Collision of Tankship *Eagle Otome* with Cargo Vessel *Gull Arrow* and Subsequent Collision with the *Dixie Vengeance* Tow
Sabine-Neches Canal, Port Arthur, Texas
January 23, 2010

Accident Report

NTSB/MAR-11/04
PB2011-916404

National Transportation Safety Board

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Notation 8205A
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Marine Accident Report

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National
Transportation
Safety Board

490 L'Enfant Plaza, SW
Washington, DC 20594

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Abstract: This report discusses the January 23, 2010, collision of the tankship *Eagle Otome* with the general cargo vessel *Gull Arrow* and the subsequent collision of tank barge *Kirby 30406*, pushed by towboat *Dixie Vengeance*, with the *Eagle Otome*. The accident occurred in the Sabine-Neches Canal in Port Arthur, Texas. The damages that resulted from this accident were $1.5 million to the *Eagle Otome*, $35,000 to the barge, and $381,000 to the *Gull Arrow*. No crewmember on board the three vessels was injured. As a result of the accident, an estimated 462,000 gallons of oil spilled into the water, and about 136 Port Arthur residents were temporarily evacuated from the area near the accident scene. Safety issues identified in this accident were pilot oversight, mariner fatigue, waterway safety, and bridge control ergonomics. As a result of the investigation, safety recommendations are issued to the U.S. Coast Guard, the Jefferson and Orange County Board of Pilot Commissioners, the Sabine Pilots Association, the American Pilots' Association, and governors of states and territories in which state and local pilots operate.

The National Transportation Safety Board is an independent Federal agency dedicated to promoting aviation, railroad, highway, marine, pipeline, and hazardous materials safety. Established in 1967, the agency is mandated by Congress through the Independent Safety Board Act of 1974 to investigate transportation accidents, determine the probable causes of the accidents, issue safety recommendations, study transportation safety issues, and evaluate the safety effectiveness of government agencies involved in transportation. The National Transportation Safety Board makes public its actions and decisions through accident reports, safety studies, special investigation reports, safety recommendations, and statistical reviews.

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Acronyms and Abbreviations

AIS	automatic identification system
APA	American Pilots' Association
API	American Petroleum Institute
CEMS	crew endurance management system
CFR	*Code of Federal Regulations*
CPAP	continuous positive airway pressure
FAA	Federal Aviation Administration
FOSC	Federal on-scene coordinator
FRMS	fatigue risk management system
IMO	International Maritime Organization
LOSC	local on-scene coordinator
MPA	Marine Preservation Association
MSU	Coast Guard Marine Safety Unit
MWT	maintenance of wakefulness testing
NOAA	National Oceanic and Atmospheric Administration
NTSB	National Transportation Safety Board
NVIC	Navigation and Inspection Circular
OSA	obstructive sleep apnea
PAWSA	ports and waterways safety assessment
PAWSS	ports and waterways safety system
S-VDR	simplified voyage data recorder
SETWAC	Southeast Texas Waterways Advisory Council
SOLAS	International Convention for the Safety of Life at Sea

SOSC	state on-scene coordinator
STAN	Southeast Texas Alerting Network
STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers
VDR	voyage data recorder
VHF	very high frequency
VTS	vessel traffic service

Executive Summary

On Saturday, January 23, 2010, about 0935 central standard time, the 810-foot-long oil tankship *Eagle Otome* collided with the 597-foot-long general cargo vessel *Gull Arrow* at the Port of Port Arthur, Texas. A 297-foot-long barge, the *Kirby 30406*, which was being pushed by the towboat *Dixie Vengeance*, subsequently collided with the *Eagle Otome*. The tankship was inbound in the Sabine-Neches Canal with a load of crude oil en route to an ExxonMobil facility in Beaumont, Texas. Two pilots were on board, as called for by local waterway protocol. When the *Eagle Otome* approached the Port of Port Arthur, it experienced several unintended heading diversions culminating in the *Eagle Otome* striking the *Gull Arrow*, which was berthed at the port unloading cargo.

A short distance upriver from the collision site, the *Dixie Vengeance* was outbound with two barges. The towboat master saw the *Eagle Otome* move toward his side of the canal, and he put his engines full astern but could not avoid the subsequent collision. The *Kirby 30406*, which was the forward barge pushed by the *Dixie Vengeance*, collided with the *Eagle Otome* and breached the tankship's starboard ballast tank and the No. 1 center cargo tank a few feet above the waterline. As a result of the breach, 862,344 gallons of oil were released from the cargo tank, and an estimated 462,000 gallons of that amount spilled into the water. The three vessels remained together in the center of the canal while pollution response procedures were initiated. No crewmember on board any of the three vessels was injured.

The National Transportation Safety Board (NTSB) determines that the probable cause of the collision of tankship *Eagle Otome* with cargo vessel *Gull Arrow* and the subsequent collision with the *Dixie Vengeance* tow was the failure of the first pilot, who had navigational control of the *Eagle Otome*, to correct the sheering motions that began as a result of the late initiation of a turn at a mild bend in the waterway. Contributing to the accident was the first pilot's fatigue, caused by his untreated obstructive sleep apnea and his work schedule, which did not permit adequate sleep; his distraction from conducting a radio call, which the second pilot should have conducted in accordance with guidelines; and the lack of effective bridge resource management by both pilots. Also contributing was the lack of oversight by the Jefferson and Orange County Board of Pilot Commissioners.

Safety issues identified in this accident include pilot oversight, mariner fatigue, waterway safety, and bridge control ergonomics. As a result of this accident investigation, the NTSB makes new recommendations to the U.S. Coast Guard, the Jefferson and Orange County Board of Pilot Commissioners, the Sabine Pilots Association, the American Pilots' Association, and governors of states and territories in which state and local pilots operate. The NTSB also reiterates a recommendation and reclassifies a recommendation to the U.S. Coast Guard.

