Risk Analysis of the Maritime Traffic in Delaware River

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Modeling of Maritime Traffic in DRB

Objectives:

- Modeling of maritime traffic logistics
- Analysis of dredging on navigational issues
- Risk assessment of the maritime traffic
- Preparedness and recovery

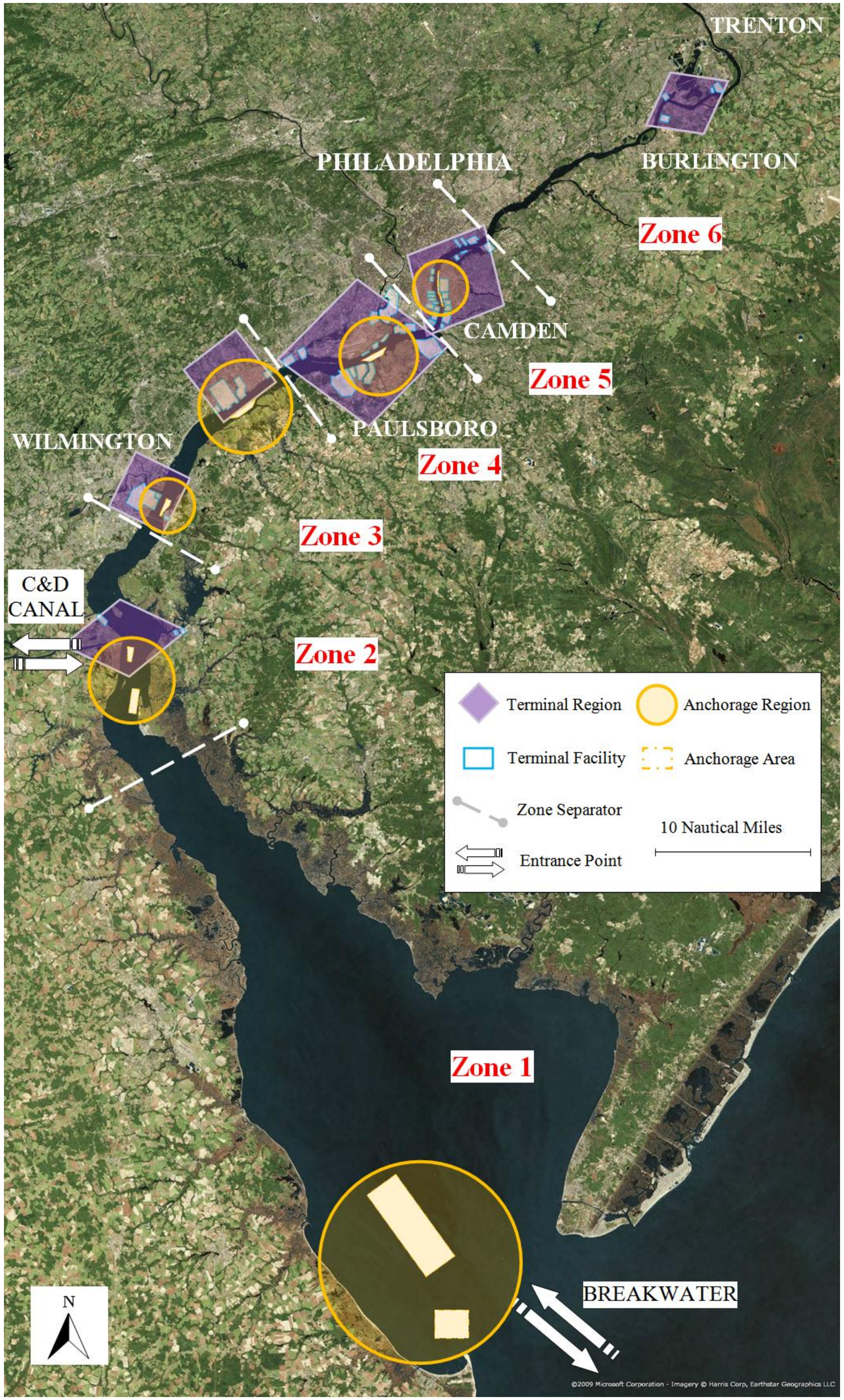
Sponsored by The AMSC, Sector Delaware Bay

Funding support by State of New Jersey Department of Transportation

Maritime Division

Delaware River and Bay (DRB)

- Fourth largest port in the US
- More than 40 port facilities with their associated businesses
- About 3,000 vessels visiting each year
- 27 million people living within 100 miles and 90 million within 500 miles
- Approximately 65% of the region’s cargo tonnage is in petroleum
- Other major cargoes are
  - steel
  - wood products
  - perishable items such as fresh fruit, nuts, cocoa beans, and meat products

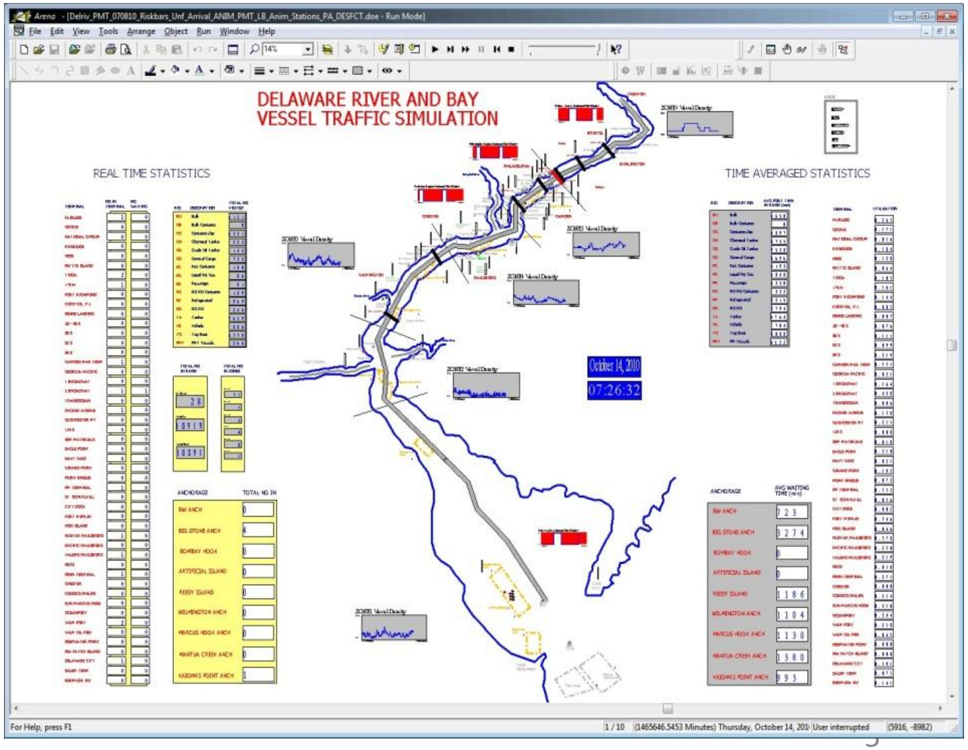


Port Operations in the River

- Entrance points:
  - Breakwater (BW) (93%)
  - Chesapeake and Delaware Canal (CD) (7%)
- Vessel Types:
  - Tankers (30%)
  - Cargo Containers (15%)
  - Bulk (14%)
  - Refrigerated (11%)
  - Vehicle (10%)
  - General Cargo (8%)
  - Tug Boats
- The maximum fresh water draft for river transit from BW to Delair, NJ is 40 feet and from Delair to Trenton, NJ it is 38 feet
- Tidal activity significantly influences the entrance of large vessels from BW
- Lightering at Big Stone Beach Anchorage
  - 43% of the tankers have underway draft above 40 feet and need lightering

The Simulation Model Components

- Vessel arrivals at BW and CD with vessel characteristics of
  - length
  - beam
  - underway draft
  - max draft
  - gross tonnage
- Terminal calls based on itinerary generation
- Vessel navigation with randomized vessel travel times to terminals and anchorages
- Terminal reservation and operations based on holding times
- Tidal and navigational rules in the River
- Lightering rules and procedure
- Anchorage selection procedure

