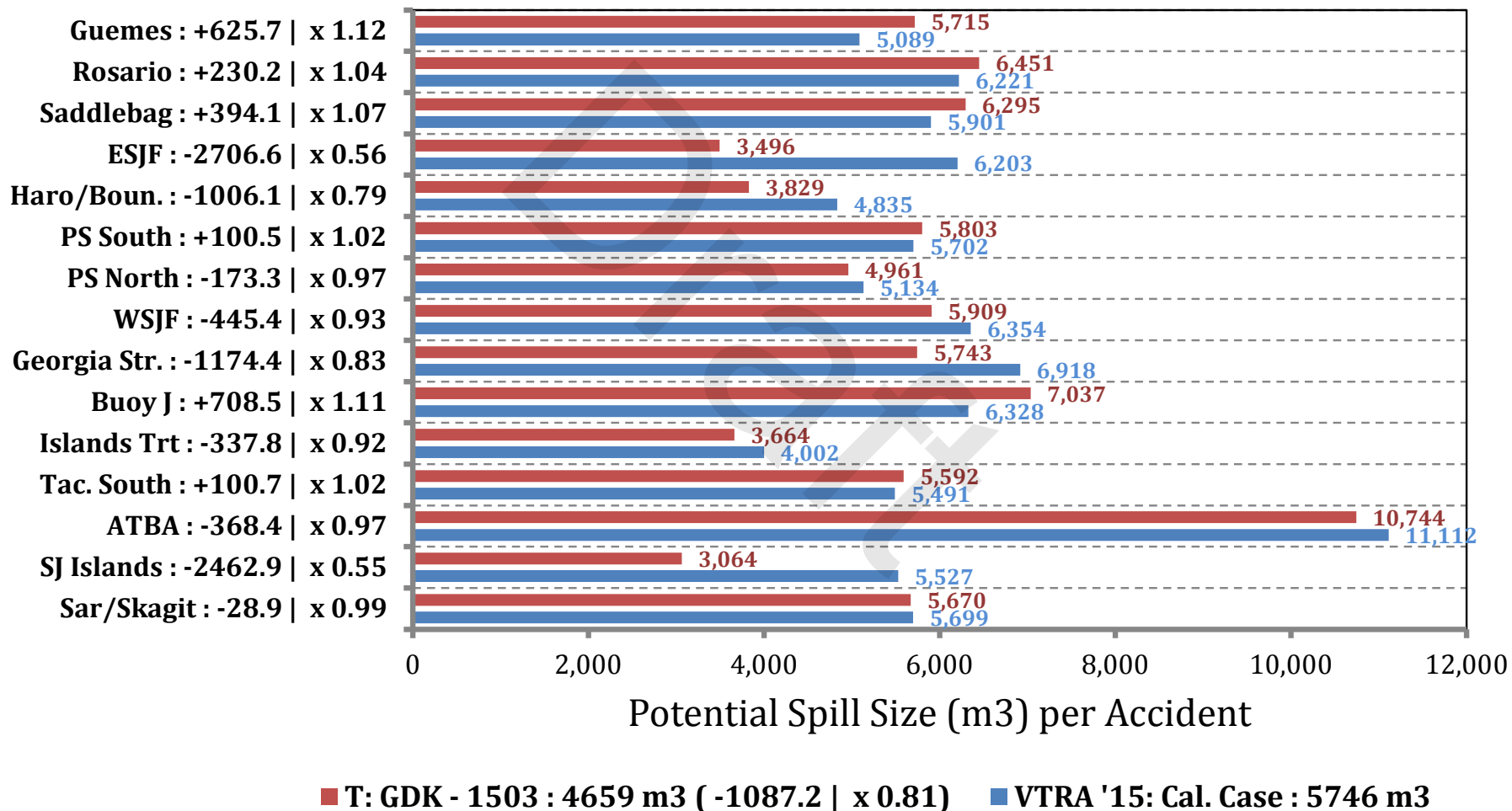


## Prob. Estimate At Least One Accident in 10 Years - ALL\_FV - Oil Spill Size Category: 2500 cubic meters or more



# VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

## Potential Spill Size (m<sup>3</sup>) per Accident - ALL\_FV - Oil Spill Size Category: 2500 cubic meters or more



# By Waterway Zone Risk Comparison

Oil Spill Size Category:

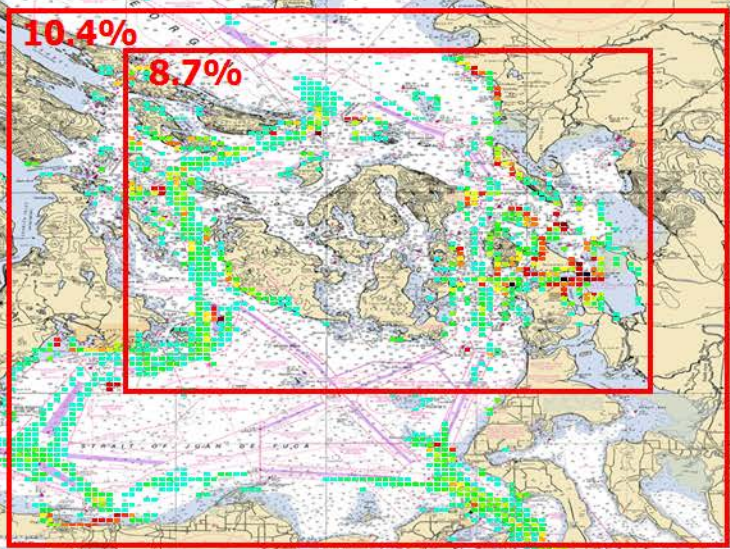
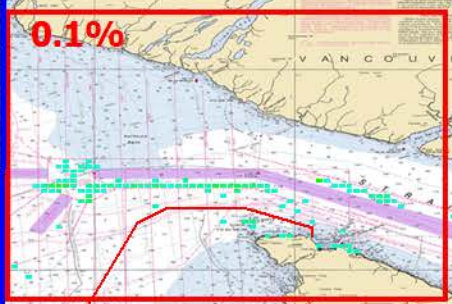
1000 m<sup>3</sup> - 2500 m<sup>3</sup>

# 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 m<sup>3</sup> - 2,500 m<sup>3</sup>**



**VTRA '15: Cal. Case**  
GEOGRAPHIC PROFILE  
OF POTENTIAL  
ANNUAL OIL LOSS  
OF ACCIDENTS  
WITH SPILL SIZE **BETWEEN**  
**1,000 m<sup>3</sup> - 2,500 m<sup>3</sup>**