1. Factual Information

Vessels:	Singapore-registered oil tankship *Eagle Otome*, official No. 386067, International Maritime Organization (IMO) No. 9051351, 810 feet long, 138 feet wide, 53,504 gross international tons, steel construction, built in 1994. Total cargo carrying capacity: 693,903 barrels (29,143,926 gallons). Bahamas-registered general cargo vessel *Gull Arrow*, official No. 720410, IMO No. 7930137, 597 feet long, 95 feet wide, 25,846 gross international tons, steel construction, built in 1982. U.S.-registered towboat *Dixie Vengeance*, official No. 506543, 74 feet long, 24 feet wide, 143 gross registered tons, built in 1966. U.S.-registered tank barge *Kirby 30406*, 297 feet long, 54 feet wide, 1,619 gross tons, built in 1993. Total cargo carrying capacity: 30,500 barrels (1,281,000 gallons). U.S.-registered tank barge *Kirby 28112*, 300 feet long, 54 feet wide, 1,632 deadweight tons, built in 2009. Total cargo carrying capacity: 28,323 barrels (1,189,566 gallons).
Accident Type:	Collision
Location:	Sabine-Neches Canal, Port of Port Arthur, Texas, latitude 29°51.6′ N, longitude 93°56.4′ W
Date:	January 23, 2010
Time:	0935 central standard time[1]
Owners:	*Eagle Otome*: AET Inc. Ltd. *Gull Arrow*: Gearbulk Shipowning Ltd. *Dixie Vengeance* and barges: Kirby Inland Marine, LLC
Property Damage:	*Eagle Otome*, $1.5 million *Gull Arrow*, $381,000 *Kirby 30406* barge, $35,000 *Dixie Vengeance*, none
Environmental Pollution:	An estimated 11,000 barrels, or about 462,000 gallons, of Olmeca crude oil released into the Sabine-Neches Canal
Injuries:	None
Complement:	*Eagle Otome*, 22 *Gull Arrow*, 29 *Kirby 30406*, none *Dixie Vengeance*, 4

[1] Unless otherwise noted, all times in this report are central standard time (universal coordinated time –6 hours) and are based on the 24-hour clock.

1.1 Accident Narrative

On January 18, 2010, the 810-foot-long tankship T/V *Eagle Otome* (figure 1) departed the Petroleos Mexicanos terminal in Pajaritos, Mexico. The Singapore-registered vessel, owned and operated by AET Inc. Ltd. (AET),[2] was carrying 576,864 barrels (24,228,288 gallons) of Olmeca crude oil[3] en route to a Sun Oil terminal in Nederland, Texas. The load constituted about 83 percent of the *Eagle Otome*'s total cargo carrying capacity.

Figure 1. *Eagle Otome*. Photo by Iain McGeachy.

Two days later, on January 20, after completing the transit north through the Gulf of Mexico, the *Eagle Otome* arrived at 2318 at the Sabine Fairway anchorage off the coast of Texas and remained anchored there for the next 3 nights. The *Eagle Otome* was originally scheduled to arrive at the Sun Oil terminal on January 25; however, on the evening of January 22, the master was notified that the ExxonMobil facility in Beaumont, just north of Nederland, would receive the tankship the next day.

[2] At the time of the accident, AET Inc. Ltd. owned and operated 69 petroleum tank vessels. The company had offices in Houston, London, Singapore, Kuala Lumpur, and Gurgaon, India.

[3] Olmeca crude oil is a light sour crude oil produced near the Bay of Campeche in the southern Gulf of Mexico. For more information, see section "1.9.4 Olmeca Crude Oil."

About 0515 on the morning of January 23, the vessel weighed anchor and at 0524, a pilot from the Sabine Pilots Association ("the first pilot") boarded the tankship for the transit to Beaumont by way of the Sabine-Neches Waterway (figure 2). On the bridge of the *Eagle Otome* were the first pilot, the master, a mate, and a helmsman. The first pilot took the conn[4] from the tankship's master and began the approach from sea toward the entrance to the Sabine-Neches Waterway. (For more information, see section "1.10 Waterway Information.") At 0533, the first pilot radioed the Sabine Pilots Association that the vessel was inbound. At 0536, he radioed vessel traffic service (VTS)[5] and informed the watchstander that he was on board the *Eagle Otome* headed for Beaumont. He ordered the tankship's speed to full ahead. The *Eagle Otome* proceeded at about 8 knots as the first pilot issued helm orders to line the tankship up for its northbound course into the fairway channel. According to the *Eagle Otome*'s voyage plan, the transit from the sea buoy (20 miles offshore) to the ExxonMobil berth at Beaumont was about 57 miles.

Figure 2. Aerial image of the region. The Sabine-Neches Waterway is marked by a yellow line. Background by Google.

[4] To have the conn is to direct the steering and propulsion of a vessel. A conning pilot has navigational control of the vessel.

[5] VTS is operated by the U.S. Coast Guard and provides active monitoring and navigational advice for vessels in especially confined and busy waterways. For more information, see section "1.11 VTS Port Arthur" in this report.

Because the *Eagle Otome*'s beam[6] was wider than 120 feet, local waterway guidelines called for two pilots to serve on the vessel through the Sabine-Neches Waterway (see section "1.15 SETWAC Protocol and Sabine Pilots Association Guidelines"). About 0750, a second Sabine pilot ("the second pilot") boarded the *Eagle Otome* as the tankship entered Sabine Pass. About 0800, after a short exchange with the first pilot, the second pilot took the conn of the *Eagle Otome*. The first pilot, still on duty, remained on the bridge to assist the second pilot.

All Sabine pilots, as standard practice, rotate the conn and associated navigational duties during the two-pilot transit through the Sabine-Neches Waterway. At 0904, when the *Eagle Otome* was about 4 miles south of Port Arthur, the two pilots switched the conn again. The first pilot who had boarded the tankship at the Sabine Fairway anchorage now again had navigational control. The *Eagle Otome* was now about 1 mile south of an area commonly referred to as the Texas Island Intersection.[7] At this location, inbound traffic needs to make about a 38-degree turn to starboard. Also at the Texas Island Intersection, the *Eagle Otome* would enter a section of the waterway called the Sabine-Neches Canal, which continued for about the next 12 miles (figure 3).[8] At 0910:32, the first pilot ordered "starboard twenty" to initiate the turn. Between 0911 and 0913, he brought the *Eagle Otome* through the Texas Island Intersection at about 8 knots without incident.

