Maritime Simulation Model of San Francisco Bay

Notes on Risk Management

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July 17, 2002

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Water Transit Authority Project WTA #02-112 under Sub Contract to ABS Consulting

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ACKNOWLEDGEMENT

Special thanks to the Water Transit Authority for the opportunity to conduct this project, to Walt E. Hanson from ABS Consulting for Project Management and Data Collection Support, Stacey W. Shonk from the California Maritime Academy for providing his detailed knowledge about the Maritime Transportation System in the San Francisco Bay, his facilitation of meetings with local area users and data collection support. We are also indebted to Philip B. Harms, Jr. from the California Maritime Academy for his help in constructing a large scale nautical map of the San Francisco Bay Area, to the US Coast Guard Vessel Traffic Service San Francisco, in particular Lt. Black and Alan M. San, without whose extremely efficient data support we would not have been able to deliver in time. Finally, we would like to thank the San Francisco Bar Pilots for donating time and knowledge on vessel movements and visibility and the ferry operators Blue and Gold and Golden Gate Bridge for allowing us to ride ferries and providing access for discussions with ferry captains while underway.

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The problem of risk management deals with the issue what risk intervention measures to implement to further reduce risk. Typically, a group of risk intervention measures is proposed and each of these risk interventions measures needs to be ranked in terms of its effectiveness. To evaluate intervention measure effectiveness in terms of risk, risk needs be defined as a quantitative metric. Multiple definitions of output metrics are possible in such evaluation. For example, risk intervention measure effectiveness may be expressed in terms of a reduction of exposure, of incidents, of accidents or in terms of consequences. Risk intervention measures follow the same classification of 4 different categories, i.e. those that intend to reduce:

1. Exposure,
2. Incidents given exposure,
3. Accidents given an incident occurred,
4. Consequences given an accident occurred.

Figure 1 below exemplifies the above classification, displaying a causal sequence. Examples of risk intervention measures of each category in the maritime domain are given in Figure 1 as well. Note that risk intervention measures in general intend to block *causal pathways*. For example, implementation of redundant propulsion systems attempts to block the incident of a single propulsion failure from resulting in an accident. Categories 1 through 3 intervention measures may be classified as prevention measures whereas category 4 measures may be classified as mitigation measures.

Through the workshops of ABS Consulting a total of 97 different potential recommendations and best practices were identified. A complete list is provided in Appendix B. Appendix A contains the classification of these potential recommendations and best practices according to the above risk intervention categories. Some of these potential recommendations and best practices could be simultaneously classified over multiple risk intervention categories. Figure 2 displays the result of classifying each risk intervention measure according to the categories above. Category 2 risk interventions measures have been further broken down into those that intend to reduce human error (2b) and those that intend to reduce mechanical failure (2a). If in the analysis presented in Figure 2 a potential recommendation was assignable to two different risk intervention categories, it would be counted as two separate risk intervention measures. This explains a total of 111 risk intervention measures in Figure 2 compared to the original 97 developed by ABS Consulting. Although each description of the risk intervention measures was different, some similarity in their descriptions did occur. Note that most of the identified risk intervention measures intend to reduce human error. The second largest group of risk intervention measures falls in the category of reducing exposure. Only 9 out of the 111 different risk intervention measure focus on the reduction of mechanical failure, while a modest amount of 11 focuses on the reduction of consequences given the accident occurred. Finally, 13 risk intervention measures intend to reduce the number of accidents after the incident occurred.

Although none of the 111 risk-intervention measures have been formally tested for effectiveness, great strides have been made in developing the tools for testing their effectiveness. To test the effectiveness of risk intervention measures, assumptions will have to be made on the effect of a risk intervention measure on its operational quantity. For example, if one were to enhance maintenance policy and procedures one would have to assume a percentage reduction in e.g. propulsion failures after the implementation of the plan. This reduction of propulsion failures would have to be propagated through an overall risk assessment model to provide estimates in e.g. the reduction of expected number of accidents or reduction in number of expected fatalities. The maritime simulation model of the San Francisco Bay developed by the George Washington University combined with the knowledge acquired through the ABS workshops are a first step to allow for such evaluation of risk intervention effectiveness.

Figure 3 below summarizes the usefulness of the maritime simulation for testing risk intervention effectiveness by category and by output metric. The **0** indicates that the 33 risk interventions measures that intend to reduce exposure (see Figure 2) can currently be tested using the maritime simulation model in terms of the output metric "reduction of exposure". All that is needed is the operational plan for each of these risk intervention measure e.g. where would traffic separation be established in the San Francisco Bay and in its subsequent representation in the maritime simulation model.

If one were interested in the reduction in terms of the number of incidents, number of accidents or consequences of these 33 risk intervention measures additional modeling is required (as indicated by the **X** in Figure 3). Specifically, risk assessment models need to be developed that describe the incidence rates of incidents, accidents and consequences on a per interaction basis. Such models were developed in the Washington State Ferry Risk Assessment (see, Van Dorp et al. 2001).

The same models would have to be developed to test the risk intervention effectiveness of the remaining 76 risk intervention measures in the categories 2 through 4 while utilizing the maritime simulation model. Although, risk intervention measures of e.g. Category 4 do not intend to reduce exposure, incidents or accidents (indicated in Figure 3 by "N/A"), the incidence rate of specific types of interactions (=exposure) is an important factor in terms of their effectiveness evaluation. For example, emergency response measures that enhance the ability to respond to a mass casualty event in restricted visibility conditions in specific locations around the San Francisco Bay will only be effective if such restricted visibility interactions occur in that location. In addition, synergistic effects may occur when multiple risk interventions are implemented at the same time. For example, reducing the number of interactions in restricted visibility (through an exposure reducing intervention measure) will affect the effectiveness of the previously mentioned emergency response measure (a consequence reducing intervention measure). The maritime simulation model was developed to allow for such testing of a group of risk intervention measures simultaneously. Another consideration that should be taken into account when evaluating risk intervention effectiveness is the phenomenon of risk migration (as part of the unintended consequences of risk intervention implementation). Specifically, measures that focus on altering the exposure of ferries also alter the dynamic behavior of the traffic patterns around the bay. While a risk intervention measure may reduce exposure in a particular location (for example around the San Francisco City Front) by diverting traffic, exposure is increased elsewhere (to which the ferry traffic is diverted). The exposure reducing measure is only a risk reduction if the positive effects outweigh the negative effects (See, Merrick et al. 2000).