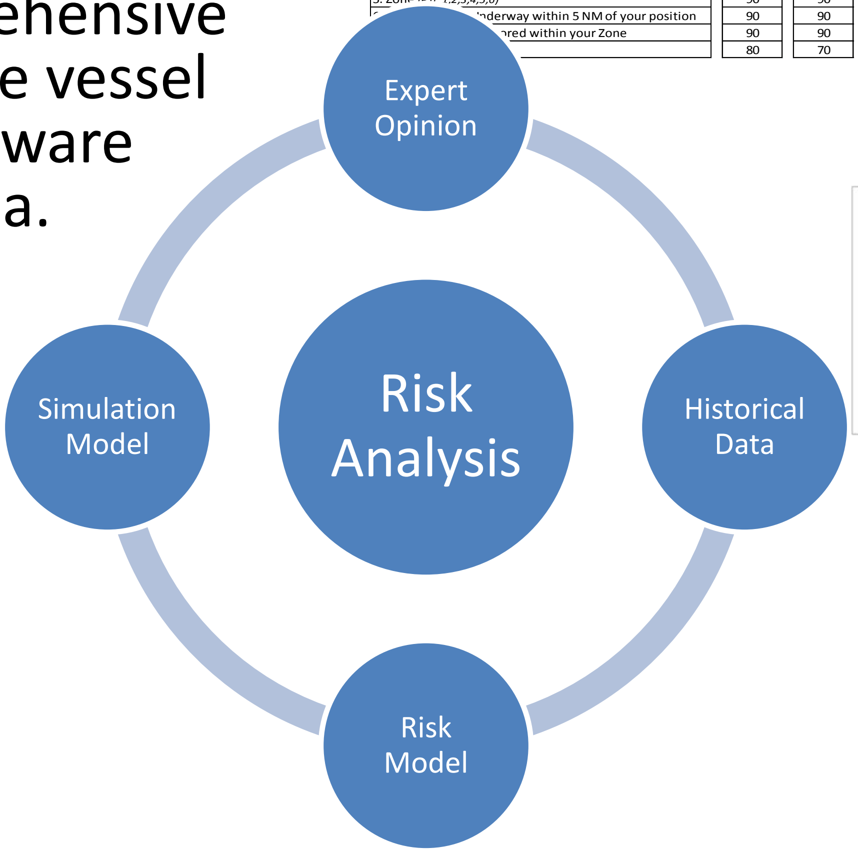


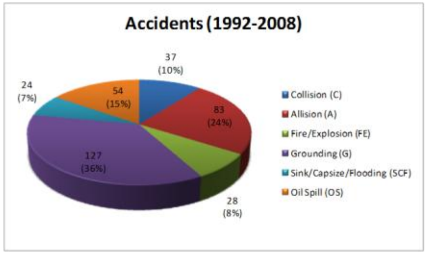
Objective and Approach

Expert opinion elicitation helps to compute the unknown accident and consequence probabilities.

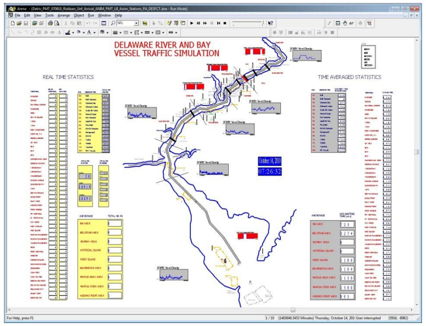
	Collision | Instigators				
Situational Attributes	HE^C	PF^C	SF^C	EF^C	OSF^C
1. Time of Day	75	30	30	40	10
2. Tide	80	70	70	10	10
3. (Your) Vessel Status *(e.g. Docked, Underway, Anchored)*	90	90	90	40	40
4. (Your) Vessel Class *(e.g. General Cargo, Dangerous Cargo)*	20	20	20	20	20
5. Zone *(e.g. 1,2,3,4,5,6)*	90	90	90	20	10
…nderway within 5 NM of your position	90	90	90	20	10
…ored within your Zone	90	90	90	20	10
	80	70	70	20	10

Perform a comprehensive risk analysis of the vessel traffic in the Delaware River and Bay area.





Accident probabilities are calibrated using historical data.

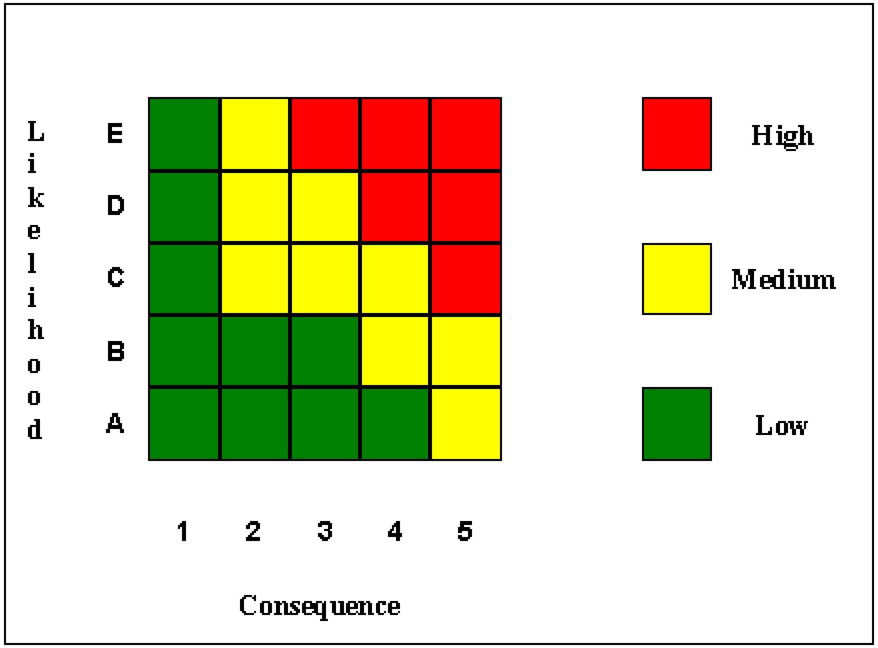


Simulation model creates all possible situations.

$$R_s(\underline{X}) = \sum_{v \in \mathcal{V}_S} \sum_{j \in \mathcal{A}} \left(\sum_{k \in \mathcal{C}_j} E\left[C_{k,j,v} \middle| A_{j,v}, \underline{X}_v \right] \times \Pr\left(A_{j,v} \middle| \underline{X}_v \right) \right)$$

A probabilistic risk model is developed.

Definition of Risk



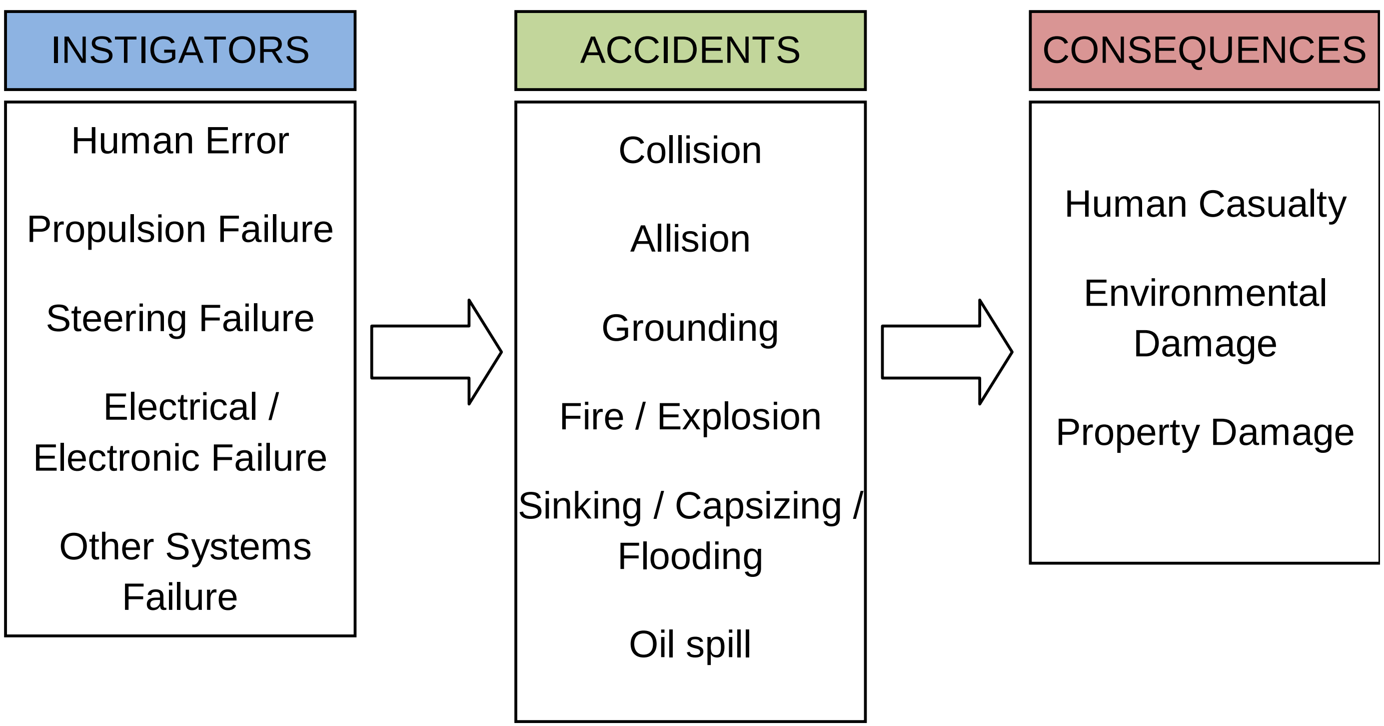
$$R_x = p_x \times C_x$$

- x represents the scenario,
- R_x is the risk of the scenario,
- p_x is the probability of occurrence of the scenario,
- C_x is the consequence of the scenario in case it occurs