[6] Beam is the width of a ship.

[7] Texas Island, a narrow peninsula jutting out into the waterway, is also sometimes referred to as Texaco Island. The name "Texas Island" originated in the early 20th century and is frequently used today; however, the Coast Guard teaches its personnel to refer to the location as "Texaco Island" because the *Coast Pilot* does so. Navigational charts of the area do not refer to the location by any name.

[8] The Sabine-Neches Canal is 400 to 450 feet wide.

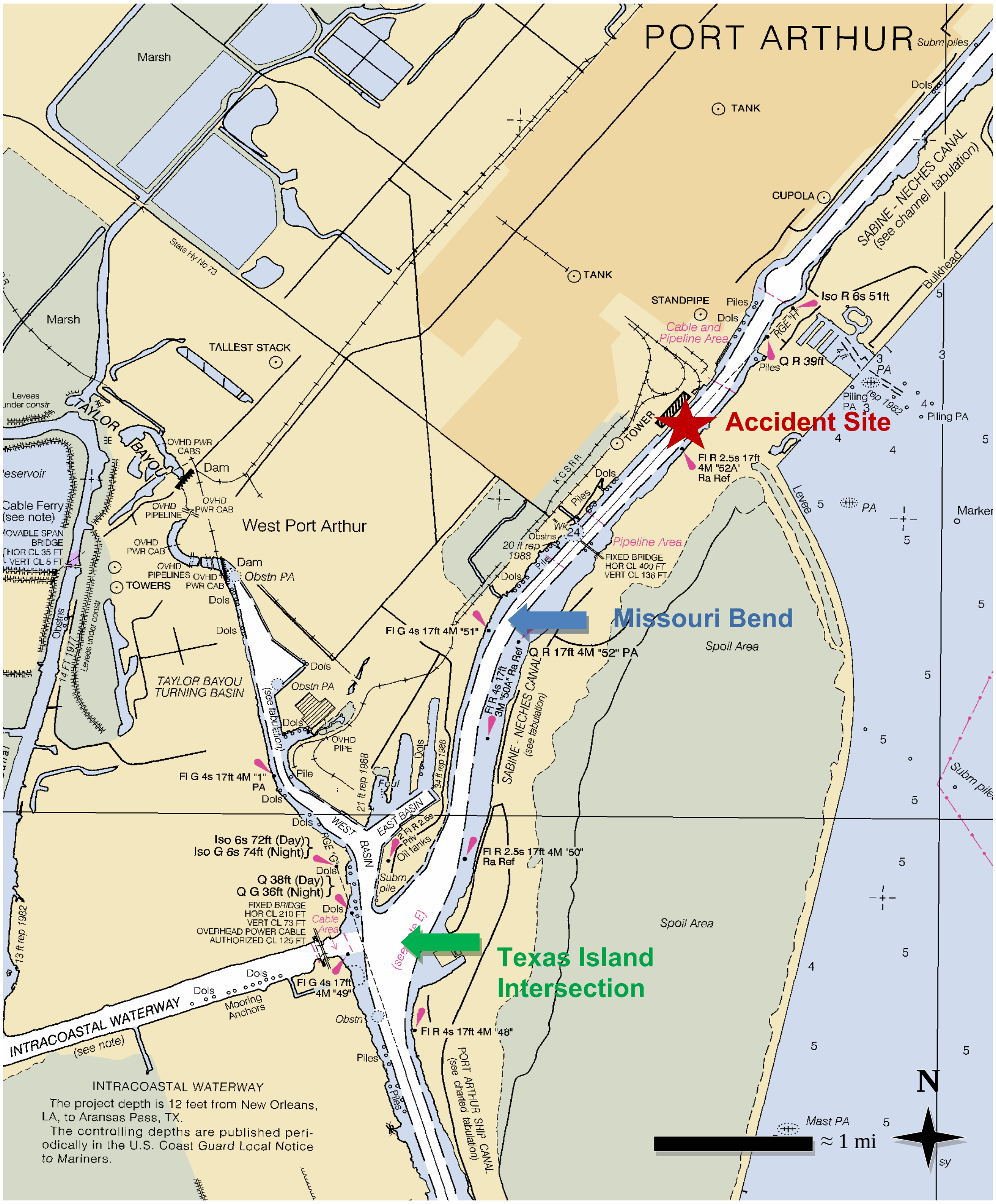

Figure 3. Section of National Oceanic and Atmospheric Administration (NOAA) chart 11342, with the Sabine-Neches Canal running north and northeast. The Texas Island Intersection is marked with a green arrow, Missouri Bend with a blue arrow, and the accident location with a red star.

At 0915, the first pilot placed a security call[9] on very high frequency (VHF) radio channel 13[10] announcing that he was on board the first of two inbound tankships near the

[9] A security call is an informational message of a safety nature that is broadcast so that anyone in the vicinity who is monitoring the channel may hear it.

Texas Island Intersection and inquiring about any outbound traffic in the vicinity of the Gulfgate Bridge[11] in Port Arthur (figure 4). He did not mention the *Eagle Otome* by name (see section "2.10 Use of Vessel Name in Radio Communication").

Figure 4. Dr. Martin Luther King, Jr. Memorial Bridge (formerly named Gulfgate Bridge) in Port Arthur, viewed looking north from on board a tankship similar to the *Eagle Otome*. The Port of Port Arthur can be seen on the left, past the bridge. Photo by the Sabine Pilots Association.

The security call was answered by the master on the towboat *Dixie Vengeance* (figure 5), which was outbound in the Sabine-Neches Canal about 3 miles north of the bridge, pushing two barges with aromatic concentrate.[12] The towboat master identified his vessel by name. The two pilots on the *Eagle Otome* were conversing with each other when the towboat master answered

[10] VHF channel 13 is used for intervessel communication (bridge-to-bridge) for navigation safety purposes. Vessels greater than 65 feet long maintain a listening watch on this channel in U.S. waters.