In sum, the question is not what specific risk intervention measure to implement but what set of risk interventions measures that minimize adverse synergistic effects and unintended consequences. The maritime simulation model of the George Washington University, combined with the knowledge acquired through the workshops of ABS consulting as well as the maritime expertise displayed by the California Maritime Academy, is well suited to answer this question. Prior maritime risk assessment studies conducted by the George Washington have resulted in a set of risk intervention measures that follows "a defense in depth" approach, i.e. a set of risk intervention measure that is distributed along the causal chain representing all four categories of risk intervention.

2. REFERENCES

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RISK INTERVENTIONS INTEND TO BLOCK CAUSAL PATHWAYS

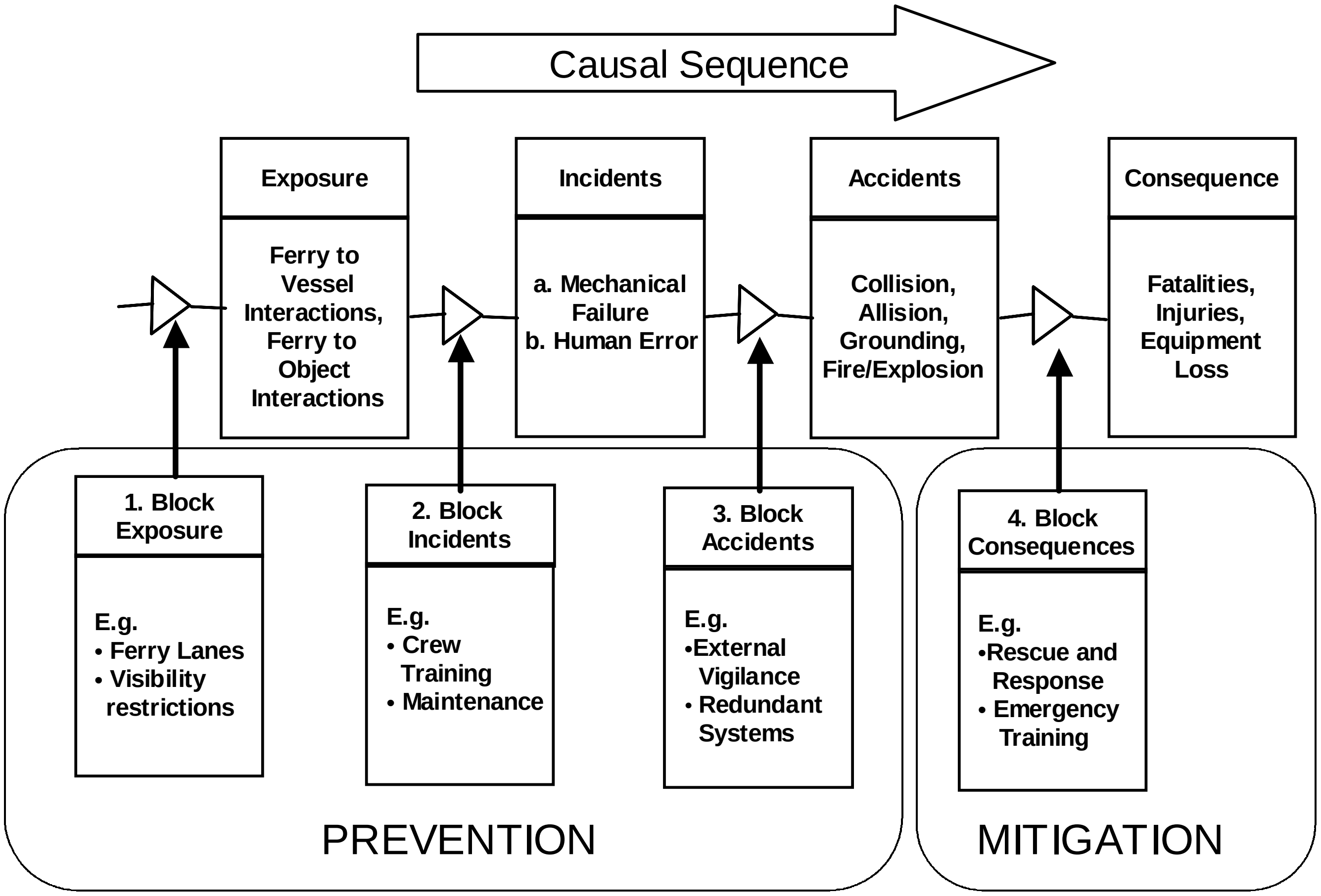

Figure 1. Categorization of Risk Intervention Measures

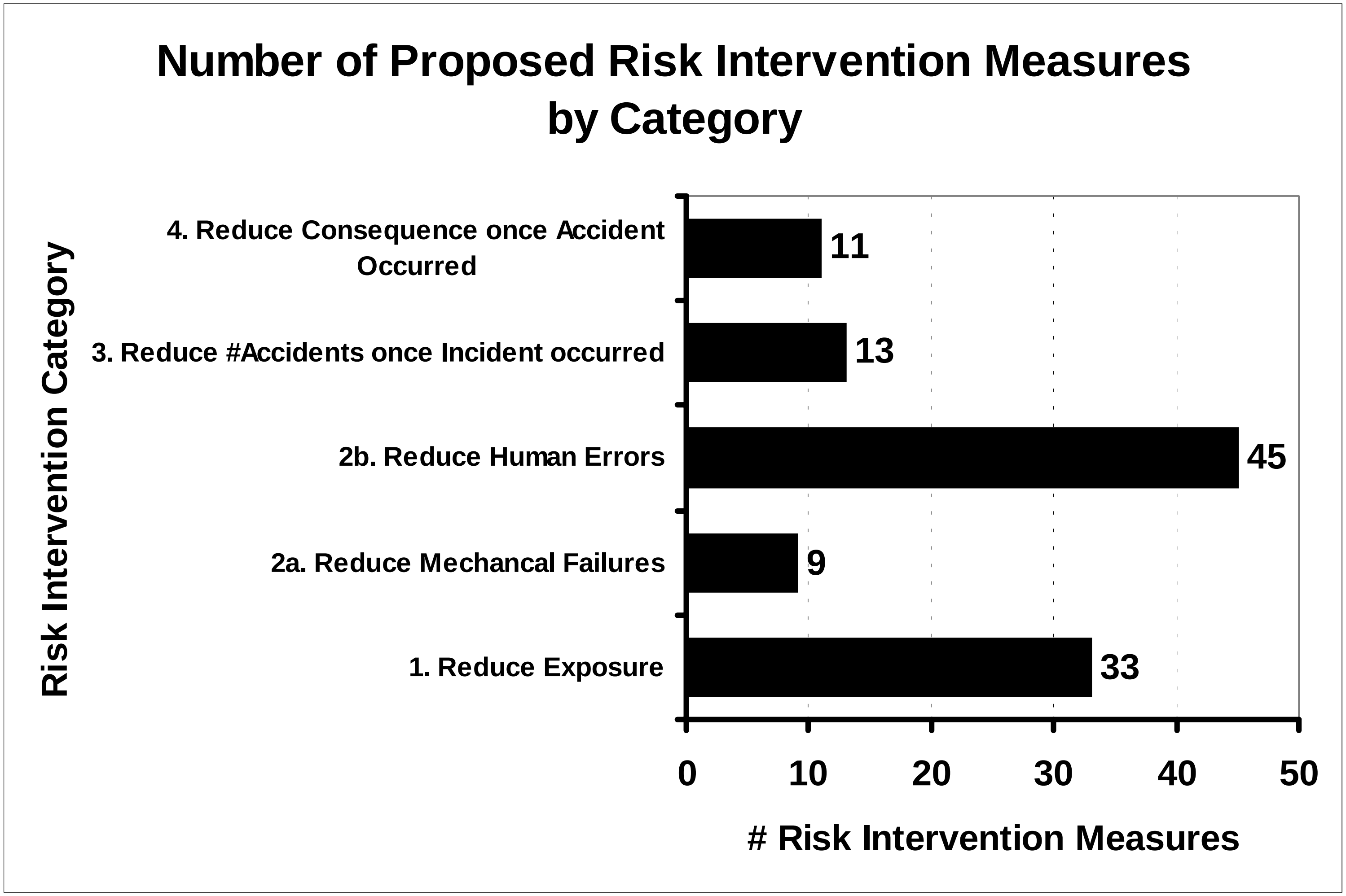

Figure 2. Categorization of Risk Intervention Measures identified during Workshops

Risk Intervention Category	Output Metric: Exposure per Year	Incidents per Year	Accidents per Year	Fatalities per Year
1. Reduce Exposure	0	X	X	X
2a. Reduce Mechancal Failures	N/A	X	X	X
2b. Reduce Human Errors	N/A	X	X	X
3. Reduce #Accidents once Incident occurred	N/A	N/A	X	X
4. Reduce Consequence once Accident Occurred	N/A	N/A	N/A	X

Figure 3. Capability of Maritime Simulation Model to Evaluate Risk Intervention Effectiveness

APPENDIX A. CLASSIFICATION OF RISK INTERVENTION MEASURES

No.	Table	Potential Risk Intervention Measure	Risk Intervention Category				
			1. Reduce Exposure	2a. Reduce Mechancal Failures	2b. Reduce Human Errors	3. Reduce Accidents once Incident occurred	4. Reduce Consequences once Accident Occurred
1	X	1			1		
2	X	2			1		
3	X	3			1		
4	X	4		1	1		
5	X	5			1		
6	X	6			1		
7	X	7					1
8	X	BP 1		1			
9	X	BP 2			1		
10	X	BP 3			1		
11	X	BP 4			1	1	
12	X	BP 5			1		
13	X	BP 6			1		
14	X	BP 7		1			
15	X	BP 8			1		
16	X	BP 9				1	
17	X	BP 10		1			
18	X	BP 11					1