≈ 0.50% Probability  
of Spill Occurrence  
in 10 years

Average of ≈ 1,628 m<sup>3</sup>  
Per Potential Spill  
(≈ 1,400 Metric Tons)

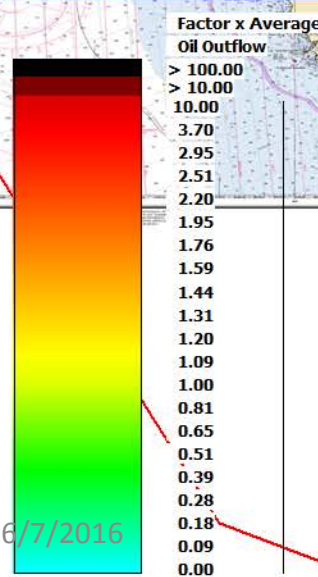
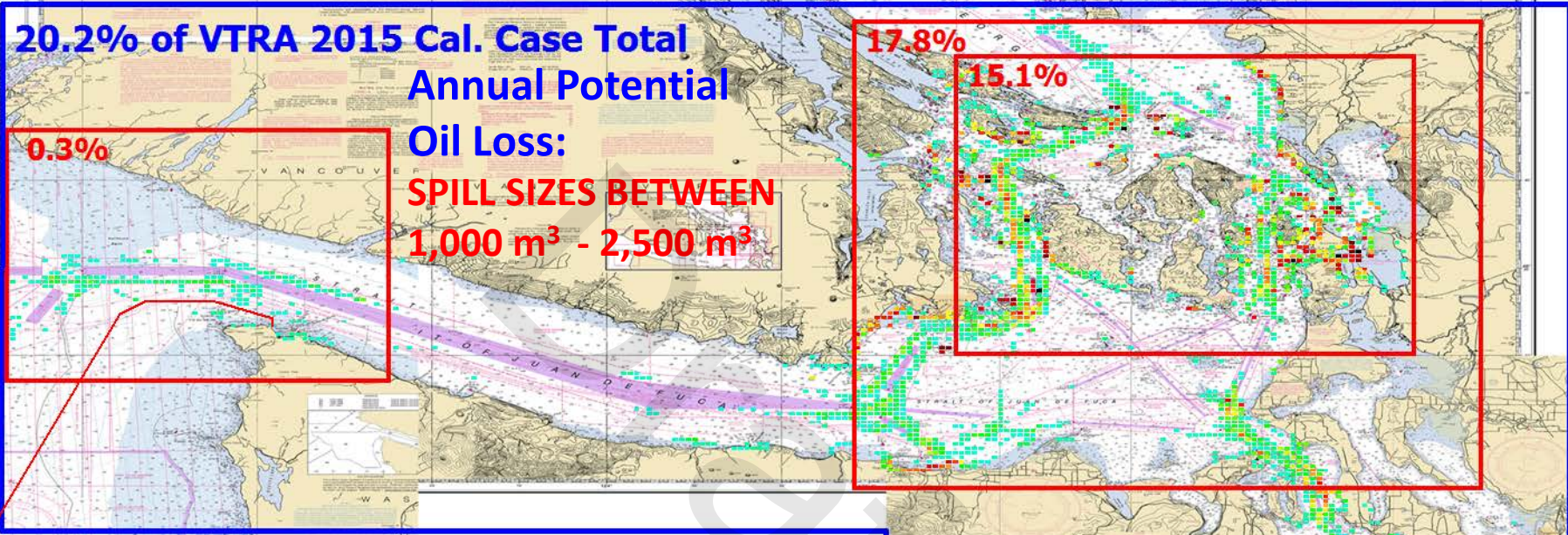
6/7/2016

5/24/2016

# VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



**T: VTRA 2015 - GW 487- KM 348 - DP Cont. 368 and Bulk 300 - ALL FV**



**VTRA '15 Case T: GDK - 1503**  
**GEOGRAPHIC PROFILE**  
**OF POTENTIAL**  
**ANNUAL OIL LOSS**  
**OF ACCIDENTS**  
**WITH SPILL SIZE BETWEEN**  
**1,000 m<sup>3</sup> - 2,500 m<sup>3</sup>**

≈ 0.80% Probability  
of Spill Occurrence  
in 10 years

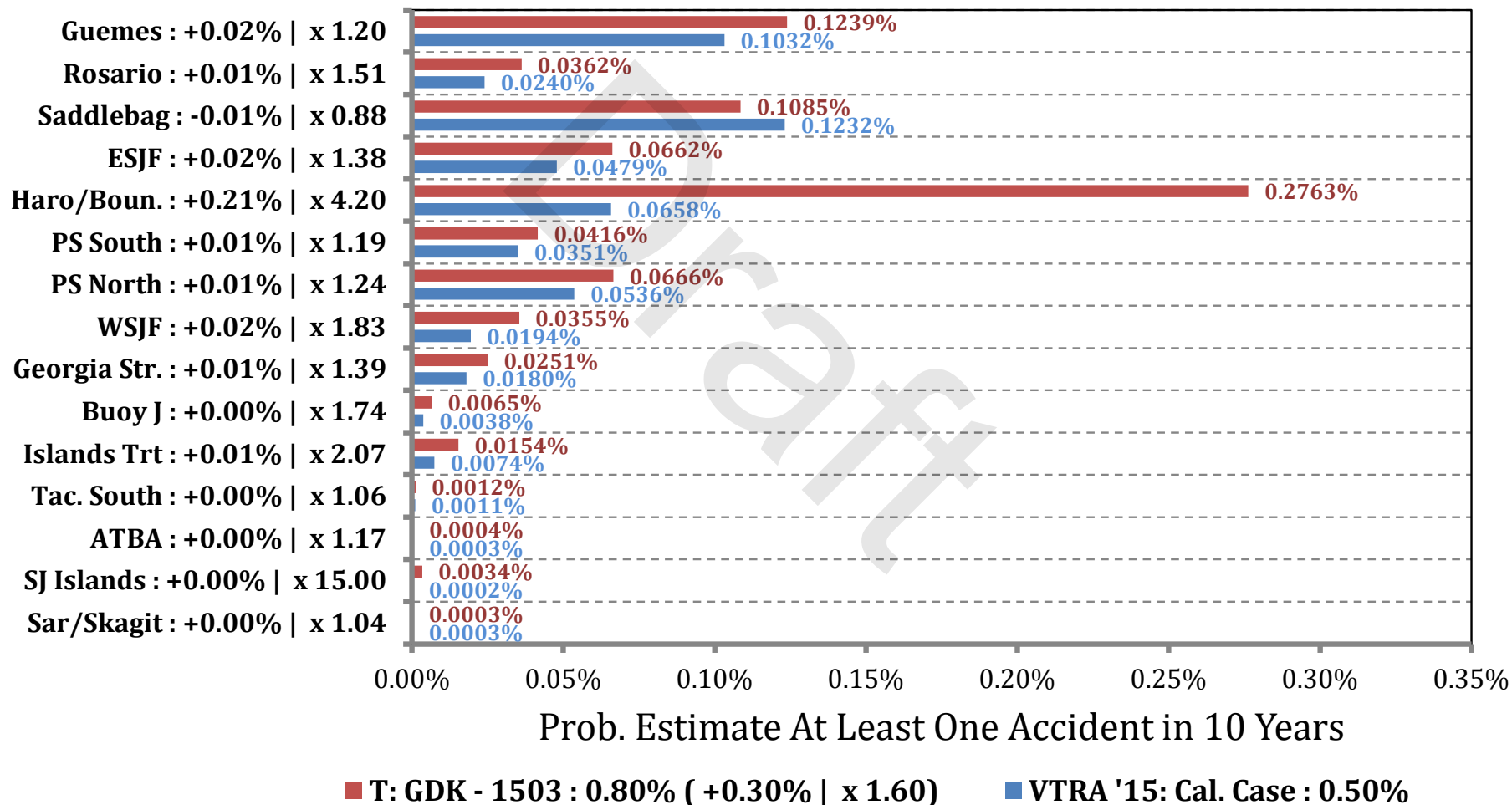
Average of ≈ 1,680 m<sup>3</sup>  
Per Potential Spill  
(≈ 1,445 Metric Tons)