[11] The first pilot referred to the bridge by its former name, Gulfgate Bridge. The bridge was renamed Dr. Martin Luther King, Jr. Memorial Bridge in 1985. Navigational charts of the area mark the location of the bridge but do not refer to it by any name.

[12] Aromatic concentrate is a feedstock for petrochemical manufacturing. It is a colorless flammable liquid with a flash point of about 10 degrees F. Aromatic concentrate is a mixture of heavy catalytic reformed naphtha, benzene, toluene, and xylene.

the call, and the tankship's simplified voyage data recorder (S-VDR)[13] did not record a response from either pilot. No further radio contact took place at that time. About 20 minutes remained until the *Eagle Otome* and the *Dixie Vengeance* were to meet and transit past each other in the canal.

Figure 5. *Dixie Vengeance* on the Sabine-Neches Canal.

At 0923, the *Eagle Otome* approached another significant turn in the canal, locally referred to as Missouri Bend, where inbound traffic needs to make about a 32-degree turn to starboard. At that point, the master on the *Dixie Vengeance* announced on VHF channel 13 that his towboat was "outbound at the schoolhouse,[14] two loads." The first pilot acknowledged the

[13] VDRs maintain continuous, sequential records of data relating to a ship's equipment and its command and control, and capture bridge audio from certain areas in the wheelhouse and on the bridge wings. Under regulation 20 of the International Convention for the Safety of Life at Sea (SOLAS) Chapter V, all passenger ships and all cargo ships of 3,000 gross tons or more built on or after July 1, 2002, are required to carry VDRs. The *Eagle Otome* was equipped with an S-VDR, which is not required to capture all of the parameters of a standard VDR but is permissible under a July 2006 amendment to SOLAS that applies to vessels built before July 1, 2002.

[14] Local marine traffic and VTS use the term "schoolhouse" to refer to a building located on the west bank of the waterway, about 2 miles north of the bridge. The building is identified by a "cupola" marking on navigation chart 11342.

call-out, mentioning the towboat by name, and engaged in a radio exchange with the towboat master that lasted about 45 seconds. The first pilot informed the towboat master that the tankship was about three-quarters of a mile south of the bridge and was the first of two inbound tankships. The towboat master informed the first pilot that the *Dixie Vengeance* was proceeding at a speed of about 7.9 knots, and the first pilot informed him that the *Eagle Otome* would be slowing down for a ship berthed at the Port of Port Arthur.[15] The two men agreed that the *Eagle Otome* and the *Dixie Vengeance* would meet each other portside-to-portside. The towboat master told the first pilot, "If I need to speed up or slow down to make it easy on both of us, let me know." The *Dixie Vengeance* master later told investigators that he could see the *Eagle Otome* from his location upriver near the schoolhouse when the tankship was near Missouri Bend. The two vessels were about 2.6 miles from each other at that point.

The last rudder order that the first pilot had given to the helmsman before the radio exchange with the *Dixie Vengeance* master was "midship," or zero rudder angle, at 0922:37. When the first pilot ended the conversation with the towboat master, the *Eagle Otome* was near Missouri Bend but had not yet begun the turn to starboard. At 0923:54, which was 1 minute 17 seconds after the midship order, the first pilot ordered "hard to starboard"[16] to initiate the turn. (Postaccident analysis of the tankship's S-VDR data revealed that bank effect[17] had already begun turning the bow to starboard by the time the first pilot's rudder order took effect.) At 0924:11, he eased the starboard turn by ordering "starboard twenty," and at 0924:17, he ordered the speed reduced from half ahead to slow ahead. At 0924:40, he eased the turn further by ordering "starboard ten." He then adjusted the turn by ordering "starboard twenty" at 0924:55. Nine seconds later, at 0925:04, he ordered "midship."

At this point, the first pilot had brought the *Eagle Otome* through Missouri Bend and was attempting to line up the tankship for the passage underneath the bridge, which was located about half a mile north of Missouri Bend. However, despite the midship rudder order, the *Eagle Otome* continued turning to starboard toward the east bank of the canal. At 0925:08, the first pilot then ordered hard to port to counter the starboard turn. When the tankship was close to the east bank, the ship straightened but then started to sheer[18] to port. As a result, the *Eagle Otome* did not steady up in the center of the canal to transit underneath the bridge but instead began crossing the canal toward the west side, approaching the bridge's west foundation. As the *Eagle Otome* sheered to port across the canal, the first pilot ordered hard to starboard rudder and full ahead on the engine to facilitate a correction toward the center of the canal.[19] At 0928:13, he asked the

[15] The *Eagle Otome* needed to slow down so that the hydrodynamic effects of passing would not pull the other ship from its berth.

[16] A "hard" rudder command usually means 35 degrees of rudder angle.

[17] Bank effect is a hydrodynamic effect caused by water pressure between the ship's bow and the near bank. The water pressure creates a cushion, which can force the bow to deflect away from the bank, back toward the center of the waterway. For more information, see section "1.2 Hydrodynamic Forces."

[18] Sheer is a hydrodynamic phenomenon that involves sudden change in the direction of a ship's head and temporary loss of steering control. It can have various causes, such as uneven depths in shallow water or bank effect. For more information, see section "1.2 Hydrodynamic Forces."

[19] A temporary order of full ahead is often used in maneuvering situations to increase water flow across the rudder. The increased flow enhances the turning effect of the rudder.

second pilot, "Is she gonna come back?" Six seconds later, the second pilot responded, "Might." About 1 minute later, after six additional rudder and engine orders, the *Eagle Otome* passed underneath the bridge, close to the west bank, on slow ahead at about 6 knots. The time was 0929.

The 597-foot-long general cargo vessel *Gull Arrow* (figure 6) was berthed at the Port of Port Arthur on the west side of the canal beyond the Dr. Martin Luther King, Jr. Memorial Bridge. Crewmembers and longshoremen were in the process of unloading the vessel's cargo.