19	X	BP 12		1	1	1	1
20	X	BP 13		1			
21	X	BP 14			1	1	1
22	X	BP 14a		1			
23	X	BP 14b	1		1		
24	X	BP 14c	1			1	
25	X	BP 14d					1
26	X	BP 14e					1
27	X	BP 14f					1
28	X	BP 14g					1
29	X	BP 14h		1			
30	X	BP 14i			1		
31	X	BP 14j					1

Figure 4. Part A: Classifying Risk Intervention Measures developed by ABS Consulting.

No.	Table	Potential Risk Intervention Measure	Risk Intervention Category: 1. Reduce Exposure	2a. Reduce Mechancal Failures	2b. Reduce Human Errors	3. Reduce Accidents once Incident occurred	4. Reduce Consequences once Accident Occurred
32	1	1	1				
33	1	2	1				
34	1	3	1				
35	1	4	1				
36	1	5	1				
37	1	6	1				
38	1	7	1				
39	1	8			1		
40	1	9			1		
41	2	1	1				
42	2	2	1				
43	2	3	1				
44	2	4	1				
45	2	5			1		
46	3	1			1	1	
47	3	2			1		
48	3	3			1		
49	3	4					
50	3	5			1		
51	3	6			1		
52	3	7			1		
53	3	8			1		
54	4	1	1		1		
55	4	2			1		
56	4	3	1				
57	4	4			1		
58	4	5	1				
59	4	6	1				
60	4	7	1		1	1	
61	4	8				1	
62	4	9				1	
63	4	10			1	1	
64	4	11			1		
65	4	12			1		
66	4	13				1	

Figure 5. Part B: Classifying Risk Intervention Measures developed by ABS Consulting.

No.	Table	Potential Risk Intervention Measure	Risk Intervention Category: 1. Reduce Exposure	2a. Reduce Mechancal Failures	2b. Reduce Human Errors	3. Reduce Accidents once Incident occurred	4. Reduce Consequences once Accident Occurred
67	5	1	1				
68	5	2	Not Assignable				
69	5	3			1		
70	5	4			1		
71	5	5		1			
72	5	6a	1				
73	5	6b	1				
74	5	7					
75	5	8a	1				
76	5	8b	1				
77	5	9	1				
78	5	10			1		
79	5	11	1				
80	5	12	1		1		
81	5	13a	1				
82	5	13b	1				
83	5	14a			1		
84	5	14b	1				
85	5	15			1		
86	6	1			1		
87	6	2	1		1		
88	6	3	1				
89	6	4a	1		1		
90	6	4b	1		1		
91	6	5			1		
92	6	6				1	
93	6	7					1
94	6	8			1	1	
95	6	9					1
96	7	1	Not Assignable				
97	7	2	Not Assignable				

Figure 6. Part C: Classifying Risk Intervention Measures developed by ABS Consulting.

APPENDIX B. LIST OF RISK INTERVENTIONS DEVELOPED BY ABS CONSULTING

The following table lists the recommendations and best practices identified by the preliminary risk analysis conducted with ferry operators.