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

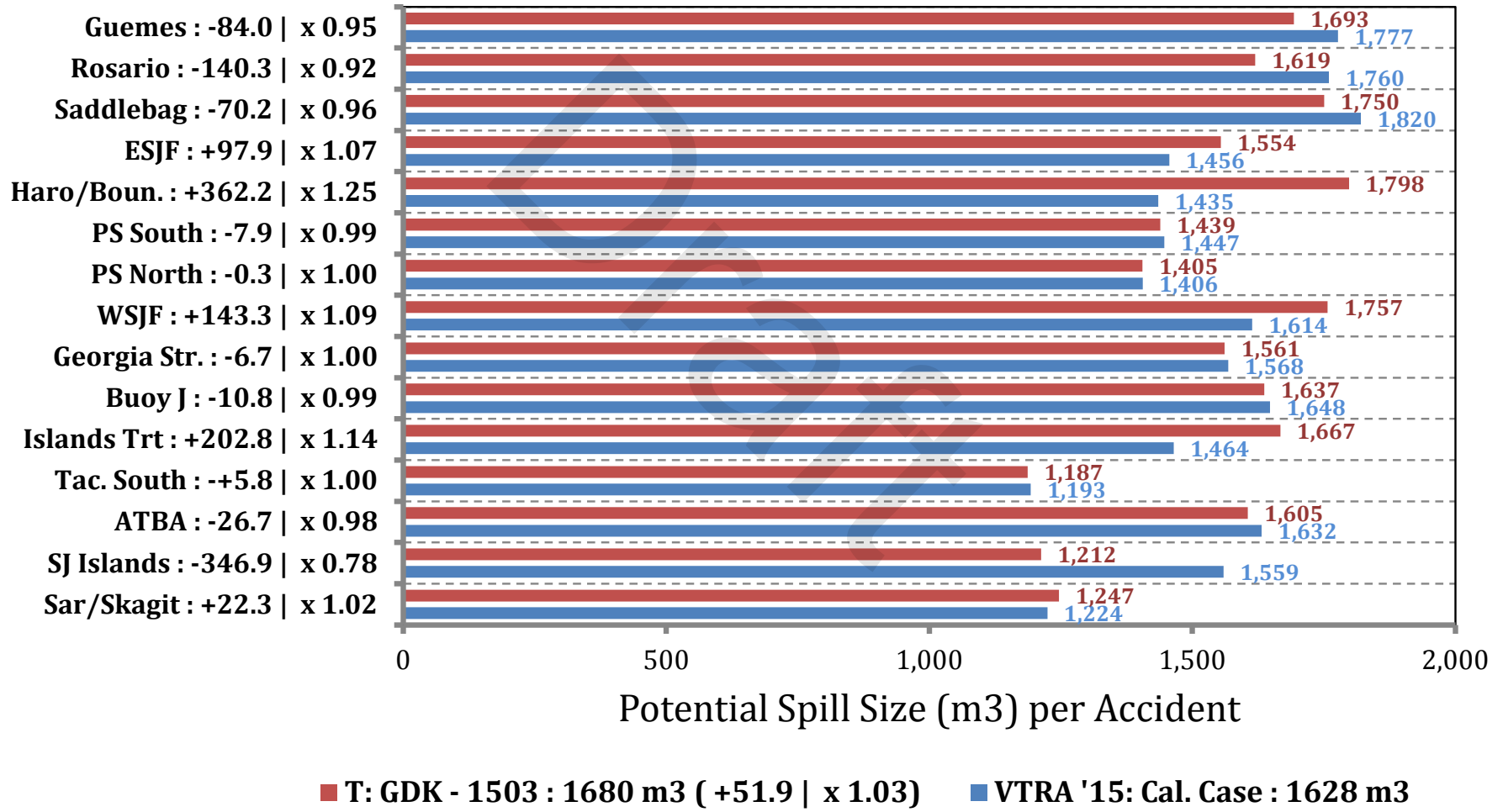




# VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



Potential Spill Size (m<sup>3</sup>) per Accident - ALL\_FV - Oil Spill Size Category: 1000 - 2500 m<sup>3</sup>



# By Waterway Zone Risk Comparison

Oil Spill Size Category:

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

# VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

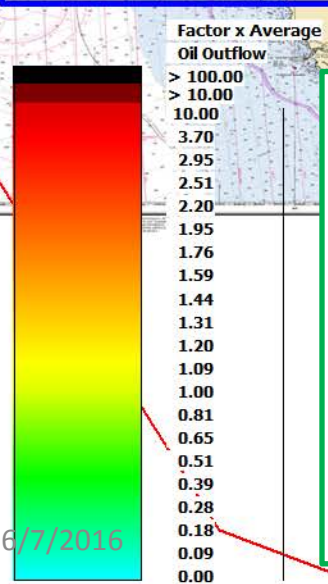


## VTRA 2015 CALIBRATION CASE - ALL FV

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

0.4%  
SPILL SIZES BETWEEN 1 m<sup>3</sup> - 1,000 m<sup>3</sup>

28.9%  
19.1%



VTRA '15: Cal. Case  
GEOGRAPHIC PROFILE  
OF ANNUAL  
POTENTIAL OIL LOSS  
OF ACCIDENTS  
WITH SPILL SIZE  
BETWEEN 1 m<sup>3</sup> - 1000 m<sup>3</sup>

≈ 53.1% Probability  
of Spill Occurrence  
in 10 years

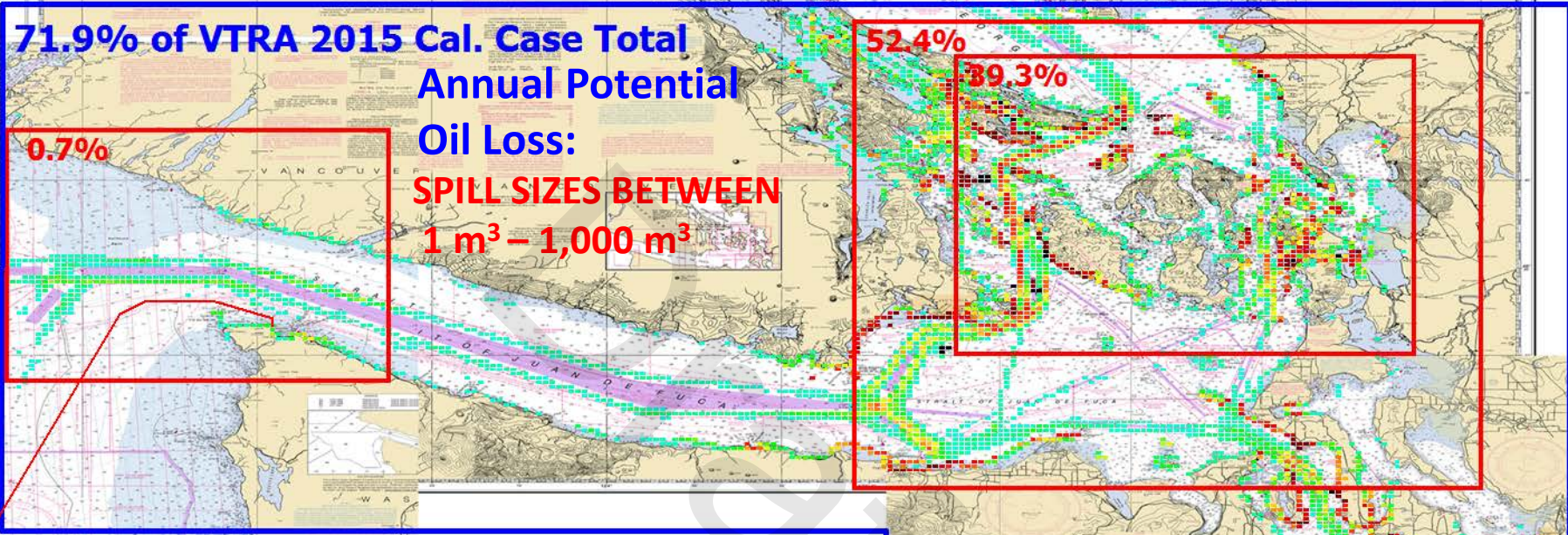
Average of ≈ 42 m<sup>3</sup>  
Per Potential Spill  
(≈ 265 barrels)

6/7/2016

5/24/2016

# VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

**T: VTRA 2015 - GW 487- KM 348 - DP Cont. 368 and Bulk 300 - ALL FV**



**VTRA '15 Case T: GDK - 1503**  
GEOGRAPHIC PROFILE OF ANNUAL POTENTIAL OIL LOSS OF ACCIDENTS WITH SPILL SIZE **BETWEEN 1 m<sup>3</sup> - 1000 m<sup>3</sup>**

≈ 67.4% Probability of Spill Occurrence in 10 years

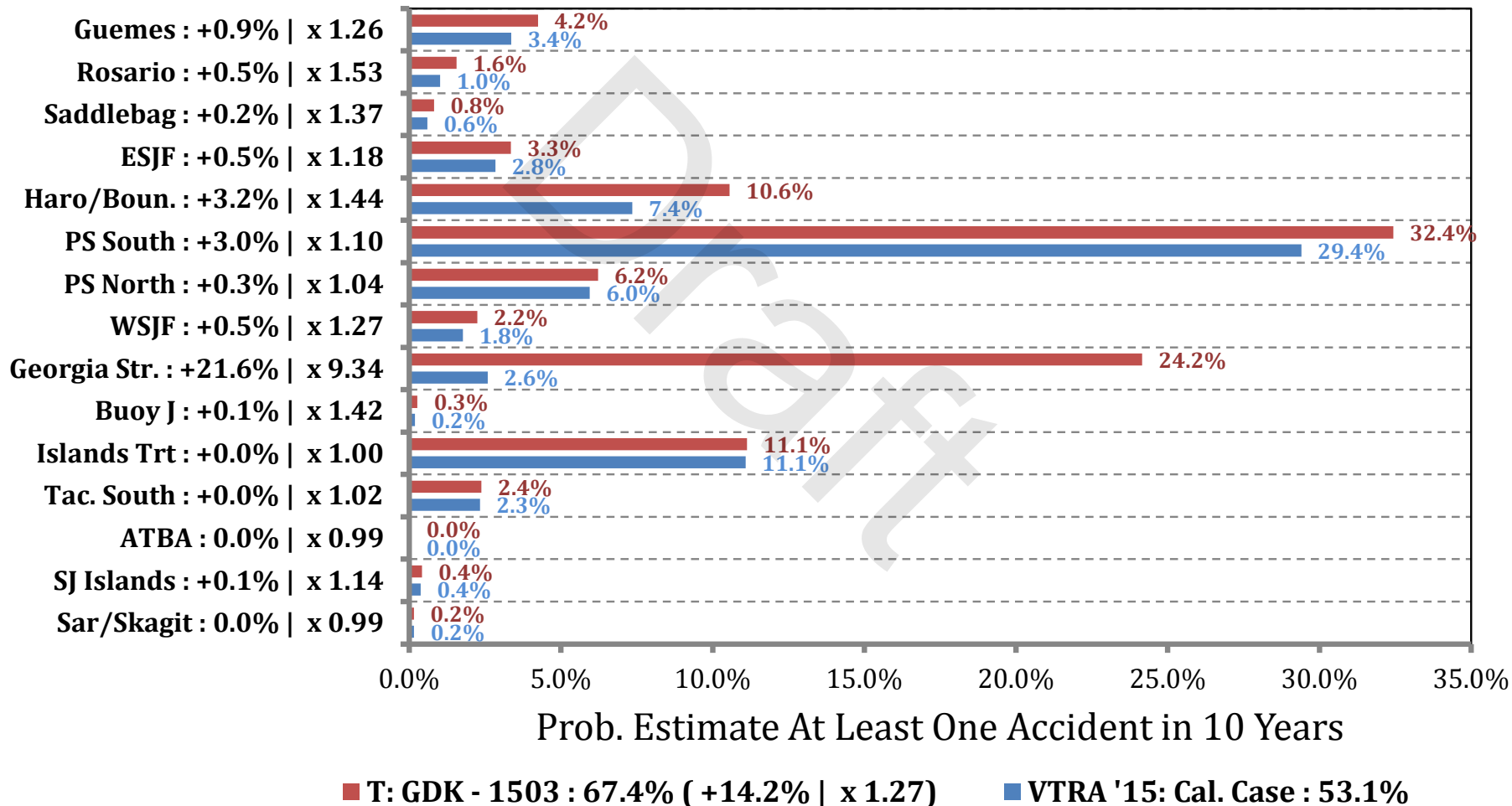
Average of ≈ 43 m<sup>3</sup> Per Potential Spill (≈ 271 Barrels)