Figure 6. *Gull Arrow*, docked portside to an unknown berth. The vessel is shown here in about the same orientation as it was on the day of the accident.

Just before the *Eagle Otome* passed underneath the bridge, the first pilot ordered hard port rudder. He later told investigators that he did this because he expected that, as the *Eagle Otome* neared the west bank of the canal, bank effect would cause the tankship to sheer to starboard and cross the canal toward the east bank. As the *Eagle Otome* passed underneath the bridge with the rudder hard to port, the second pilot and the master briefly conversed about the local area newspapers that the pilots, as a courtesy, had brought on board with them. The first pilot asked the master to place a crewmember on the bow in case they would need to use the anchor, to which the master responded that a crewmember had been on the bow all along.

As the first pilot expected, the *Eagle Otome* began sheering to starboard once its port bow came close to the west bank of the canal. At 0931:26, the first pilot ordered the engine from slow ahead to half ahead. The S-VDR then recorded the second pilot saying, “Take care of the ship. Don’t worry about that one at the dock.” Ten seconds later, at 0931:36, the master asked, “Want full ahead, sir?” The second pilot added, “Rapido.” At 0931:46, the first pilot ordered the speed to full ahead. In his postaccident interview with National Transportation Safety Board (NTSB) investigators, the *Eagle Otome* master stated that he thought that more engine power would help counteract the sheering. At 0931:49, he told the pilots, “I can give more if you want.” Neither pilot answered the master. Seventeen seconds later, at 0932:06, the first pilot ordered the engine reduced from full ahead to half ahead.

At this point, with the rudder still at hard to port, the *Eagle Otome* had sheered from the west bank and was approaching the east bank. At 0932:33, the first pilot ordered the rudder to midship, and at 0932:43, he ordered hard to starboard to counteract an anticipated sheer to port caused by the effect of the east bank. Three seconds later, at 0932:46, the master instructed the crewmember to remove the bars[20] from both anchors, and the crewmember acknowledged the order.

When the *Eagle Otome*’s starboard bow came close to the east bank, the tankship began sheering to port, despite the hard to starboard rudder command (figure 7). At 0933:14, the first pilot asked the second pilot, “Will you talk to this next tow?” The second pilot answered, “What do you want me to tell them? Just one whistle or look out here we come?” The first pilot replied, “One, yeah, look out, the one there is *Vengeance*.” However, neither the S-VDR nor the VHF radio recordings indicated that the second pilot contacted the towboat as the first pilot instructed him to do.

[20] Anchor bars prevent anchors from slipping or deploying if the anchor brake fails. The bars are the last safety mechanism to remove before releasing the anchor brake.

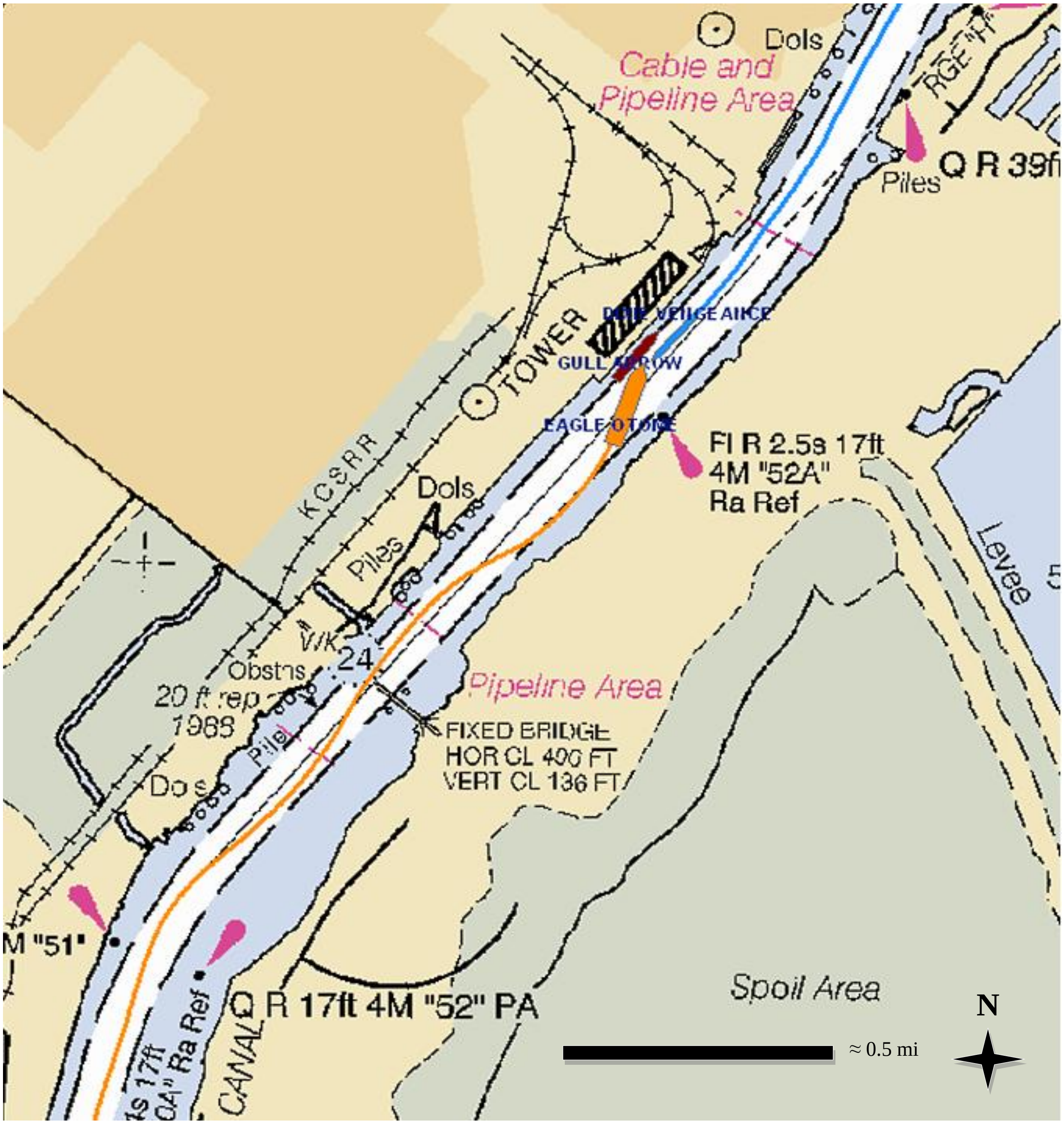

Figure 7. Trackline of the *Eagle Otome*, obtained from the tankship's S-VDR, overlaid as an orange line on NOAA chart 11342, and trackline of the *Dixie Vengeance*, obtained from automatic identification system (AIS)[21] data, overlaid as a blue line.