Table X. A Listing of Recommendations and Best Practices and Respective Loss Sequences That Would Be Affected By Their Implementation

Recommendations (Rec) and Best Practices (BP)	Affected Loss Sequences (No. Loss Type - Phase of Operation - Area of Interest)
Rec 1. Consider having a licensed operator trained in engine restart procedures	1.1 Allision - Moor/unmoor - Vessel-related
Rec 2. Consider developing/expanding an outreach program to recreational boaters that addresses prudent actions when navigating near ferries	1.11 Collision - Maneuvering - Vessel-related 1.35 Grounding/stranding - Maneuvering - Vessel-related
Rec 3. Consider developing/expanding a vessel security plan that outlines plausible malicious acts and their countermeasures (both preventive and mitigative)	1.11 Collision - Maneuvering - Vessel-related 1.27 Flooding - Maneuvering - Vessel-related 1.28 Flooding - Maintenance/repair - Vessel-related 1.42 Explosion/fire-passenger area - Loading/unloading passengers - Vessel-related 1.43 Explosion/fire-passenger area - Maneuvering - Vessel-related 1.50 Explosion/fire-nonpassenger area - Loading/unloading passengers - Vessel-related 1.51 Explosion/fire-nonpassenger area - Maneuvering - Vessel-related 1.53 Explosion/fire-nonpassenger area - Fueling - Vessel-related 2.11 Toxic material - Maneuvering - Passenger-related 3.2 Soft tissue injury - Loading/unloading passengers - Crew-related 3.3 Soft tissue injury - Maneuvering - Crew-related 3.11 Toxic material - Maneuvering - Crew-related
Rec 4. Consider installing closed-circuit television cameras in unmanned engineering spaces with monitors on the bridge to provide additional data to the master that would be helpful for identifying problems (e.g., failing equipment and unauthorized entry)	1.27 Flooding - Maneuvering - Vessel-related 1.28 Flooding - Maintenance/repair - Vessel-related 1.51 Explosion/fire-nonpassenger area - Maneuvering - Vessel-related 3.11 Toxic material - Maneuvering - Crew-related
Rec 5. Consider ergonometrically designing vessel workspaces to facilitate maintenance and operational tasks. Provide ample clearances around equipment requiring routine preventive maintenance. Design control stations to minimize error-likely situations.	3.4 Soft tissue injury - Maintenance/repair - Crew-related 3.28 Temperature extremes - Maintenance/repair - Crew-related

Recommendations (Rec) and Best Practices (BP)	Affected Loss Sequences (No. Loss Type - Phase of Operation - Area of Interest)
Rec 6. Consider requiring crew and technicians to maintain physical standards. The standards could be similar to those required to attain USCG certification.	3.1 Soft tissue injury - Moor/unmoor - Crew-related 3.2 Soft tissue injury - Loading/unloading passengers - Crew-related 3.4 Soft tissue injury - Maintenance/repair - Crew-related 3.5 Soft tissue injury - Fueling - Crew-related 3.6 Soft tissue injury - Other support activity - Crew-related 3.7 Soft tissue injury - Emergency preparations - Crew-related 3.8 Soft tissue injury - Emergency response - Crew-related
Rec 7. Consider a passive restraint system that can be used by passengers in the case of rough sea conditions or when abrupt change in course or speed is anticipated	1.1 Allision - Moor/unmoor - Vessel-related 1.3 Allision - Maneuvering - Vessel-related 1.8 Allision - Emergency response - Vessel-related 1.11 Collision - Maneuvering - Vessel-related 1.16 Collision - Emergency response - Vessel-related 1.35 Grounding/stranding - Maneuvering - Vessel-related 1.40 Grounding/stranding - Emergency response - Vessel-related 2.3 Soft tissue injury - Maneuvering - Passenger-related 2.8 Soft tissue injury - Emergency response - Passenger-related
BP 1. Design and implement a preventive maintenance system that meets or exceeds manufacturer's service requirements	1.1 Allision - Moor/unmoor - Vessel-related 1.3 Allision - Maneuvering - Vessel-related 1.8 Allision - Emergency response - Vessel-related 1.9 Collision - Moor/unmoor - Vessel-related 1.11 Collision - Maneuvering - Vessel-related 1.16 Collision - Emergency response - Vessel-related 1.33 Grounding/stranding - Moor/unmoor - Vessel-related 1.35 Grounding/stranding - Maneuvering - Vessel-related 1.43 Explosion/fire-passenger area - Maneuvering - Vessel-related 1.49 Explosion/fire-nonpassenger area - Moor/unmoor - Vessel-related 1.51 Explosion/fire-nonpassenger area - Maneuvering - Vessel-related 1.53 Explosion/fire-nonpassenger area - Fueling - Vessel-related 2.1 Soft tissue injury - Moor/unmoor - Passenger-related 2.19 Electrical shock - Maneuvering - Passenger-related 2.22 Electrical shock - Other support activity - Passenger-related 3.1 Soft tissue injury - Moor/unmoor - Crew-related 3.17 Electrical shock - Moor/unmoor - Crew-related 3.18 Electrical shock - Loading/unloading passengers - Crew-related 3.19 Electrical shock - Maneuvering - Crew-related 3.21 Electrical shock - Fueling - Crew-related 3.22 Electrical shock - Other support activity - Crew-related

Recommendations (Rec) and Best Practices (BP)	Affected Loss Sequences (No. Loss Type - Phase of Operation - Area of Interest)
BP 2. Require a licensed master to complete an extended familiarization training program aboard the hull and route before being qualified as master-in-charge	1.1 Allision - Moor/unmoor - Vessel-related 1.3 Allision - Maneuvering - Vessel-related 1.8 Allision - Emergency response - Vessel-related 1.9 Collision - Moor/unmoor - Vessel-related 1.11 Collision - Maneuvering - Vessel-related 1.33 Grounding/stranding - Moor/unmoor - Vessel-related 1.35 Grounding/stranding - Maneuvering - Vessel-related
BP 3. Design the terminal to facilitate docking under both prevailing and seasonal environmental conditions	1.1 Allision - Moor/unmoor - Vessel-related 1.8 Allision - Emergency response - Vessel-related 1.9 Collision - Moor/unmoor - Vessel-related 1.33 Grounding/stranding - Moor/unmoor - Vessel-related
BP 4. When conditions make it difficult for the master-in-charge to effectively maintain situational awareness, assign another person to the bridge watch (i.e., another licensed master or a senior deckhand) to share the workload and serve as a safety double check	1.1 Allision - Moor/unmoor - Vessel-related 1.8 Allision - Emergency response - Vessel-related 1.9 Collision - Moor/unmoor - Vessel-related 1.11 Collision - Maneuvering - Vessel-related 1.16 Collision - Emergency response - Vessel-related 1.35 Grounding/stranding - Maneuvering - Vessel-related 1.40 Grounding/stranding - Emergency response - Vessel-related
BP 5. Design and install gangway systems (1) that help steady the ferry and hold it firmly to its dock, (2) that can be adjusted to accommodate changing environmental forces, and (3) that can be manipulated by crew having different physical abilities	1.2 Allision - Loading/unloading passengers - Vessel-related 2.2 Soft tissue injury - Loading/unloading passengers - Passenger-related 3.2 Soft tissue injury - Loading/unloading passengers - Crew-related
BP 6. Install, operate, and maintain technology (e.g., portable pilot units, and/or automatic identification system tracking and display) to facilitate communication of intent and to audit conformance with navigational protocols	1.11 Collision - Maneuvering - Vessel-related
BP 7. Install, operate, and maintain a backup radar and separate power supplies for radars	1.11 Collision - Maneuvering - Vessel-related
BP 8. Train/certify all bridge watchstanders in radar operation	1.11 Collision - Maneuvering - Vessel-related
BP 9. Periodically survey the water depth in vicinity of a terminal to identify shoaling, and set and maintain private markers to identify shoal water	1.33 Grounding/stranding - Moor/unmoor - Vessel-related 1.35 Grounding/stranding - Maneuvering - Vessel-related