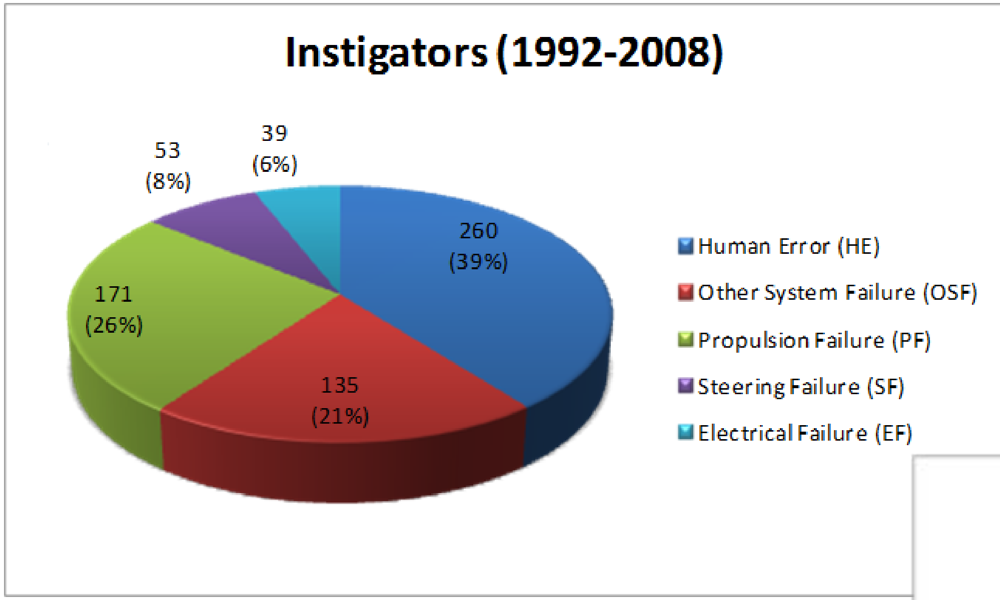
Risk Framework

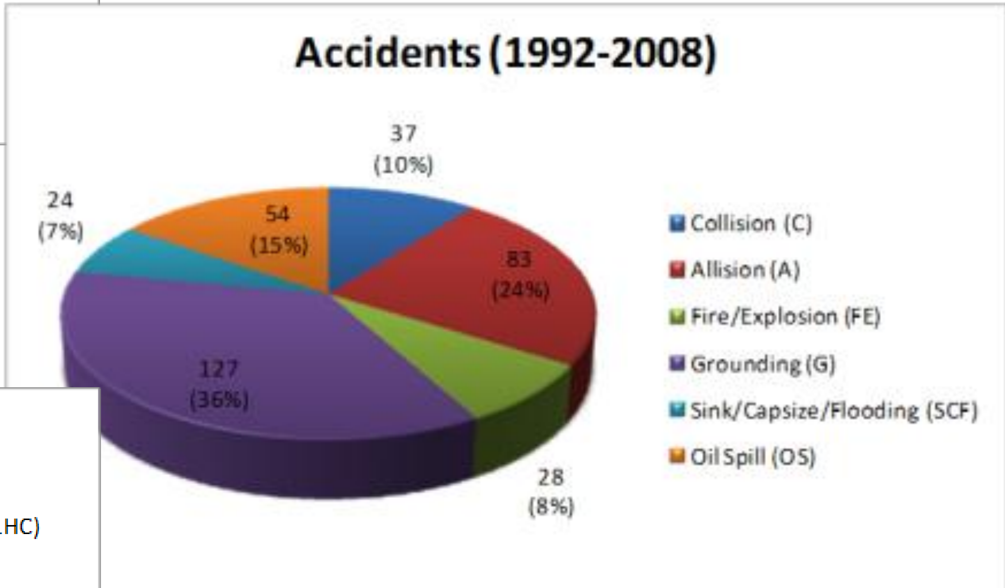
- Accidents typically occur as a result of a chain of events rather than being independent single events.

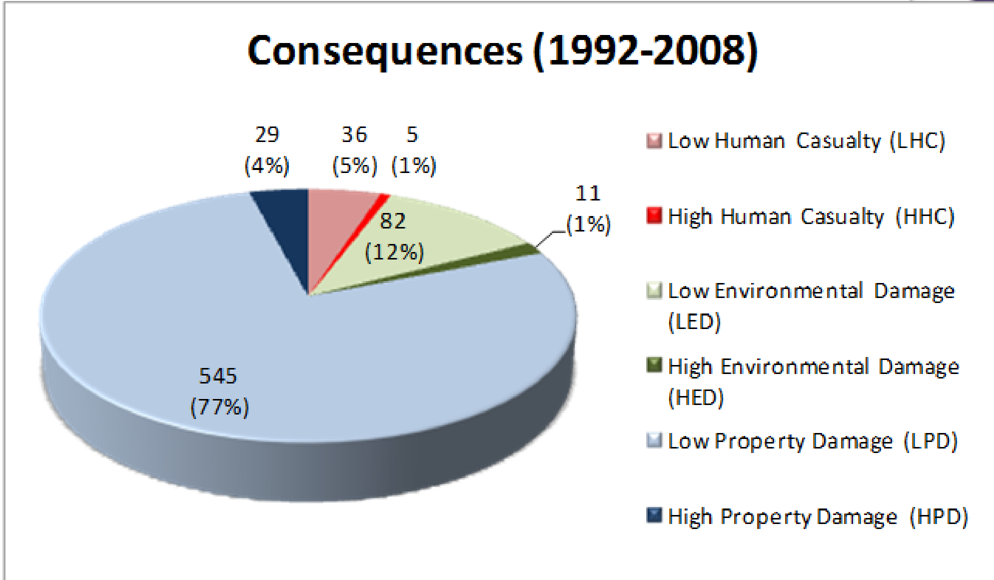
- The initial step of the risk analysis process is to identify reasons and outcomes of accidents.



Historical Accident Data of 1992 to 2008 in DRB







Relationship among Instigators, Accidents and Consequences

v: vessel no
I : instigator type
j : accident type
k : consequence type

	P(Accident | Instigator)	Accidents					
		Collision	Allision	Grounding	Fire / Explosion	Sinking / Capsizing / Flooding	Oil Spill
Instigators	Human Error	0.1269	0.2463	0.3993	0.0560	0.0299	0.0336
	Propulsion Failure	0.0349	0.0349	0.0291	0.0174	0.0001	0.0058
	Steering Failure	0.0566	0.0377	0.0943	0.0002	0.0002	0.0755
	Electrical / Electronic Failure	0.0003	0.0256	0.0513	0.0513	0.0003	0.0003
	Other Systems Failure	0.0074	0.0662	0.0662	0.0735	0.1029	0.2941

$$\Pr(A_{j,v}) = \sum_i \Pr(A_{j,v} \mid I_{i,v}) \times \Pr(I_{i,v})$$

	P(Consequence | Accident)	Consequences		
		Human Casualty	Environmental Damage	Property Damage
Accidents	Collision	0.0417	0.0833	0.8750
	Allision	0.0435	0.0761	0.8804
	Grounding	0.0368	0.0588	0.9044
	Fire / Explosion	0.2273	0.0682	0.7045
	Sinking / Capsizing / Flooding	0.0294	0.3529	0.6176
	Oil Spill	0.0800	0.7200	0.2000

$$\Pr(C_{k,v}) = \sum_j \Pr(C_{k,v} \mid A_{j,v}) \times \Pr(A_{j,v})$$

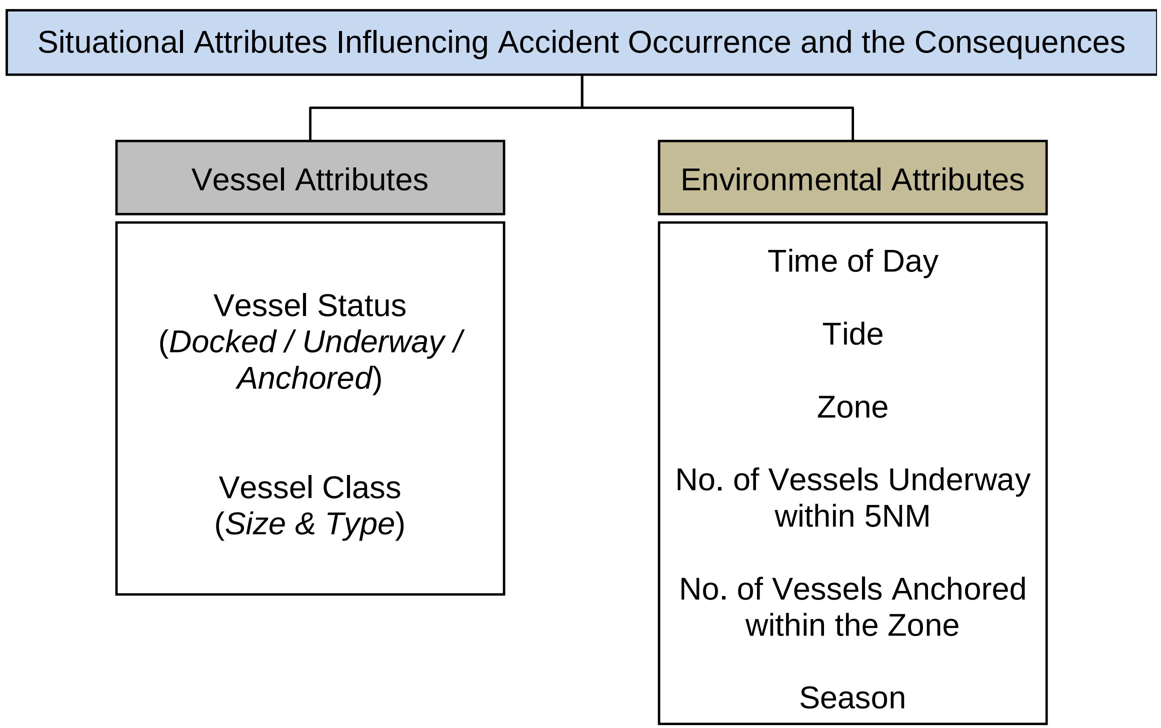
$$E[C_{k,j,v} \mid A_{j,v}] = E[C_{k,j}] \times \Pr(C_{k,v} \mid A_{j,v})$$