6/7/2016

5/29/2016

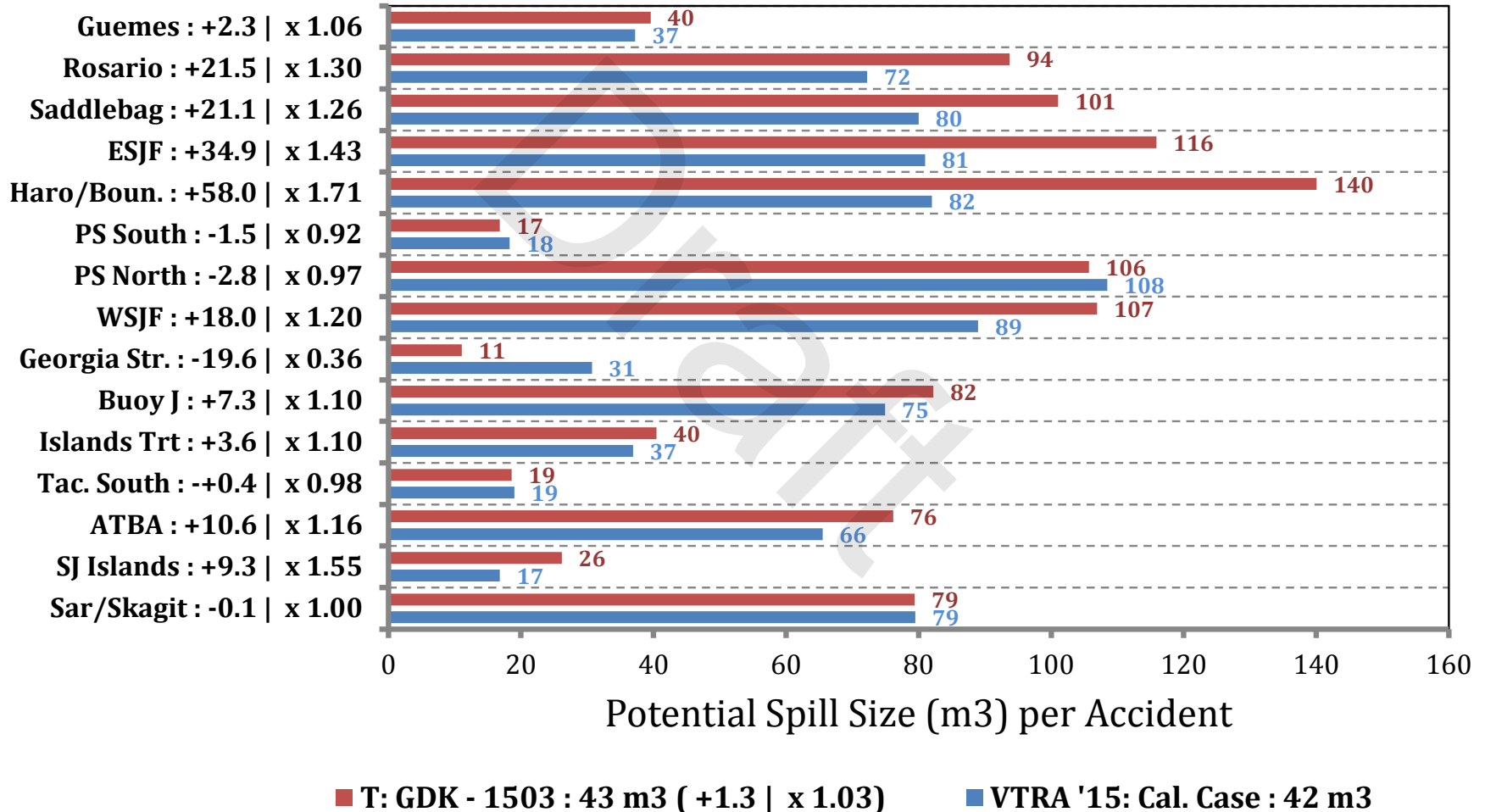
# VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