Recommendations (Rec) and Best Practices (BP)	Affected Loss Sequences (No. Loss Type - Phase of Operation - Area of Interest)
BP 10. Conduct periodic electrical safety inspections and daily check of ground faults. Install a bridge alarm/indicator that alerts the licensed master of the location of electrical shorts	1.43 Explosion/fire-passenger area - Maneuvering - Vessel-related 1.46 Explosion/fire-passenger area - Other support activity - Vessel-related 1.51 Explosion/fire-nonpassenger area - Maneuvering - Vessel-related 2.19 Electrical shock - Maneuvering - Passenger-related 2.22 Electrical shock - Other support activity - Passenger-related 3.17 Electrical shock - Moor/unmoor - Crew-related 3.18 Electrical shock - Loading/unloading passengers - Crew-related 3.19 Electrical shock - Maneuvering - Crew-related 3.21 Electrical shock - Fueling - Crew-related 3.22 Electrical shock - Other support activity - Crew-related 3.24 Electrical shock - Emergency response - Crew-related
BP 11. Install and maintain a fixed fire suppression system that has sufficient capacity to flood the engineroom twice with CO2 or equivalent fire suppression agent	1.51 Explosion/fire-nonpassenger area - Maneuvering - Vessel-related 1.52 Explosion/fire-nonpassenger area - Maintenance/repair - Vessel-related 1.53 Explosion/fire-nonpassenger area - Fueling - Vessel-related
BP 12. Eliminate or minimize hazardous materials used in maintenance and repair	3.12 Toxic material - Maintenance/repair - Crew-related
BP 13. Use a closed gauging system for checking fuel levels	3.13 Toxic material - Fueling - Crew-related

Recommendations (Rec) and Best Practices (BP)	Affected Loss Sequences (No. Loss Type - Phase of Operation - Area of Interest)
BP 14. Develop company policy and standard procedures for emergency, and adverse weather and normal operating conditions. Implement and enforce procedures through training and company communications. Audit conformance. Provide job aids for critical procedures	1.3 Allision - Maneuvering - Vessel-related 1.11 Collision - Maneuvering - Vessel-related 1.16 Collision - Emergency response - Vessel-related 1.35 Grounding/stranding - Maneuvering - Vessel-related 1.40 Grounding/stranding - Emergency response - Vessel-related 1.49 Explosion/fire-nonpassenger area - Moor/unmoor - Vessel-related 1.51 Explosion/fire-nonpassenger area - Maneuvering - Vessel-related 1.52 Explosion/fire-nonpassenger area - Maintenance/repair - Vessel-related 1.56 Explosion/fire-nonpassenger area - Emergency response - Vessel-related 2.8 Soft tissue injury - Emergency response - Passenger-related 2.16 Toxic material - Emergency response - Passenger-related 2.24 Electrical shock - Emergency response - Passenger-related 2.32 Temperature extremes - Emergency response - Passenger-related 2.65 Medical distress - Maneuvering - Passenger-related 3.1 Soft tissue injury - Moor/unmoor - Crew-related 3.2 Soft tissue injury - Loading/unloading passengers - Crew-related 3.4 Soft tissue injury - Maintenance/repair - Crew-related 3.5 Soft tissue injury - Fueling - Crew-related 3.6 Soft tissue injury - Other support activity - Crew-related 3.8 Soft tissue injury - Emergency response - Crew-related 3.16 Toxic material - Emergency response - Crew-related 3.20 Electrical shock - Maintenance/repair - Crew-related 3.64 Falling overboard - Emergency response - Crew-related 3.65 Medical distress - Maneuvering - Crew-related
BP 14a. Develop, communicate, and enforce standard operating procedures for ferry startup and shutdown	1.49 Explosion/fire-nonpassenger area - Moor/unmoor - Vessel-related
BP 14b. Develop, communicate, and enforce navigational protocols for routes	1.11 Collision - Maneuvering - Vessel-related
BP 14c. Identify areas/conditions in which meeting, crossing, or overtaking may significantly increase the risk of collision and develop/enforce a " no passing" policy for those areas	1.3 Allision - Maneuvering - Vessel-related 1.11 Collision - Maneuvering - Vessel-related 1.35 Grounding/stranding - Maneuvering - Vessel-related
BP 14d. Develop and exercise vessel mutual assistance plans	2.8 Soft tissue injury - Emergency response - Passenger-related 2.16 Toxic material - Emergency response - Passenger-related 2.24 Electrical shock - Emergency response - Passenger-related 2.32 Temperature extremes - Emergency response - Passenger-related 3.16 Toxic material - Emergency response - Crew-related