Instigators	P(Instigator)
Human Error	0.0054
Propulsion Failure	0.0034
Steering Failure	0.0011
Electrical / Electronic Failure	0.0008
Other Systems Failure	0.0027

$$R_v = \sum_k \sum_j \sum_i E[C_{k,j,v} \mid A_{j,v}] \times \Pr(A_{j,v} \mid I_{i,v}) \times \Pr(I_{i,v})$$

Situational Attributes

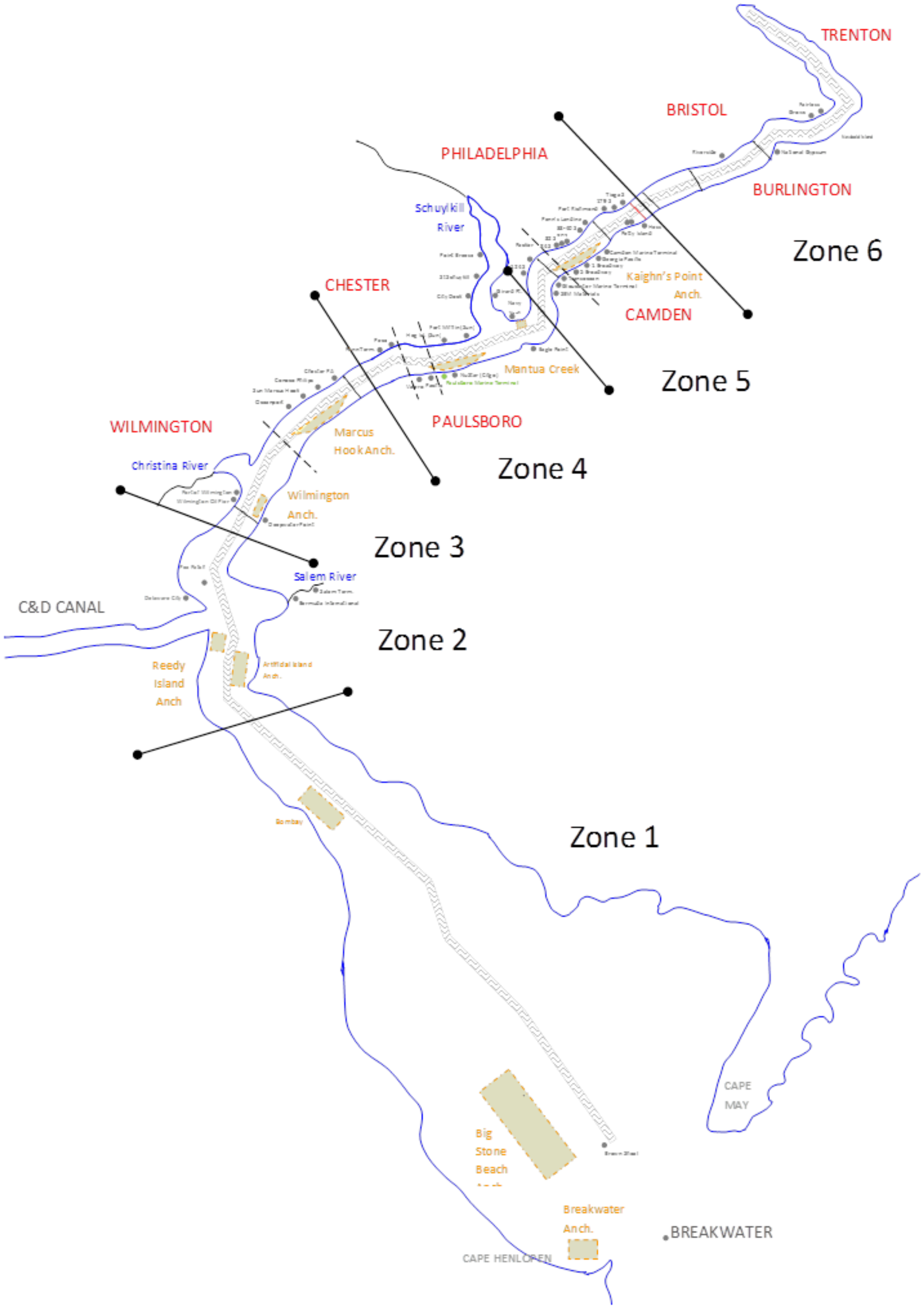
- Situational attributes are factors that may increase or decrease the chances of an instigator or accident happening or the scale of consequences



Levels of Situational Attributes

Variable	Situational Attribute	Possible Values	States
X_1	Time of Day	2	Day, Night
X_2	Tide	2	High, Low
X_3	Vessel Status	3	Docked, Underway, Anchored
X_4	Vessel Class	10	General Cargo < 150m, General Cargo ≥ 150m, Tugboat / Barge, Passenger ≥ 100GT, Petroleum Tanker < 200m, Petroleum Tanker ≥ 200m, Chemical Tanker < 150m, Chemical Tanker ≥ 150m, LNG / LPG, Lightering Barge
X_5	Zone	6	Delaware Bay, CD Canal Region, Wilmington Region, Paulsboro Region, Philadelphia Region, Upper Delaware River
X_6	No. of Vessels within 5NM	3	0 or 1 vessel, 2 to 3 vessels, more than 3 vessels
X_7	No. of Vessels Anchored in the Zone	3	0 or 1 vessel, 2 to 3 vessels, more than 3 vessels
X_8	Season	4	Fall, Winter, Spring, Summer

There are a total of 25,920 different possible situations for a selected set of 8 situational attributes.



Quantification of Risks

- How frequent does any particular situation occur?
- For a given situation, how often do instigators occur?
- If an instigator occurs, how likely is a particular accident?
- If an accident occurs, what would be the expected damage to human life, environment and property?

Mathematical Risk Model

The instantaneous risk for a given zone *s* based on the states of the situational attributes as observed at a particular instance

Situational attribute set regarding vessel *v* in zone *s*

$$R_s(\underline{X}) = \sum_{v \in \mathcal{V}_s} \sum_{j \in \mathcal{A}} \left(\sum_{k \in \mathcal{C}_j} E\left[C_{k,j,v} \middle| A_{j,v}, \underline{X}_v \right] \times \Pr\left(A_{j,v} \middle| \underline{X}_v \right) \right)$$

The set of vessels navigating in zone *s* at the observed instance

Consequence type *k* due to accident type *j* regarding vessel *v* in zone *s*

Accident type *j* regarding vessel *v* in zone *s*

$$\Pr\left(A_{j,v} \middle| \underline{X}_v \right) = \sum_{i \in \mathcal{I}_\varphi} \Pr\left(A_{j,v} \middle| I_{i,v}, \underline{X}_{i,v} \right) \times \Pr\left(I_{i,v} \middle| \underline{X}_{i,v} \right)$$

Instigator type *i*, regarding vessel *v* in zone *s*

Probabilities Given a Situation

- Due to lack of data, given a situation estimation of any probability requires expert judgment elicitation.

Calibration constant — The effect of a situation — Cardinality of a level of a situation

$$\Pr\left(\Phi \middle| \underline{X}\right) = P_{\Phi}(\underline{\beta}^{T}\ \underline{X}) = P_{\Phi}.(\beta_1 X_1 + \ldots + \beta_n X_n)$$

For a given event Φ,

- the effect of a situation is represented by β
- the effect of a level of a situation is represented by X
- P_{Φ} is the calibration constant which calibrates the associated probability using historical data.

Expert Judgment Elicitation Questionnaires

Beta Questionnaires

- β values are directly asked to the survey respondents.
- Experts are again expected to put a value between 0 (no relation) and 100 (direct relationship / correlation) to the blocks provided
- Values averaged over individual responses and later scaled down to less than 1.0.

$$\Pr(HE|X_s) = P^{he} \cdot (\beta^{he}.X^{he}) = P^{he} \cdot (\beta_1^{he}.X_1^{he} + \beta_2^{he}.X_2^{he} + \ldots + \beta_8^{he}.X_8^{he})$$

	Instigator				
Situational Attributes	HE	PF	SF	EF	OSF
1. Time of Day	80	10	10	10	10
2. Tide	80	25	25	10	5
3. (Your) Vessel Status *(e.g. Docked, Underway, Anchored)*	90	90	90	90	90
4. (Your) Vessel Class *(e.g. General Cargo, Dangerous Cargo)*	50	20	20	20	20
5. Zone *(e.g. 1,2,3,4,5,6)*	80	10	10	10	10
6. No. of Vessels Underway within 5 NM of your position	85	10	10	10	10
7. No. of Vessels Anchored within your Zone	60	10	10	10	10
8. Season	75	30	30	10	50

Cardinality Questionnaires

	HE	PSF	OSF
	Instigator		
1. Time of Day			
a. Day	30	30	10
b. Night	80	50	50
2. Tide			
a. High	50	10	10
b. Low	80	30	10
3. (Your) Vessel Status			
a. Docked	0	0	10
b. Underway	90	90	50
c. Anchored	30	0	10
4. (Your) Vessel Class			
a. General Cargo	50	50	50
b. Dangerous Cargo	60	40	40
5. Zone ***(Geographical – Infrastructure only)***			
a. 1	50	50	10
b. 2	65	60	20
c. 3	60	60	20
d. 4	70	60	20
e. 5	70	60	20
f. 6	60	60	20
6. No. of Vessels Underway within 5 NM of your position			
a. 0-1	60	20	10
b. 2-3	70	40	20
c. more than 3	75	50	20
7. No. of Vessels Anchored within your Zone			
a. 0-1	20	10	10
b. 2-3	30	20	10
c. more than 3	50	30	10
8. Season			
a. Fall	60	30	10
b. Winter	80	50	20
c. Spring	70	60	10
d. Summer	50	20	10

$$\Pr(HE \mid X_s) = P^{he} \cdot (\beta_1^{he}.X_1^{he} + \beta_2^{he}.X_2^{he} + \ldots + \beta_8^{he}.X_8^{he})$$

Cardinality Questionnaires

- X values are directly asked to the survey respondents.
- Experts are again expected to put a value between 0 (no relation) and 100 (direct relationship / correlation) to the blocks provided.
- Values averaged over individual responses and later scaled down to less than 1.0.