## Prob. Estimate At Least One Accident in 10 Years - ALL\_FV - Oil Spill Size Category: 1 - 1000 m<sup>3</sup>



# VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

## Potential Spill Size (m<sup>3</sup>) per Accident - ALL\_FV - Oil Spill Size Category: 1 - 1000 m<sup>3</sup>



# By Waterway Zone Risk Comparison

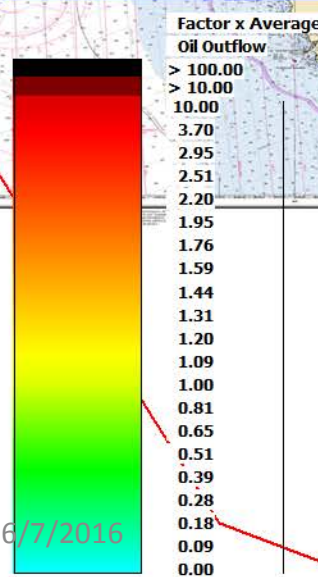
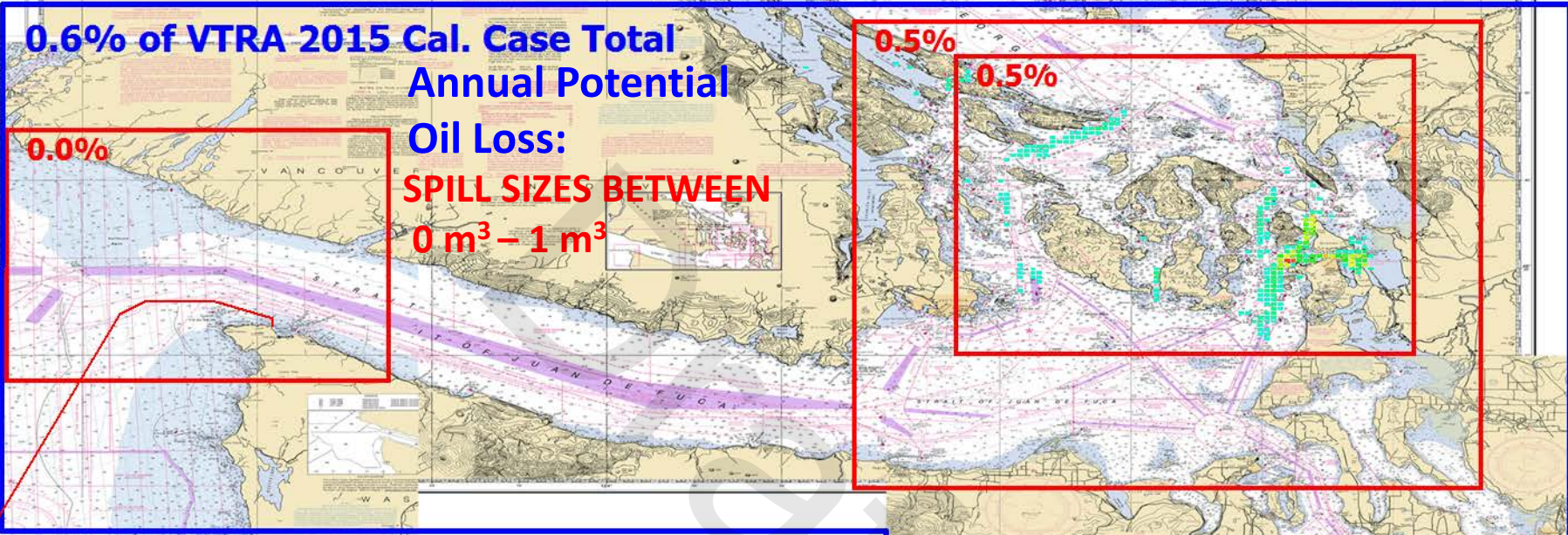
Oil Spill Size Category:

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

# 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 m<sup>3</sup> - 1 m<sup>3</sup>**

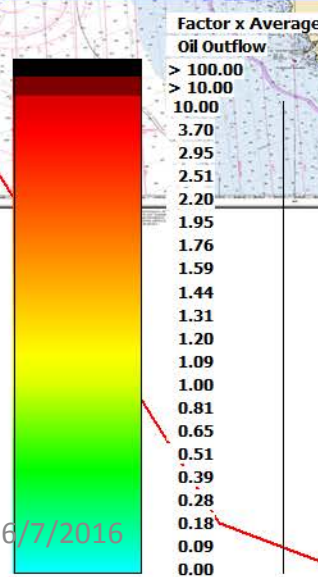
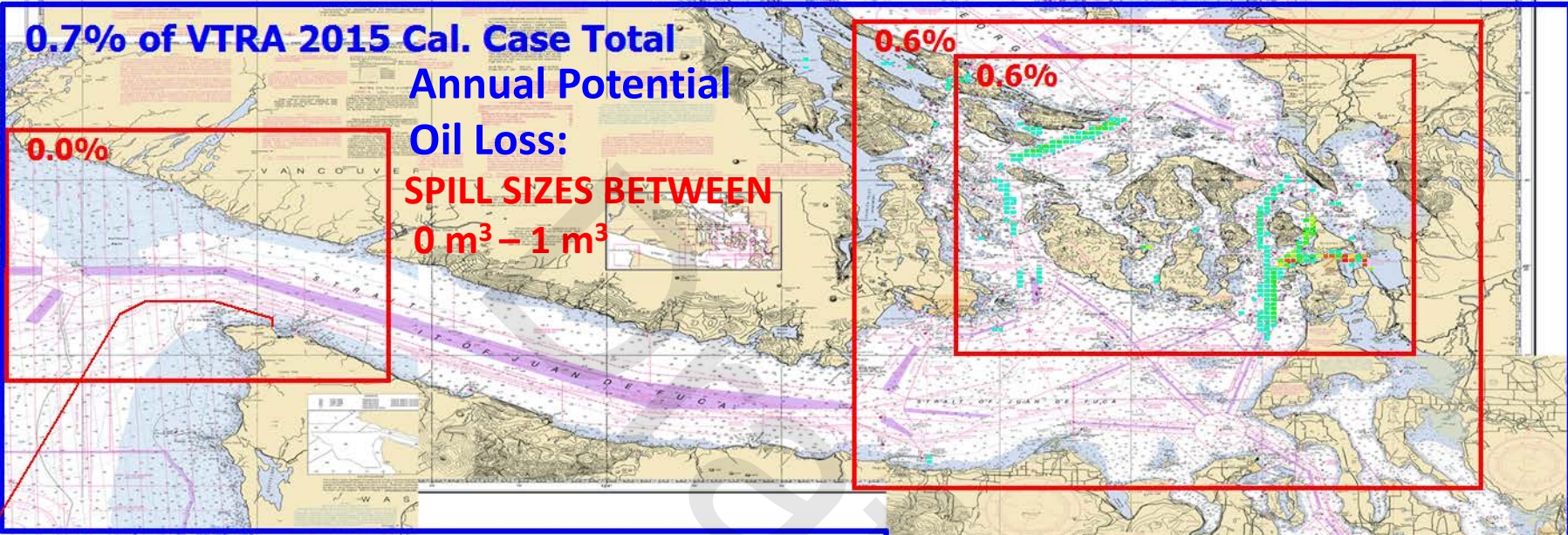
≈ 100% Probability  
of Spill Occurrence  
in 10 years