At 0933:35, the first pilot ordered full ahead on the engine. He told investigators that he did this to increase the water flow across the rudder and thereby enhance the rudder's

[21] AIS is a maritime navigation safety communications system. At 2- to 12-second intervals on a moving vessel, the AIS automatically transmits vessel information, including the vessel's name, type, position, course, speed, navigational status, and other safety-related information to appropriately equipped shore stations, other vessels, and aircraft. The rate at which the AIS information is updated depends on vessel speed and whether the vessel is changing course. The AIS also automatically receives information from similarly equipped vessels.

effectiveness. The *Eagle Otome* master told investigators that, to speed implementation of the full ahead order, he then used the engine order telegraph, which was set to bridge control, to increase the tankship's speed from full ahead to "navigational full ahead." This would gradually increase the tankship's propeller revolutions from about 65 rpm to 90 rpm.[22] To complete the navigational full ahead, a specific button labeled "program by-pass" on the engine control console must be pushed.[23] In his attempt to activate the navigational full ahead, however, the master inadvertently pushed a button marked "manual emergency stop," which was identically shaped and located immediately adjacent to the "program by-pass" button (figure 8).

Figure 8. Section of the engine control console on the *Eagle Otome*. Activating the navigational full ahead required pushing the button marked with a green arrow. However, the master inadvertently pushed the "manual emergency stop" button, marked with a red arrow. (The arrows were added to this image; they are not featured on the actual engine control console.)

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[22] A portion of the increased rpm would take effect within seconds. The remainder of the increased rpm would take effect over the course of several minutes to avoid damage to the engine.

[23] On large marine propulsion diesel engines, the engine control system restricts the rate of loading above the normal maneuvering range to prevent damage to the engine from uneven heating. The ship's crew can manually override or bypass the engine loading program in case of emergency, and on the *Eagle Otome* this override required pushing the "program by-pass" button.

Pressing the "manual emergency stop" button caused an alarm to sound, which the S-VDR recorded at 0933:46. One second later, the first pilot instructed the master to drop the starboard anchor, and 20 seconds later ordered the engine full astern. The anchor dropped about 30 seconds after the first pilot ordered it. The master was able to restart the engine about 45 seconds after stopping it, and he then put it to full astern.[24] The first pilot later told investigators that he did not realize that the engine had stopped when he ordered the anchor released. He said that he had already determined at that point that the full ahead engine order, which he had applied about 12 seconds earlier, had not successfully corrected the ship, and thus he ordered the anchor dropped and the engine astern.

About this time, 0934, the *Eagle Otome* was far to the right in the channel. The *Dixie Vengeance* master, who was about 1,000 feet upriver at that point, told investigators that he thought that the *Eagle Otome* was so close to the east bank that the tankship's position would need to be corrected by coming a bit toward the center of the canal. At 0933:55, he radioed, "You sure are wide." No one on board the *Eagle Otome* responded.

The *Dixie Vengeance* master saw the tankship begin to cross the canal toward his side. At 0934:20, he radioed, "Inbound ship looking okay?" and then saw the *Eagle Otome*'s anchor drop. No one on the *Eagle Otome* answered the towboat master's radio call.

The first pilot told investigators that while the *Eagle Otome* was sheering across the canal toward the *Gull Arrow*, he stepped out onto the port bridge wing of the tankship to get a better view of the situation. While on the bridge wing, he sounded 12 blasts of the whistle to alert nearby vessels. The tankship's S-VDR recorded the blasts beginning at 0934:23, and the *Dixie Vengeance* master and the master on board the *Gull Arrow* both said that they heard the whistle blasts. At the time, the *Gull Arrow* master was on the cargo vessel's bridge checking on the installation of a new radar. He stepped out onto his starboard bridge wing, which faced the canal, and saw the tankship heading toward his vessel. He told investigators that he realized that a collision was imminent and that he sounded the *Gull Arrow*'s general alarm. Shortly thereafter, about 0935, the *Eagle Otome*'s port bow struck the *Gull Arrow*'s starboard side.[25]

When the *Dixie Vengeance* master saw the *Eagle Otome*'s anchor drop, he immediately put his engines full astern and alerted his crew by sounding the emergency alarm. According to AIS data retrieved from the *Dixie Vengeance*, the towboat was able to reduce speed from about 6.5 knots to about 4.4 knots but could not avoid the accident. Within seconds of the collision between the *Eagle Otome* and the *Gull Arrow*, the *Kirby 30406*, which was the forward barge being pushed by the *Dixie Vengeance*, collided with the *Eagle Otome* and breached the tankship's starboard ballast tank and the No. 1 center cargo tank a few feet above the waterline.

[24] NTSB investigators determined that when the master inadvertently stopped the engine, the *Eagle Otome*'s speed was about 5.7 knots. According to the vessel's maneuvering diagrams, even if the engine had been put to full astern at that point, the *Eagle Otome* would have needed about 2,625 feet to stop, given the tankship's speed and load. Less than 500 feet separated the *Eagle Otome* and the *Gull Arrow* at that point. When the *Eagle Otome* struck the *Gull Arrow*, the tankship's speed was about 4.6 knots.

[25] The *Eagle Otome*'s S-VDR recorded a sound similar to a metallic clang at 0935:17. It is not known whether this sound resulted from the tankship's collision with the *Gull Arrow* or from the subsequent collision with the *Dixie Vengeance* tow.