Probability of Instigator Given Situation

$$\Pr\left(I_i \middle| \underline{X}_i\right) = P_i.(\underline{\beta}_i^T \underline{X}_i)$$

	Instigator		
	HE	PSF	OSF
1. Time of Day			
a. Day	30	30	10
b. Night	80	50	50
2. Tide			
a. High	50	10	10
b. Low	80	30	10
3. (Your) Vessel Status			
a. Docked	0	0	10
b. Underway	90	90	50
c. Anchored	30	0	10
4. (Your) Vessel Class			
a. General Cargo	50	50	50
b. Dangerous Cargo	60	40	40
5. Zone ***(Geographical – Infrastructure only)***			
a. 1	50	50	10
b. 2	65	60	20
c. 3	60	60	20
d. 4	70	60	20
e. 5	70	60	20
f. 6	60	60	20
6. No. of Vessels Underway within 5 NM of your position			
a. 0-1	60	20	10
b. 2-3	70	40	20
c. more than 3	75	50	20
7. No. of Vessels Anchored within your Zone			
a. 0-1	20	10	10
b. 2-3	30	20	10
c. more than 3	50	30	10
8. Season			
a. Fall	60	30	10
b. Winter	80	50	20
c. Spring	70	60	10
d. Summer	50	20	10

	Instigator				
Situational Attributes	HE	PF	SF	EF	OSF
1. Time of Day	80	10	10	10	10
2. Tide	80	25	25	10	5
3. (Your) Vessel Status *(e.g. Docked, Underway, Anchored)*	90	90	90	90	90
4. (Your) Vessel Class *(e.g. General Cargo, Dangerous Cargo)*	50	20	20	20	20
5. Zone *(e.g. 1,2,3,4,5,6)*	80	10	10	10	10
6. No. of Vessels Underway within 5 NM of your position	85	10	10	10	10
7. No. of Vessels Anchored within your Zone	60	10	10	10	10
8. Season	75	30	30	10	50

Vessel Type	Instigator (Aggregate)
1. General Cargo < 150 (m)	60
2. General Cargo ≥ 150 (m)	50
3. Tugboat / Barge	80
4. Passenger ≥ 100 GT	10
5. Petroleum Tanker < 200 (m)	30
6. Petroleum Tanker ≥ 200 (m)	20
7. Chemical Tanker < 150 (m)	30
8. Chemical Tanker ≥ 150 (m)	20
9. LNG / LPG	10
10. Lightering Barge	90

Beta Questionnaires:

- Ask the effect of a situational attribute on the occurrence of an instigator in a particular vessel

Cardinality Questionnaires:

- Ask the importance of a level of a situational attribute on the occurrence of an instigator in a particular vessel

Probability of Accident Given Instigator and Situation

$$\Pr\left(A_j \middle| I_i, \underline{X}_i\right) = P_{j,i}.(\underline{\beta}_{j,i}^T \underline{X}_{j,i})$$

	Accident | Instigator		
	HE	PSF	OSF
1. Time of Day			
a. Day	70	70	10
b. Night	90	90	50
2. Tide			
a. High	40	40	10
b. Low	60	60	20
3. (Your) Vessel Status			
a. Docked	90	0	10
b. Underway	70	90	10
c. Anchored	90	0	10
4. (Your) Vessel Class			
a. General Cargo	50	50	10
b. Dangerous Cargo	90	90	30
5. Zone ***(Geographical – Infrastructure only)***			
a. 1	20	30	10
b. 2	20	30	15
c. 3	50	70	20
d. 4	50	70	20
e. 5	50	70	20
f. 6	20	30	15
6. No. of Vessels Underway within 5 NM of your position			
a. 0-1	50	50	10
b. 2-3	70	60	20
c. more than 3	90	90	20
7. No. of Vessels Anchored within your Zone			
a. 0-1	50	50	10
b. 2-3	60	60	20
c. more than 3	70	70	20
8. Season			
a. Fall	60	10	0
b. Winter	80	30	10
c. Spring	70	10	0
d. Summer	20	10	0

	Collision | Instigators				
Situational Attributes	HE^C	PF^C	SF^C	EF^C	OSF^C
1. Time of Day	75	30	30	40	10
2. Tide	80	70	70	10	10
3. (Your) Vessel Status *(e.g. Docked, Underway, Anchored)*	90	90	90	40	40
4. (Your) Vessel Class *(e.g. General Cargo, Dangerous Cargo)*	20	20	20	20	20
5. Zone *(e.g. 1,2,3,4,5,6)*	90	90	90	20	10
6. No. of Vessels Underway within 5 NM of your position	90	90	90	20	10
7. No. of Vessels Anchored within your Zone	90	90	90	20	10
8. Season	80	70	70	20	10

Vessel Type	Accident | Instigator (Aggregate)
1. General Cargo < 150 (m)	60
2. General Cargo ≥ 150 (m)	50
3. Tugboat / Barge	70
4. Passenger ≥ 100 GT	50
5. Petroleum Tanker < 200 (m)	60
6. Petroleum Tanker ≥ 200 (m)	50
7. Chemical Tanker < 150 (m)	60
8. Chemical Tanker ≥ 150 (m)	50
9. LNG / LPG	50
10. Lightering Barge	80

Beta Questionnaires:

- Prepared for all accident types separately
- Ask the effect of a situational attribute on the likelihood of an accident, given an instigator taking place on a particular vessel

Cardinality Questionnaires:

- Combined into one questionnaire for any type of accident.
- Ask the importance of attribute levels on the likelihood of an accident, given an instigator taking place on a particular vessel.

Expected Consequence Given Accident and Situation

$$\Pr\left(C_{k,j}\left|A_j, \underline{X}_k\right.\right) = P_{k,j}.(\underline{\beta}_{k,j}{}^{T}\underline{X}_k)$$

Situational Attributes	Consequences | Collision		
	HC	EnvD	ProD
1. Time of Day	90	80	90
2. Tide	10	95	30
3. (Your) Vessel Status *(e.g. Docked, Underway, Anchored)*	90	80	80
4. (Your) Vessel Class *(e.g. General Cargo, Dangerous Cargo)*	90	95	90
5. Zone *(e.g. 1,2,3,4,5,6)*	80	90	90
6. No. of Vessels Underway within 5 NM of your position	90	70	90
7. No. of Vessels Anchored within your Zone	10	10	10
8. Season	80	80	70

	Consequence | Accident		
	Human Casualty	Environmental Damage	Property Damage
1. Time of Day			
a. Day	50	50	50
b. Night	90	90	90
2. Tide			
a. High	10	10	10
b. Low	10	60	70
3. (Your) Vessel Status			
a. Docked	10	40	20
b. Underway	90	70	90
c. Anchored	50	40	60
4. (Your) Vessel Class			
a. General Cargo	50	40	50
b. Dangerous Cargo	70	90	70
5. Zone *(Geographical – Infrastructure only)*			
a. 1	80	70	60
b. 2	70	80	70
c. 3	75	80	70
d. 4	75	80	75
e. 5	75	80	75
f. 6	60	80	70
6. No. of Vessels Underway within 5 NM of your position			
a. 0-1	50	60	50
b. 2-3	60	70	60
c. more than 3	50	70	70
7. No. of Vessels Anchored within your Zone			
a. 0-1	70	50	50
b. 2-3	70	50	60
c. more than 3	75	50	70
8. Season			
a. Fall	50	50	60
b. Winter	90	90	60
c. Spring	50	70	70
d. Summer	20	50	90

Vessel Type	Consequence | Accident		
	HC	EnvD	ProD
1. General Cargo < 150 (m)	50	60	60
2. General Cargo ≥ 150 (m)	50	70	70
3. Tugboat / Barge	60	70	70
4. Passenger ≥ 100 GT	100	30	30
5. Petroleum Tanker < 200 (m)	80	80	80
6. Petroleum Tanker ≥ 200 (m)	80	80	80
7. Chemical Tanker < 150 (m)	80	80	80
8. Chemical Tanker ≥ 150 (m)	80	80	80
9. LNG / LPG	90	20	90
10. Lightering Barge	20	90	90

Beta Questionnaires:

- Prepared for all accident types separately
- Ask the effect of a situational attribute on the severity of the consequence given an accident has happened.