Average of ≈ 0.01 m<sup>3</sup>  
Per Potential Spill  
(≈ 2.4 gallons)



# VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

T: VTRA 2015 - GW 487- KM 348 - DP Cont. 368 and Bulk 300 - ALL FV



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

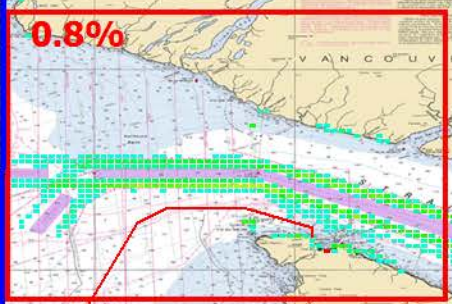
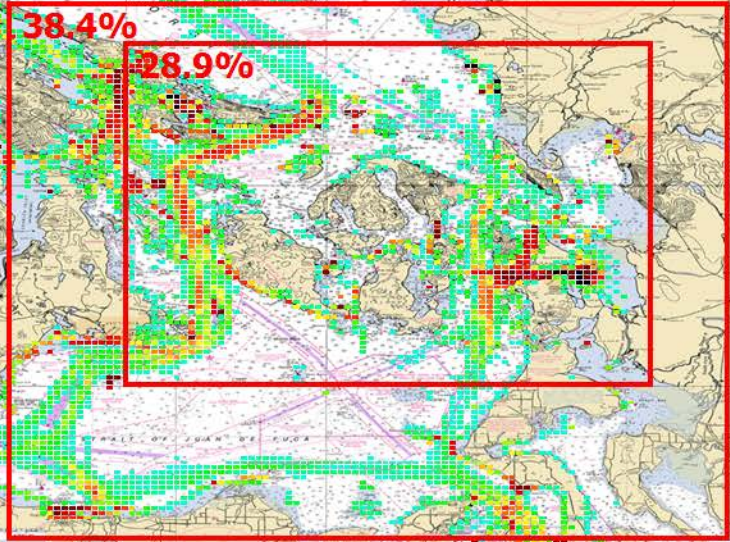
Average of ≈  $0.01 \text{ m}^3$  Per Potential Spill (= 2.1 gallons)

# 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 Case T: GDK - 1503  
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 ≈  $0.01\text{ m}^3$  Per Potential Spill (≈ 2.4 gallons)

6/7/2016

5/24/2016

# VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

T: VTRA 2015 - GW 487- KM 348 - DP Cont. 368 and Bulk 300 - ALL FV

132.5% of VTRA 2015 Cal. Case Total  
Potential Annual

# Accidents:

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

1.3%

63.8%

53.6%

Factor x Average  
Oil Outflow

- > 100.00
- > 10.00
- 10.00
- 3.71
- 2.95
- 2.51
- 2.20
- 1.95
- 1.76
- 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 '15 Case R: KM - 348

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

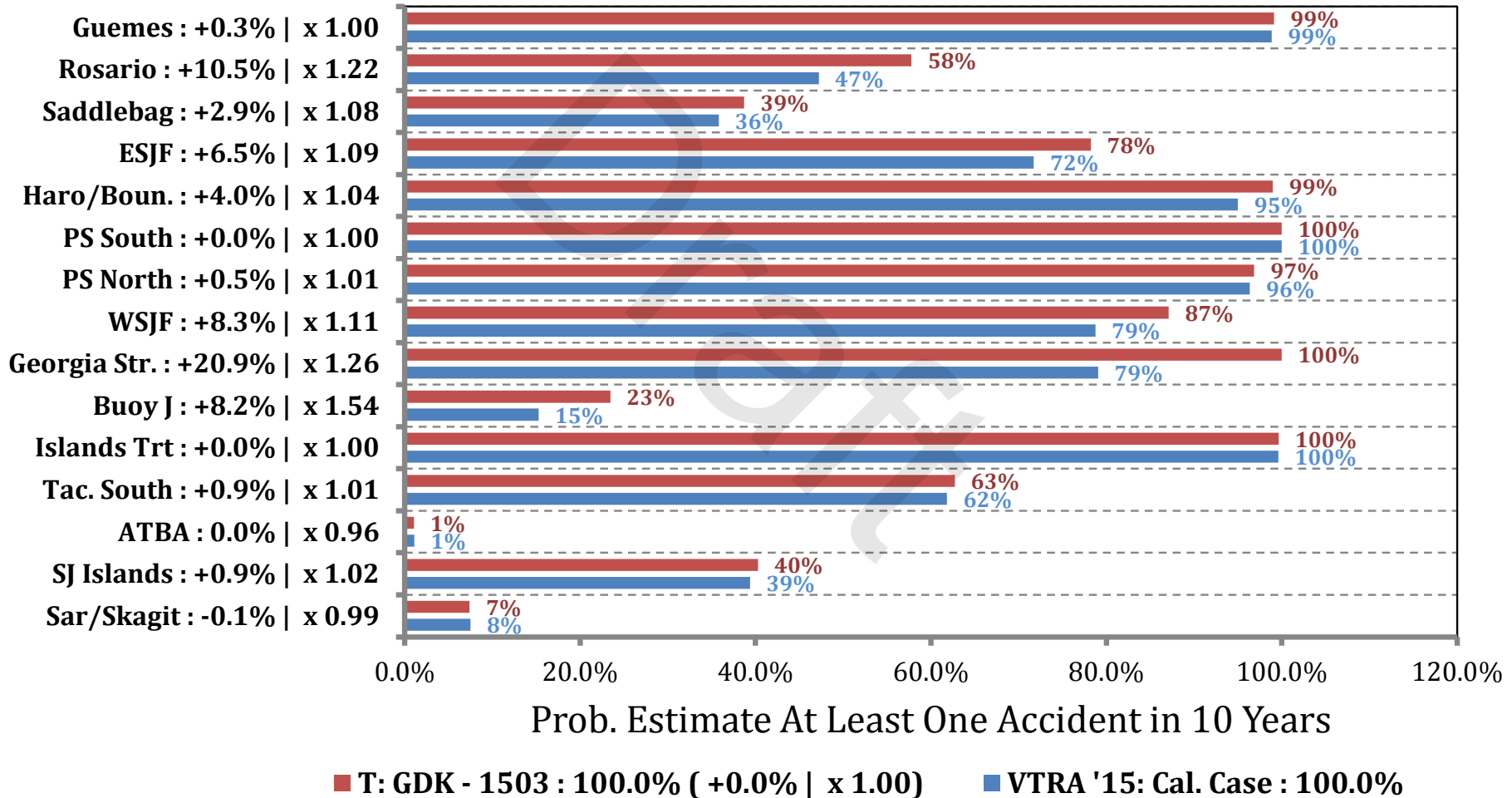
Average of ≈  $0.01 \text{ m}^3$   
Per Potential Spill  
(= 2.1 gallons)