Recommendations (Rec) and Best Practices (BP)	Affected Loss Sequences (No. Loss Type - Phase of Operation - Area of Interest)
BP 14e. Develop and exercise emergency response protocols to facilitate communication and ferry traffic control during emergencies	1.16 Collision - Emergency response - Vessel-related 1.40 Grounding/stranding - Emergency response - Vessel-related
BP 14f. Determine with emergency care providers (e.g., ambulance services) locations along a route at which the ferry can transfer people in medical distress	2.65 Medical distress - Maneuvering - Passenger-related 3.65 Medical distress - Maneuvering - Crew-related
BP 14g. Develop, communicate, and enforce a hot work permit program	1.52 Explosion/fire-nonpassenger area - Maintenance/repair - Vessel-related
BP 14h. Develop, communicate, and enforce lock-out/tag-out program	3.20 Electrical shock - Maintenance/repair - Crew-related
BP 14i. Develop, communicate, and enforce a safe lifting program for deckhands	3.1 Soft tissue injury - Moor/unmoor - Crew-related 3.2 Soft tissue injury - Loading/unloading passengers - Crew-related 3.4 Soft tissue injury - Maintenance/repair - Crew-related 3.5 Soft tissue injury - Fueling - Crew-related 3.6 Soft tissue injury - Other support activity - Crew-related 3.8 Soft tissue injury - Emergency response - Crew-related
BP 14j. Develop and enforce standards for emergency training. Establish a frequency for emergency drills that meets or exceeds USCG requirements. Establish criteria for measuring drill performance. Require all shifts and all crew on each shift to participate. Document training.	1.16 Collision - Emergency response - Vessel-related 1.32 Flooding - Emergency response - Vessel-related 1.40 Grounding/stranding - Emergency response - Vessel-related 1.48 Explosion/fire-passenger area - Emergency response - Vessel-related 1.56 Explosion/fire-nonpassenger area - Emergency response - Vessel-related 2.64 Falling overboard - Emergency response - Passenger-related 2.65 Medical distress - Maneuvering - Passenger-related 3.8 Soft tissue injury - Emergency response - Crew-related 3.64 Falling overboard - Emergency response - Crew-related

1. Should Traffic Lanes Be Established?

The assessment identified contributing factors and estimated the cumulative impact on risk of collision for interactions between ferries that are operating at high-speed, and for interactions between ferries and other San Francisco Bay area users: commercial traffic that is actively monitored by the USCG VTS, recreational boaters, and commercial fishermen. The assessment concluded that risks were significant for interactions (1) between ferries, and (2) between ferries and recreational boaters.

<u>A system of ferry lanes should be established</u>. Table 1 outlines recommendations for building a system of ferry lanes. This system could provide added controls to better manage the risk of collisions between ferries and may improve the safety of navigation in the vicinity of recreational boaters. The strengths of the proposed system appear to outweigh its perceived weaknesses.

Table 1. Recommendations for Building a System of Ferry Lanes

Recommendations
1. Consider defining specific lanes for ferries travelling to and from their origins
2. Consider having lanes from different origins join to form common transit routes to major destinations
3. Consider locating routes to minimize interactions with recreational boaters a. Consider having the ferry lanes parallel traditional commercial routes b. Consider having the ferry lanes use the center divider area between shipping lanes
4. Consider making the separation between the "to" and "from" lanes sufficient enough so that nonconformance with lane usage can be recognized by other vessel traffic
5. Consider making lane usage a universal requirement for all commuter ferries regardless of their operating speed. Commuter ferries include ferries serving airports, recreational destinations (i.e., Golden Gate National Recreational Area runs)
6. Consider making lanes not an exclusive right-of-way for ferries. Ferries will be required to comply with the Rules of the Road. Where ferries may be restricted in maneuverability, other vessels that are not constrained are required by the Rules of the Road to give way
7. Consider establishing lanes under WTA jurisdiction. Conditions for a ferry concession would require the operator to obey the ferry lanes and deviate only when *Rules of the Road* would dictate that such action would be prudent to avoid a collision
8. Consider uniquely identifying ferries operating at high speed a. Consider using a special warning (i.e., visual and/or audible) for ferries. Flashing yellow lights have been mounted on ferries to alert other vessels b. Consider designing of high-speed ferries such that their profile provides other vessels with a clear understanding of which way the ferry is headed
9. Consider an outreach program for recreational boaters that shows where ferry hazards exist a. Consider posting warning signs about ferry lanes at marinas that are near these lanes b. Consider posting warning signs in waterways where ferries are restricted in their ability to maneuver and near approaches to ferry terminals

2. Should There Be Positive Versus Passive Control of Ferry Traffic?

Additional services beyond what are afforded by the USCG VTS should be considered for expanded high-speed ferry service. The high-level risk assessment suggests that WTA consider a system of moderate positive control, in which a central control point gives each ferry permission to proceed to a berth, get underway, enter a specific route, and cross key waypoints. This "flow control" system seems tolerant of ferry traffic flow deviations caused by environmental conditions and ferry interactions with other vessels. Also it appears adequate to reduce congestion at headways. Table 2 lists recommendations that could improve predictability and reduce congestion.

Table 2. Recommendations for Added Controls to Improve Predictability and Reduce Congestion

Recommendations
1. Consider establishing a system of ferry lanes
2. Consider designating flow relief areas
3. Consider further study of flow control as a risk mitigation strategy for headway congestion
4. Consider coordinating schedules of ferry operator to minimize interactions between ferries along ferry lanes and at headways for major destination terminals
5. Consider assigning ferries route designators, similar to an airline flight numbers that would identify the intent of each ferry (e.g., ETD/origin and ETA/destination). The route designator should be visually displayed on the sides and bow of the ferry as well as used in voice radio communications regarding ferries

3. Will the Increase in Traffic Saturate Communications?

Without changing typical communication strategies used during interactions between ferries and interactions between ferries and other commercial vessels, the relay of critical navigation data via voice radio could be impacted. This is not solely because of ferry service expansion, rather because vessel traffic, in general, is expected to increase in the Bay Area. Table 3 summarizes recommendations that participants generated during the analysis.

Table 3. Recommendations for Improving the Communication of Data Critical to Safe Navigation

Recommendations
1. Consider studying how other VTS, which have greater traffic flows, package critical vessel/navigation data for messages
2. Consider other ways to manage communications a. Consider having different types of vessels checking-in on specific channels b. Consider broadcasting the general shipping picture on another voice radio frequency
3. Consider requesting the Federal government study the level of radio voice communications (e.g., channels 12, 13, and 14) to quantitatively determine current use and extrapolate the possibility of saturation
4. Consider studing the impact ferry lane location may affect communications
5. Consider installing AIS tracking and display systems on high-speed ferries to reduce the need for voice radio exchanges to obtain critical data on other vessels required to have AIS
6. Consider studying how the AIS tracking and display system will be used by the ferry master to ensure that the man-machine interface does not create error-likely situations
7. Consider studying how ferries and recreational boaters can better communicate a. Consider including study findings in outreach programs to recreational boaters b. Consider posting ways to communication with ferries on the ferry lane warnings at/near marinas
8. Consider assigning route designators to ferries. Route designators would be similar to airline flight numbers in that they would be linked to a scheduled departure/arrival time and location a. Consider having route designators displayed on ferries so that they are visible at a distance during day and night b. Consider an outreach program to other Bay users to describe the route designators and where they can be located. Include route designators on ferry lane warnings posted at/near marinas

4. Are Traffic Controls Needed for Unusual Weather?

The expanded high-speed ferry service should consider augmenting or enhancing existing risk controls during adverse weather conditions. The assessment did not determine whether existing risk controls would be adequate when high-speed ferry service is expanded; however, risk of collision is expected to increase during high-wind events, and significantly increase in reduced visibility. Interactions between ferries and recreational boaters are expected to have the greatest change in risk caused by adverse weather conditions. Table 4 summarizes recommended risk control options to augment or enhance existing risk controls.