Cardinality Questionnaires:

- Combined into one questionnaire for any type of accident.
- Ask the importance of attribute characteristics on the severity of the consequence given an accident has happened.

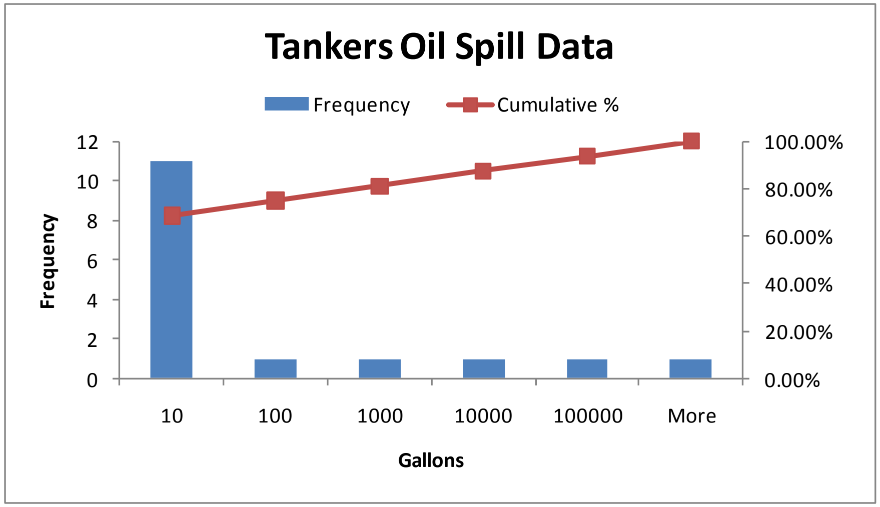
Consequence Quantification

$$E\left[C_{k,j}\,|\,A_j,\underline{X}_k\right]=\boxed{C_{k,j}}\cdot\Pr\left(C_{k,j}\,|\,A_j,\underline{X}_k\right)$$

Environmental Damage

Oil Spill (Gallons)	*Average Response Cost/Gallon ($)*	*Environmental Cost/Gallon ($)*	*Socioeconomic Cost/Gallon ($)*	*Total Cost/Gallon ($) (Present Value)*
< 500	199	90	50	401.98
500 - 1000	197	87	200	573.92
1000 - 10K	195	80	300	681.83
10K - 100K	185	73	140	471.95
100K - 1000K	118	35	70	264.43
> 1M	82	30	60	203.96

*Etkin, D.S. (2004), Modeling oil spill response and damage costs, *Proceedings of the Fifth Biennial Freshwater Spills Symposium*

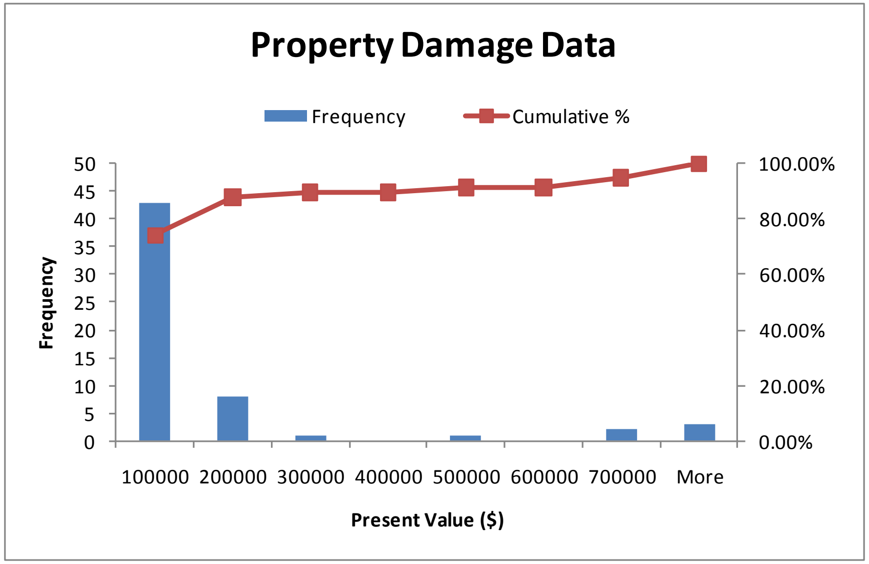


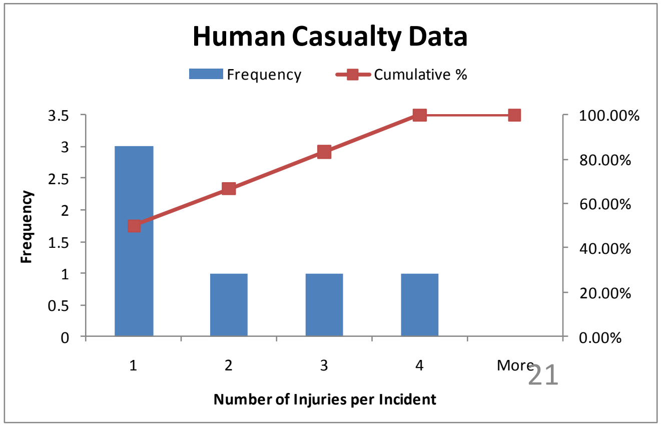
Human Casualty

Average Comprehensive Cost by Injury Severity	
Death	$4,300,000
Nonincapacitating evident injury	$55,300
No injury	$2,400

**U.S. National Safety Council 2009 Values

Property Damage





Calibration of Probabilities

- Calibration process makes sure that long-run probabilities are legitimate probabilities.
- It is achieved by making an initial simulation run with the calibration constants in the risk model being 1.0.
- The calculated calibration constants replace all 1.0s in the preliminary run, making the model ready for risk calculations.

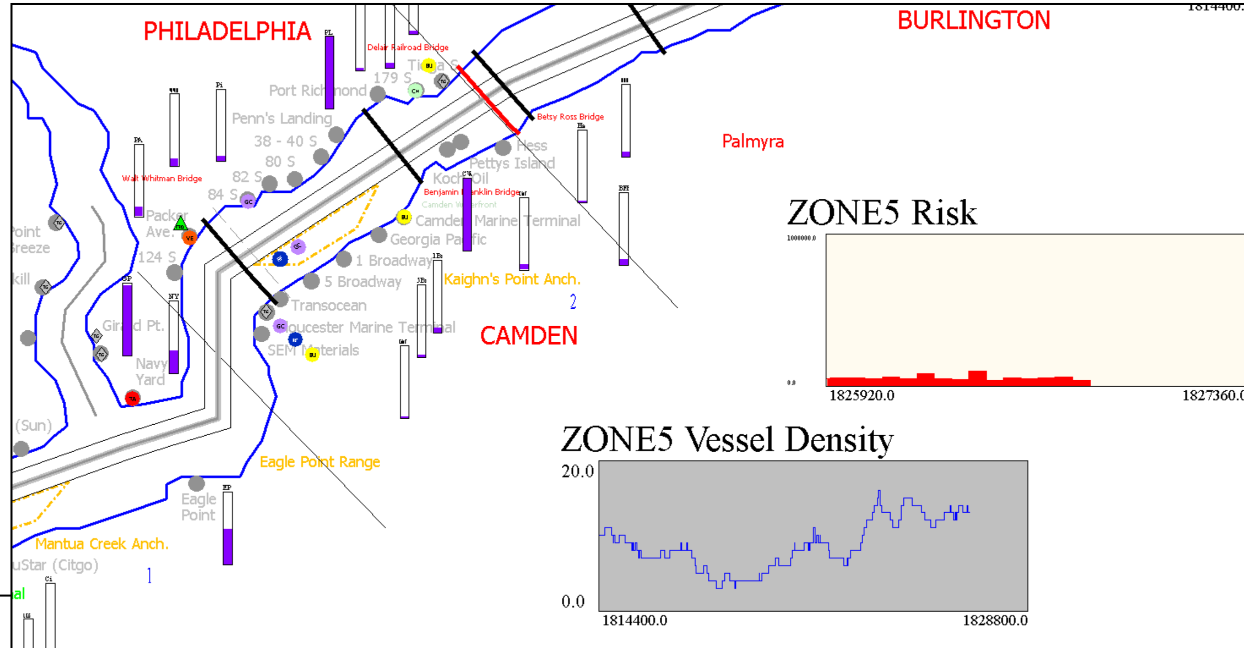
$$\Pr\left(C_{k,j} \middle| A_j, \underline{X}_k\right) = P_{k,j} . (\underline{\beta}_{k,j}{}^T \underline{X}_k) \quad \Rightarrow \quad P_{k,j} = \frac{\Pr\left(C_{k,j} \middle| A_j, \underline{X}_k\right)}{\underline{\beta}_{k,j}{}^T \underline{X}_k}$$