As a result of the breach, an estimated 462,000 gallons of crude oil spilled into the water. The vessels remained together in the center of the canal while pollution response procedures were initiated (figure 9). (For more information, see section “1.9 Oil Spill and Recovery Efforts.”)

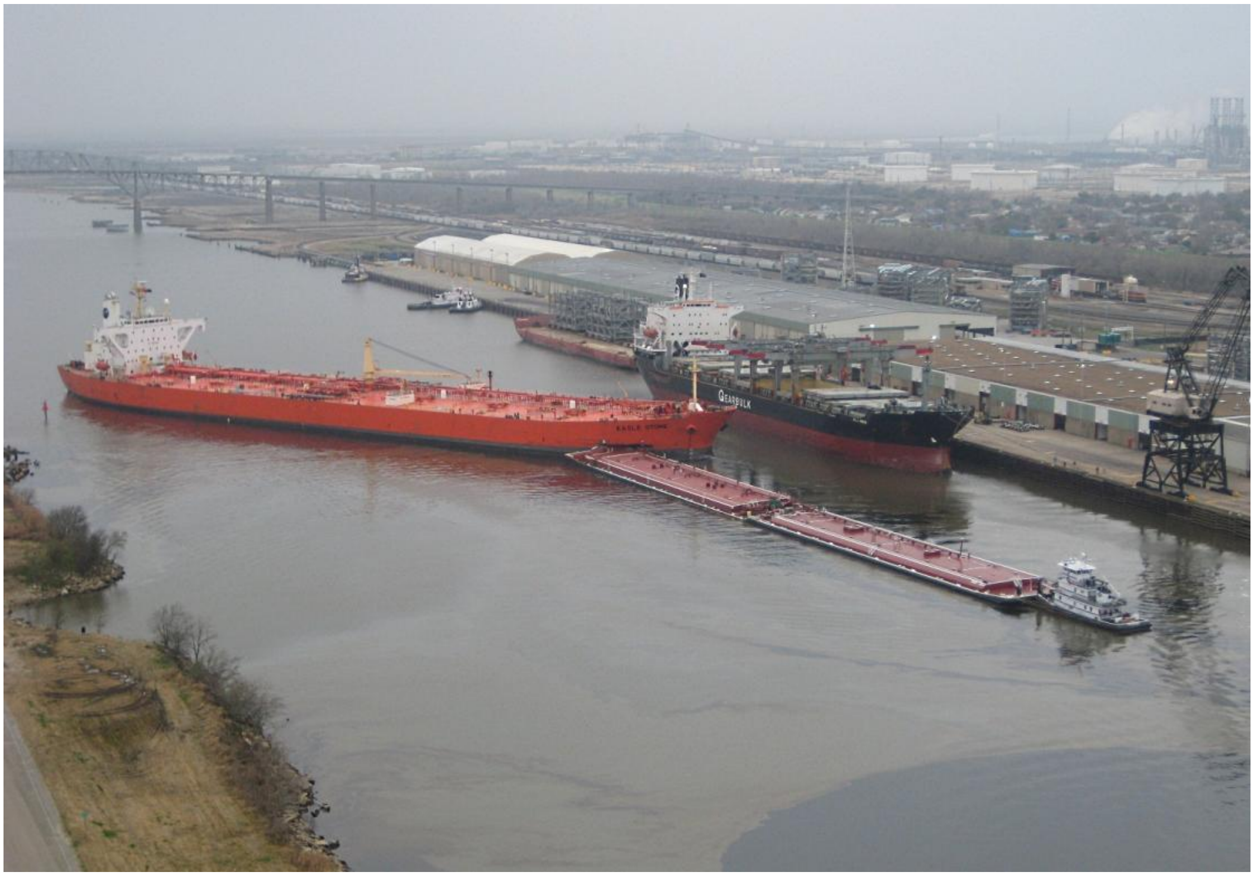

Figure 9. The three vessels after the accident. Overflight photo by the Coast Guard, looking west-southwest.

Shortly after midnight on January 24, as the tide in the waterway changed, the current’s movement dislodged the *Kirby 30406* from the *Eagle Otome*. The crew of the *Dixie Vengeance* maneuvered the towboat and the two barges downriver and anchored near the bridge. The *Eagle Otome* remained in the same anchored position as pollution recovery efforts continued.

1.2 Hydrodynamic Forces

The hydrodynamic force referred to as “bank effect,” which the *Eagle Otome* encountered on the day of the accident, is common. In fact, pilots and experienced mariners regularly use bank effect to their benefit in maneuvering vessels in narrow waterways. The following are brief and general descriptions[26] of the hydrodynamic forces that played a role in the *Eagle Otome*’s transit on the day of the accident.

[26] The descriptions are derived from Henry Hooyer’s book, *Narrow Channels and Their Effects on Ship Handling*, Cornell Maritime Press, Inc., 1983, pp. 85–87 and 89.

Bank Effect and Using Bank Effect to Advantage. When a ship is transiting close to a waterway bank, water builds up between the bow of the ship and the bank. The water build-up results in higher pressure against the bow on the "on-shore" side and a lower pressure on the "off-shore" side. The drop in pressure on one side creates an imbalance, and the imbalance is the source of the bow's deflection away from the bank. To keep the ship to one side of the waterway, rudder must be applied; the closer the ship is to the bank, the more rudder is needed to compensate for bank effect.

Bank effect can be used to mariners' advantage, such as in navigating a bend in a narrow waterway. Just before entering the bend, the ship is allowed to come closer to the outside bank of the bend. Once bank effect begins pushing the ship's bow away from the bank, the mariner can control the bank effect with, as an example, 10 degrees of rudder. While in the bend, the ship will then turn without rudder effort—that is, with the rudder at midship or with only a few degrees of rudder input—because stern suction (explained below) makes the ship turn.

Stern Suction. When a ship encounters bank effect and its bow sheers, the stern comes closer to the bank from which the bow sheered. As a result of the stern's proximity to the bank, suction on the stern becomes stronger. Large tankships such as the *Eagle Otome* generate strong suction effect in narrow waterways because the length of the ship gives the suction extra leverage and the wide beam causes the ship to ride lower in the water. Mariners who are experienced in taking ships through narrow waterways are able to anticipate suction and control it (such as using the suction to turn the ship).