Table 4. Recommended Risk Control Options to Augment/Enhance Existing Risk Controls, Which Mitigate Adverse Weather Effects on Safe Navigation

Recommendations
Waterway Risk Management Strategy
1. Consider having integrated surveillance capabilities (i.e., AIS and radar) at VTS and any centers exerting positive control over ferries 2. Consider ways to facilitate relay of information between VTS and ferries a. Consider generating special reports to suit the needs of the ferry system b. Designating a radio frequency on which the ferry system and VTS can communicate 3. Consider technology that can help VTS detect and forecast foggy conditions
Public Outreach-based Risk Management Strategy
4. Consider expanding information to Bay Area users about ferry concerns during adverse weather
Ferry System-based Risk Management Strategy
5. Consider establishing ferry lanes during adverse weather 6. Consider using a system of positive control during adverse weather 7. Consider strategies that help all ferry masters to manage their risks better during adverse weather a. Consider designing ferry schedules that have time built in for weather delays b. Consider actively monitoring compliance with company policies c. Consider issuing weather alerts that direct implementation of risk controls 8. Consider capabilities that can identify and track deadheads a. Consider marking deadheads with floats that are visible at day and night b. Consider operating a drift model, which could use Physical Oceanographic Real-time Systems (PORTS™) or other inputs, to forecast where to look for reported deadheads

Table 4. Recommended Risk Control Options to Augment/Enhance Existing Risk Controls, Which Mitigate Adverse Weather Effects on Safe Navigation (cont'd)

Recommendations
Shipboard Risk Management Strategy
9. Consider expanded use of infrared technology to aid detection of objects 10. Consider expanded use of an additional operator on the bridge and having that person qualified to perform master duties 11. Consider using AIS tracking and display system. Consider integrating this system with the ferry's radar and ECDIS 12. Consider hands-free communication sets for ferry masters 13. Consider vessel designs that reduce high-wind effects during low-speed operation

5. What Is the Impact on Localized Safety around Major Headway Terminals?

Expanded ferry service can increase the risk of collision, grounding, and/or allision in headways around major terminals. Although not having representation from key stakeholders made the assessment of specific risk concerns and risk controls less certain, the participants were confident that the following strategies could mitigate the impact on safe navigation in headways caused by expanded ferry service.

- Elimination of hazardous conditions in (1) waterways within the boundary of headways, (2) terminal design, and (3) ferry design

- Application of a risk-based, top-down, systems approach for managing vessel interactions

The assessment did not determine which risk control option or combination of options would be practical for each major terminal. However the Ferry Building, which has several high-risk issues, should benefit if all options were implemented. For other major terminals, headways will have to be defined and the risk impacts determined before evaluating options and developing a practical risk management system. Table 5 summarizes the recommended risk control options generated by this assessment.

Table 5. Recommended Risk Control Options that Could Mitigate the Impact on Safe Navigation in Major Headways Caused by Expanded Ferry Service

Recommendations
Strategies to eliminate hazardous conditions
1. Consider developing and implementing a dredging plan that provides adequate navigable water for ferry approaches and turning basins at major terminals 2. Consider assessing and managing the risk of other fixed and floating obstructions (e.g., physical hazards to the ferry and line-of-sight obstructions) in the headway 3. Consider designing berths to facilitate, as much as practical, arrivals and departures during both prevailing and adverse weather conditions. Also consider designing adequate mitigative safeguards (e.g., fendering systems and spacing of berths) 4. Consider performing a human reliability analysis of navigation tasks and implement changes as necessary 5. Consider requiring and operating redundant propulsion and steering systems in headways. Also consider assessing the need for and implementing as appropriate other equipment reliability programs
Applications of a risk-based, top-down, systems approach for managing vessel interactions
6. Consider designing schedules as a system of ferry routes that ➢ Reduce the number of interactions between ferries while in transit and in major headways ➢ Provide masters/headway controllers the ability to slow down ferries in transit so they do not worsen conditions at a highly congested headway 7. Consider making berths, services, and contact points at major destination terminals common for all users. The intent is to create greater flexibility and speed in arranging berth changes. This recommendation could affect how the terminal is operated, managed, and designed.

Table 5. Recommended Risk Control Options that Could Mitigate the Impact on Safe Navigation in Major Headways Caused by Expanded Ferry Service (cont'd)

Recommendations
Applications of a risk-based, top-down, systems approach for managing vessel interactions (cont'd)
8. Consider assessing the risk of collision between ferries, which are transiting to/from nearby terminals, and ferries that are arriving/departing a specific major terminal. If the risk of collision is unacceptable, consider implementing one or both of the following options. a. *Option 1*- Consider establishing headway boundaries that encompasses the approaches to all of those terminals b. *Option 2* - Consider establishing a flow control system over all ferries in the headway. For headways that extend around multiple terminals and have a flow control system, consider making the headway control point responsible for submitting to the VTS the sail plan for ferries that are exiting the headway 9. Consider having the masters contact a centralized terminal organization for an optimal berth assignment. For headways that have a flow control system, the controller could assign berths 10. Consider having ferry masters develop guidance for approaches under varying weather conditions for the ferry routes serving a terminal. Also consider enforcing the use of these best practices by other terminal users 11. Consider assessing the risk of collision between ferries proceeding to/from major terminals. If risk of collision is unacceptable, consider implementing a flow control system a. Consider having a headway controller direct terminal users when to begin their approach to/from a berth. The controller could monitor and report the traffic situation within the headway as it relates to a terminal user. Permission to proceed to/from a berth would indicate that the situation is safe to navigate. 12. Consider developing additional protocols that are adhered to by all terminal users regarding safe navigation to and from the terminal (e.g., restricting other terminal users from crossing the path of a ferry on final approach to a berth) 13. Consider requesting major headways that have many interactions between ferries and other VMRS users designated by the USCG as a VTS Special Area. Also consider pursuing through the Habor Safety Committee, added safety protocols for the VTS Special Area. a. *Option 1*. Consider establishing limits of approach to major headways. This requires federal rulemaking. b. *Option 2*. Consider requiring VMRS users to (1) report when they enter major headways and (2) establish passing arrangements with ferries proceeding to/from the major terminal. This requires the issuance of a local USCG Captain of the Port Order.