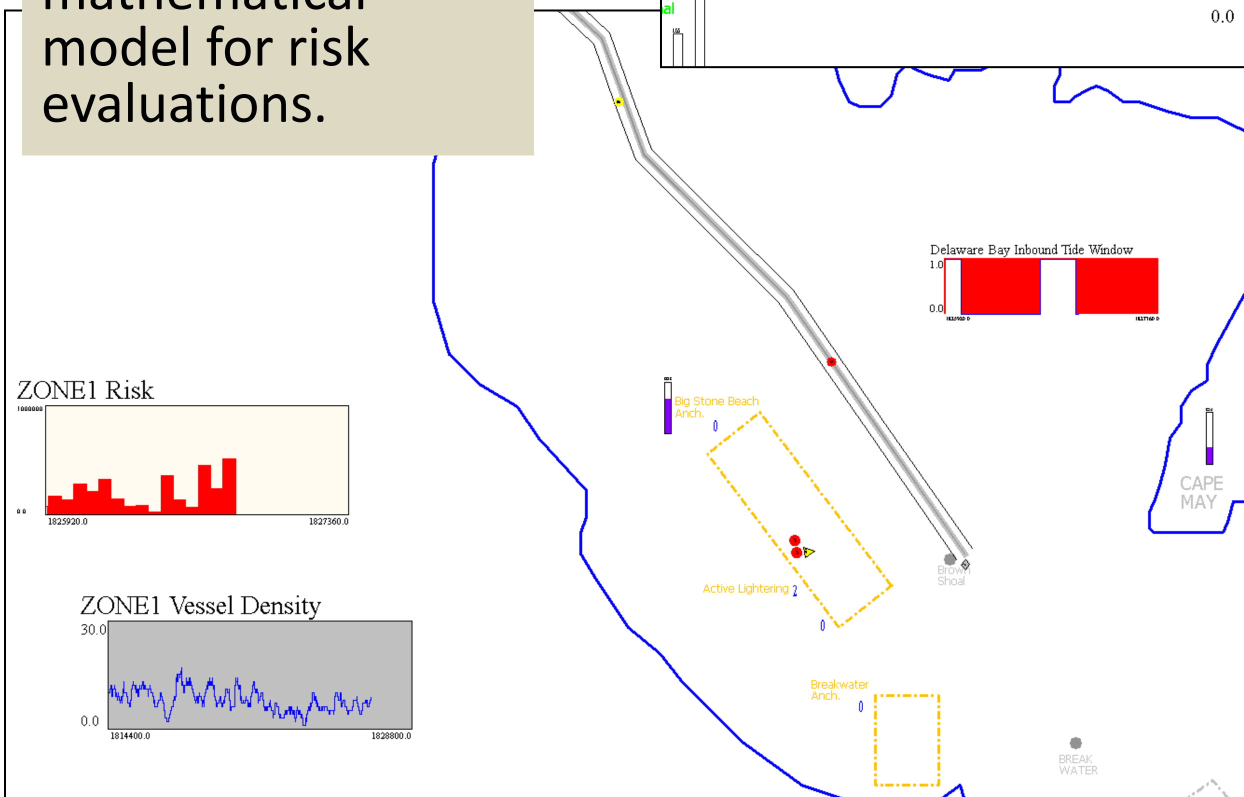
From historical data

From simulation

Risk Evaluations

The simulation model generates all possible situations and passes them on to the mathematical model for risk evaluations.





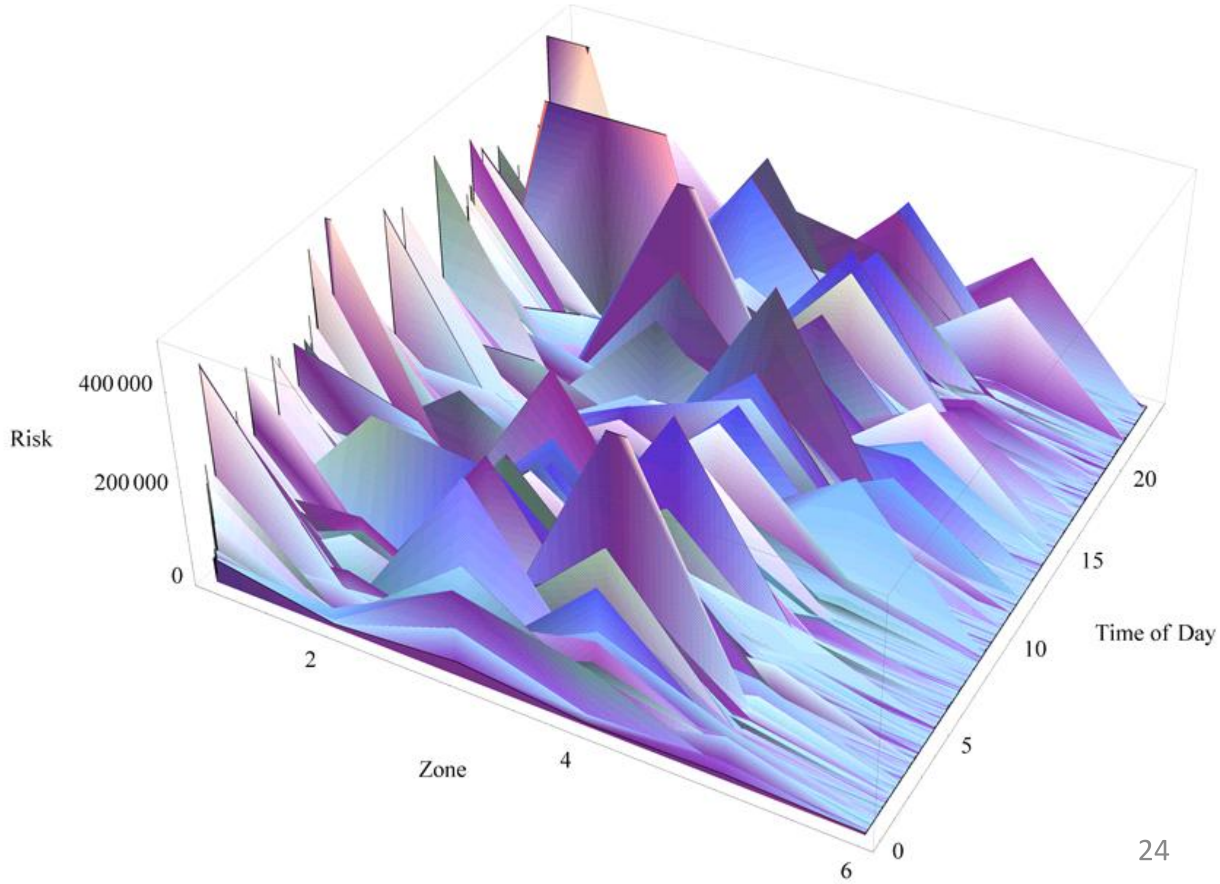
- This process is carried out at every short time interval (i.e., 60 minutes) at each zone to produce a temporal risk profile of the entire river.
- At every time step, using the situation attribute values, the risk model calculates probabilities of all types of accidents to occur given the situation at the time.
- The model uses these probabilities to calculate corresponding risks.

Instantaneous Risks

- Risks over a full year are mapped per 24-hour period to generate a risk profile for the entire river.

- Risks are calculated using one replication of the model over 30 years.

- Most of the higher risk values are observed in Zone 1 followed by Zone 4 as compared to other zones.

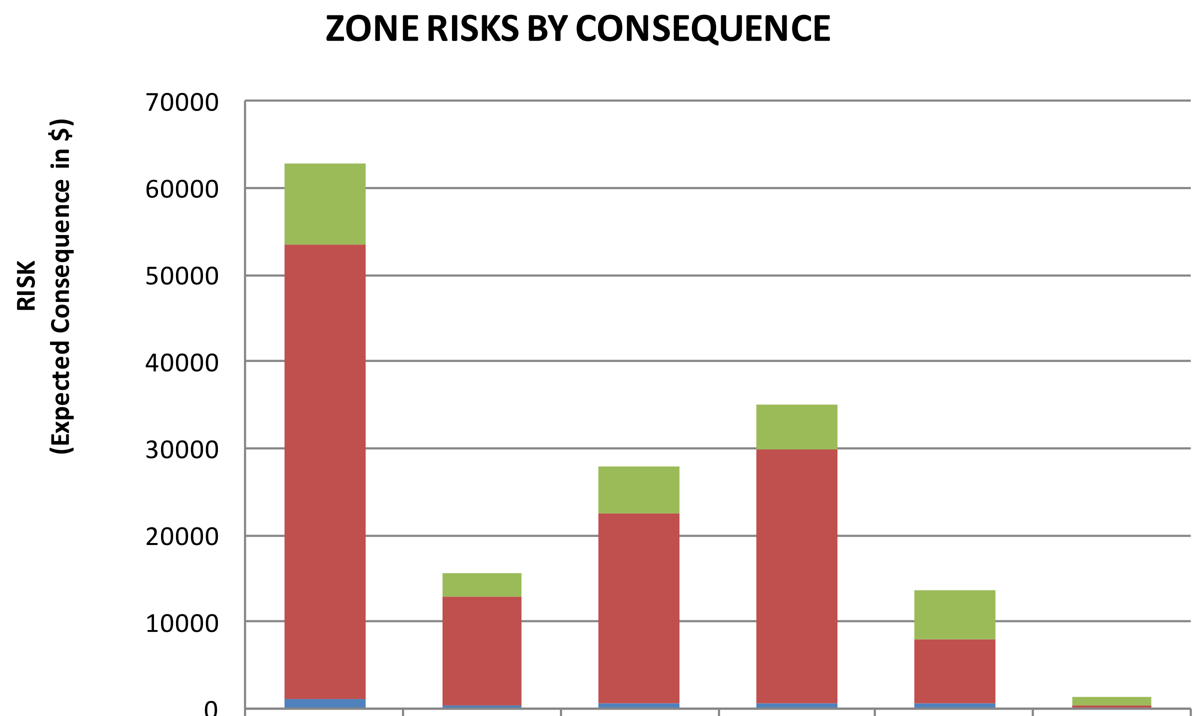


The Average Total Risks in Zones by Consequence Type

- Almost in all zones, environmental damage is the dominant consequence.