6/7/2016

5/29/2016

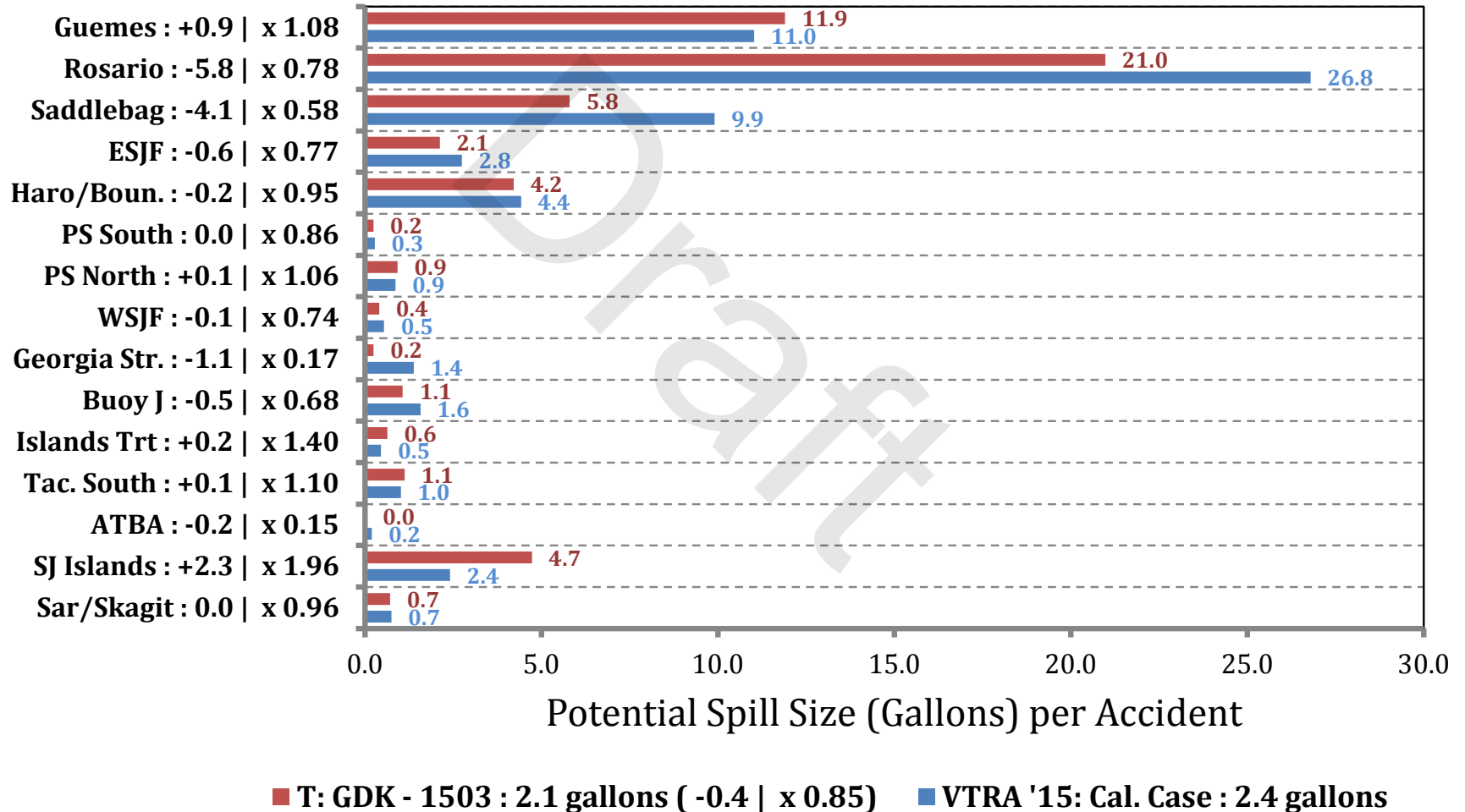
# VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

## Prob. Estimate At Least One Accident in 10 Years - ALL\_FV - Oil Spill Size Category: 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
<b>VTRA '15 CAL. CASE</b>	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 <sup>3</sup> )	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
<b>VTRA '15 CASE T: GDK - 1503</b>	Base Case % Potential Annual Oil Loss	67.7% ( +27.9%   x1.70 )	20.2% ( +8.0%   x1.65 )	71.9% ( +24.5%   x1.52 )	0.7% ( +0.09%   x1.15 )	160.5% ( +60.5%   x1.60 )
	Base Case % Potential Annual Accident Frequency	0.02% ( +0.01%   x2.10 )	0.02% ( +0.01%   x1.60 )	2.6% ( +0.8%   x1.48 )	132.5% ( +34.3%   x1.35 )	135.1% ( +35.1%   x1.35 )
	Average potential spill size per accident (in m <sup>3</sup> )	4659 ( -1085.8   x0.81 )	1679 ( +52.0   x1.03 )	43.2 ( +1.2   x1.03 )	0.01 ( 0.0   x0.85 )	1.8 ( +0.3   x1.19 )
	Probability of at least one accident in 1 year by spill size	0.10% ( +0.05%   x2.10 )	0.08% ( +0.03%   x1.60 )	10.6% ( +3.3%   x1.45 )	99.7% ( +1.0%   x1.01 )	99.7% ( +1.0%   x1.01 )
	Probability of at least one accident in 10 years by spill size	0.97% ( +0.51%   x2.09 )	0.80% ( +0.30%   x1.60 )	67.4% ( +14.2%   x1.27 )	100.0% ( 0.0%   x1.00 )	100.0% ( 0.0%   x1.00 )
	Probability of at least one accident in 25 years by spill size	2.42% ( +1.26%   x2.08 )	2.00% ( +0.75%   x1.60 )	93.9% ( +8.9%   x1.10 )	100.0% ( 0.0%   x1.00 )	100.0% ( 0.0%   x1.00 )