Table 5. Recommended Risk Control Options that Could Mitigate the Impact on Safe Navigation in Major Headways Caused by Expanded Ferry Service (cont'd)

Recommendations
Applications of a risk-based, top-down, systems approach for managing vessel interactions (cont'd)
14. Consider outreach programs at nearby marinas for recreational boaters a. Consider posting warnings at marinas that are near a headway. Indicate that ferry traffic will be arriving/departing frequently b. Consider marking areas of high conflict between ferries and recreational boaters with buoys or fixed aids warning boaters to remain clear 15. Consider outreach programs through fishing associations and the USCG commercial fishing vessel safety program

6. What Is the Risk Impact relative to High-speed Ferry Operations?

When ferry service is expanded, safety of high-speed transit could be affected by more vessel interactions, ramifications from headway congestion, adverse weather, and communication problems, and work conditions that create error-likely situations. The assessment primarily recommended a ferry system-wide risk management strategy and shipboard-based risk management strategy to maintain the safety of high-speed ferry operations in San Francisco Bay. Table 6 summarizes the recommended risk control options generated by this assessment.

Table 6. Recommended Risk Control Options to Mitigate Risks relative to More Ferries Transiting at High Speed

Recommendations
Waterway Risk Management Strategy
1. Consider, as a minimum, having the ferry company relay information to VTS regarding potential backups forming in the ferry routes and at headways
Ferry System-based Risk Management Strategy
2. Consider strengthening management systems that promote prudent seamanship a. Consider designing ferry schedules to include time for likely weather-induced delays b. Continue to communicate and enforce company policy that supports risk-based decisions, which are consistent with the *Rules of the Road* and prudent seamanship c. Consider routinely recognizing safe navigation decisions of ferry masters 3. Consider establishing a system of ferry lanes, which includes assigning route identifiers for ferries, and specifying flow relief areas to mitigate traffic congestion a. Consider developing/enforcing route-specific navigation protocols b. Consider a shoreside AIS tracking and display system to monitor conformance with navigation protocols 4. Consider implementing a system that regulates the flow of ferry traffic through the ferry lanes during adverse weather conditions. Also consider studying the effectiveness of a Bay-wide flow control system to relieve ferry traffic congestion at major terminals. Such a control system might be implemented in several ways. a. *Option 1* - The WTA Bay-wide system could be totally separate from the VTS. This option requires employing shifts of experienced mariners as controllers and could require added investment in communications technology. To facilitate information exchange, a cooperative arrangement between WTA and VTS is recommended whereby WTA controllers would provide the initial report for ferries entering the VTS area. VTS may desire that WTA controller-derived reports are transmitted electronically to minimize voice communication and relay time b. *Option 2* - The WTA Bay-wide system shares resources with the VTS. This option requires employing shifts of experienced mariners as controllers and could require a shared investment in processing technology. The option may afford WTA controllers more monitoring capabilities
Shipboard Risk Management Strategy

5. Consider automation, displays, and layouts that reduce error-likely situations. Consider having human factors engineers and masters of high-speed commuter ferries participate in the design review of new ferries
   a. Consider installing AIS tracking and display systems that are integrated with ECDIS and/or radar displays in the ferry bridge. 33 CFR Parts 161 and 164.43 will require AIS on all domestic passenger vessels carrying 50 or more passengers for hire. The capability to track and display AIS information is not required for passenger vessels
   b. Consider state-of-the-industry communications technology (e.g., hands-free communication) on the ferry bridge
   c. Consider installing radios and speakers and bridge wings of ferries. (Recommendation specifically made by USCG VTS)
   d. Consider using electronic aids (e.g., GPS, ECDIS, or APRA) to alert ferry masters to turns. (Recommendation specifically made by USCG VTS)

6. Consider vessel designs that reduce the likelihood of topside damage during high-speed transits in typical sea states generated by winter high-wind events

7. Consider a passive restraint system (e.g., seatbelts, additional handholds, and airline seating) that can be used by passengers

Table 6. Recommended Risk Control Options to Mitigate Risks relative to More Ferries Transiting at High Speed (cont'd)

Recommendations
Shipboard Risk Management Strategy (cont'd)
8. Consider assigning another person to the bridge watch (i.e., another licensed master or a senior deckhand) to share the workload and serve as a safety double check when conditions make it difficult for the master-in-charge to effectively maintain situational awareness. The Final Report of the Passenger Vessel Association/ USCG High-speed Vessel Natural Working Group dated February 1, 2002 describes a process for determining when a second watchstander should be assigned based on the following factors: visibility, time of operations, vessel complexity, route complexity, special weather conditions or sea state, and corporate/crew experience 9. Consider making the San Francisco Bay Voluntary Mutual Assistance Program (V-MAP) mandatory for all ferries operated for WTA (Recommendation specifically made by USCG VTS)

7. *Should Compliance with the IMO Safety Code for High-speed Craft Be Mandatory?*

Compliance with the HSC Safety Code is prudent and beneficial. The HSC Safety Code is a higher standard of safety than 46 CFR Subchapter K. Applying an existing higher safety standard should increase confidence in the operational safety of individual high-speed ferries, lower their insurance premiums, and may improve resale opportunities at the end of their service life. If costs prohibit meeting all HSC Safety Code requirements, the new ferries should be built to be ready to comply with HSC Safety Code. By taking the recommended actions in Table 7, WTA may be able to obtain useful cost information for deciding whether full compliance is feasible.

Table 7. Recommended Next Steps for Deciding the Appropriate Level of Compliance with the HSC Safety Code

Recommendations
1. Consider requesting shipyards provide separate quotes for construction costs that comply with (1) the HSC Safety Code, and (2) 46 CFR Subchapter K 2. Consider requesting shipyards and ferry operators identify - a. Which parts of the HSC Safety Code they consider impractical, ineffective, or too costly for managing the risks b. What alternative methods they consider can provide equivalent risk control in place of the controversial requirements