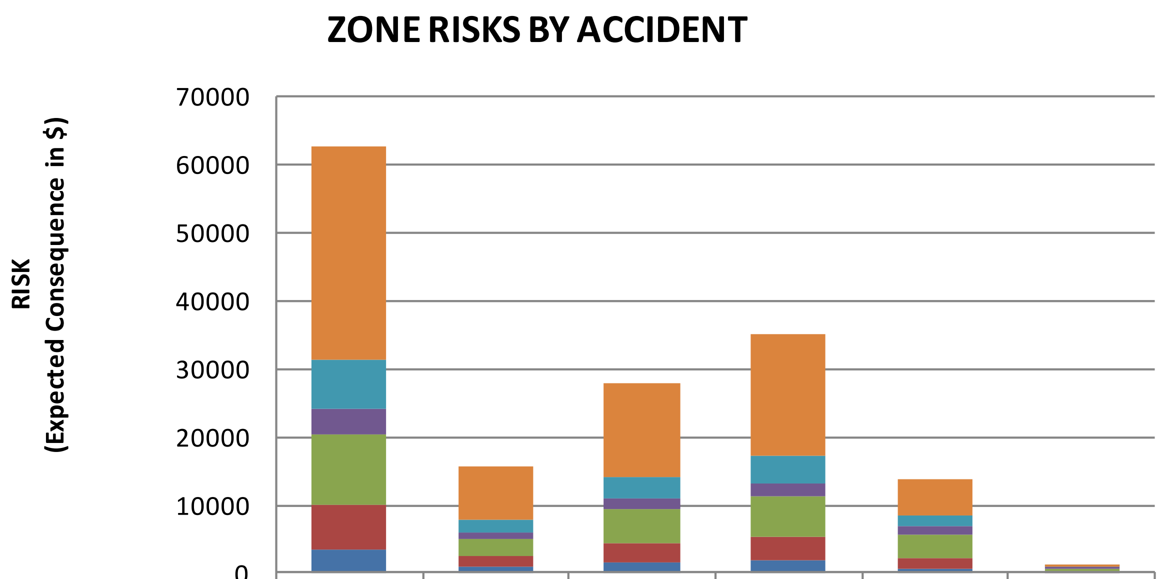
- In Zone 1, the risk of environmental damage is high due to the lightering activity in the Big Stone Beach Anchorage.

- Frequency of visits and length of stay for tankers in Zones 3 and 4 are higher than other zones due to higher number of oil terminals in these zones.



ZONE	1	2	3	4	5	6
Property Damage	9278.1	2592.3	5227.8	5152.1	5618.5	1022.5
Environmental Damage	52536	12671	22074	29324	7562.4	172.38
Human Casualty	955.62	264.75	498.74	483.49	501.85	91.241

The Average Total Risks in Zones by Accident Type

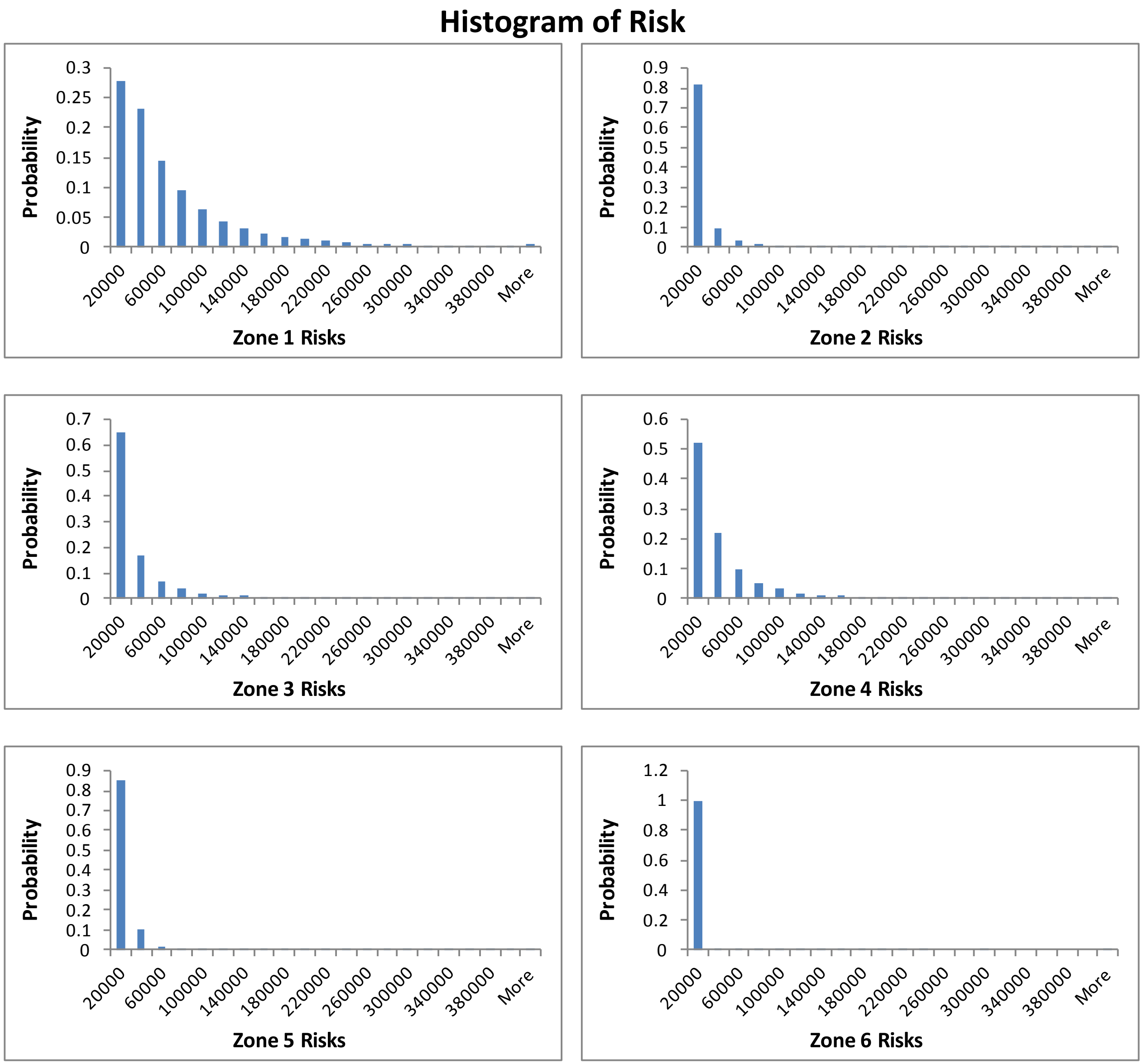


ZONE	1	2	3	4	5	6
Oil Spill	31405	7869.6	13670	17900	5213.2	237.15
Sinking / Capsizing / Flooding	7333.2	1777.9	3174.9	4035.2	1571.9	151.9
Fire / Explosion	3657	918.86	1688	1873.6	1267.7	195.86
Grounding	10319	2592.7	4940.6	5781.2	3489.1	489.76
Allision	6589.8	1566	2879.3	3556.5	1503.5	161.25
Collision	3465.8	803.48	1448.4	1813.2	637.08	50.219

ZONE

- Risks are classified based on accident types to provide accident-type impact on zone risks
- Average risks for <u>Zones 1, 3 and 4</u> are higher than the risks of other zones.
- <u>Oil Spill (OS)</u> and <u>Grounding (G)</u> seem to be the major accidents having the biggest impact on risk.

Distribution of Risks by Zones



- The histograms showing the risk for Zones 2, 5 and 6 exhibit low risk values
- Zones 1, 3 and 4 show heavy tails to the right indicating high risks observed in these zones.

Questions??

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INSTIGATORS

– Human Error (HE) may include “not following the policies or best practice”, “communication breakdown”, “inadequate situational awareness” and etc.

– Propulsion Failure (PF) may include “engine breakdown”, “contaminated fuel problem”, “propeller problem” and etc.

– Steering Failure (SF) may include “hydraulic system failure”, “rudder problem” and etc.

– Electrical / Electronic Failure (EF) may include “generator failure”, “computer software problems”, “navigation and communication system failure” and etc.

– Other Systems Failure (OSF) may include “hull structure problems”, “cargo and cargo control systems failure” and etc.

CONSEQUENCES

– Human Casualty (HC) may include death, permanent disabling injury, and minor injury.

– Environmental Damage (EnvD) may include impact to wild life and habitat, loss of commercial and recreational use, danger to human life and contamination of the water supply.

– Property Damage (ProD) may include damage to the vessel or other properties involved in the accident.