Breaking a Sheer. Before a sheer develops, bank effect should be anticipated and preemptive rudder applied, such as a momentary 20 or 30 degrees. If that does not steady the ship, increasing the engine rpm can help. Increased engine thrust translates quickly into stronger rudder force (longitudinal inertia prevents the ship from gaining speed too quickly). When the ship steadies under hard rudder and increased engine rpm, the engine should be brought back to the original speed and, if the ship is still close to the bank, the rudder should be decreased gradually. The reason for the gradual rudder decrease is that, as long as the ship is close to the bank, the ship is still under the influence of bank effect. Until the ship is clear of bank effect, some amount of rudder should be applied.

1.3 Injuries

No crewmembers on board any of the three vessels were injured. Four longshoremen who were offloading the *Gull Arrow*'s cargo reported minor injuries in the 2 days following the accident.

1.4 Toxicological Testing

Postaccident drug and alcohol testing[27] was conducted shortly after the accident under Coast Guard supervision. Both pilots and on-duty bridge and engineroom personnel on the

[27] Federal regulations at 46 *Code of Federal Regulations* (CFR) 4.06 require postaccident drug and alcohol testing on all individuals engaged in or employed on board a vessel directly involved in any accident that meets the criteria of a serious marine incident, defined at 46 CFR 4.03-2 as (a) a marine casualty or accident that results in any of the following: (1) one or more deaths, (2) injury that requires medical treatment beyond first aid and

Eagle Otome, the towboat master and the three crewmembers on the *Dixie Vengeance*, and VTS Port Arthur watchstander personnel were tested for illegal drugs and alcohol. In addition, the entire *Eagle Otome* crew was tested for alcohol. All tests were conducted in accordance with Federal regulations, and all results were negative for the presence of alcohol and illegal drugs.

1.5 Postaccident Vessel Testing

1.5.1 *Eagle Otome*

The *Eagle Otome*'s steering system was a conventional electrohydraulic, double-ram, rapson-slide[28] type, positioning a single rudder. Two independent hydraulic pumps were fitted for redundancy and increased rudder response. When the vessel maneuvered in confined waters, both hydraulic pumps were placed in operation to meet the required rudder slew rate.[29]

NTSB investigators tested the steering system on the *Eagle Otome* following the accident and found it to be operating properly. The rudder moved from 35 degrees on one side to 30 degrees on the other side in 23 seconds, with both steering pumps in operation. The steering power failure alarms were tested and shown to operate properly. A visual examination of the steering system exterior did not indicate any significant hydraulic leaks or other maintenance deficiencies.

1.5.2 *Dixie Vengeance*

Coast Guard investigators conducted a postaccident inspection of the *Dixie Vengeance*. All of the mechanical systems that the investigators inspected were found to be in proper working order.

1.6 Damage

1.6.1 *Eagle Otome*

The *Eagle Otome* sustained damage to both its port and starboard sides. The damage resulting from the collision with the *Gull Arrow* was located at the tankship's forward upper port

renders the individual unfit to perform routine duties, (3) property damage exceeding $100,000, (4) actual or constructive total loss of an inspected vessel, or (5) actual or constructive total loss of any uninspected vessel that exceeds 100 gross tons; (b) discharge of 10,000 or more gallons of oil into U.S. waters; or (c) the release of a reportable substance into the environment of the United States. On June 20, 2006, new Coast Guard regulations (46 CFR 4.06-3) took effect requiring alcohol testing within 2 hours of a serious marine incident and the collection of drug-test specimens within 32 hours. The five illicit drugs tested for are amphetamines, cocaine, marijuana, opiates, and phencyclidine.

[28] A rapson-slide mechanism converts rectilinear port/starboard motion produced by heavy rams into accurate movement directly coupled to the ship's rudder post by crosshead pin/slider/fork components.

[29] SOLAS Chapter II-1, Regulation 29.3.2 requires that the main steering gear and rudder stock on vessels be capable of putting the rudder over from 35 degrees on either side to 30 degrees on the other side in not more than 28 seconds. Regulation 29.6.1.1 allows a cargo ship to have all power units in operation to achieve this required rudder slew rate.

side. The damage to the portside shell plating and internal structure extended horizontally about 55 feet and down about 12 feet from the main deck. The damaged compartments in this area were the No. 1 port ballast tank, the forward cofferdam,[30] and the bosun store room, and involved buckling, detachment, and fracturing of the internal structure, which was inset about 3 feet as a result of the impact. The main deck plating, deck railings, and port bulwark were also damaged in this area (figure 10).

Figure 10. Portside damage to the *Eagle Otome*.

The subsequent collision with the *Kirby 30406* created a hole in the *Eagle Otome*'s starboard hull about 30 feet aft of the tankship's bow, above the waterline (figure 11). The side shell plating was punctured and inset across an area about 43 feet long and 10 feet high, extending from the No. 1 starboard ballast tank to the forward cofferdam. Frames and stringers in this area were buckled, fractured, and completely detached in several locations. The damage to the *Eagle Otome* was estimated at $1.5 million.

[30] A cofferdam is a void or empty space separating two or more compartments for the purpose of insulation or for preventing liquid contents of one compartment from entering another in case of a leak.

Figure 11. Starboard side of the *Eagle Otome*, with the *Kirby 30406* lodged in it.

1.6.2 *Gull Arrow*

The *Gull Arrow* sustained a gash about 100 feet long and 3 feet high just below its starboard-side gunwale.[31] According to a surveyor's report, the structural frames in this area were buckled, with six frames broken and distorted. The shell plating below the gash was inset between 1 and 3 feet. On the main deck, 16 sections of handrails, stanchions, and brackets were bent over to an angle of about 45 degrees (figure 12). In the interior spaces of the damaged area, including the engine machine shop and maintenance tunnel, damage was sustained to electrical conduits and to various piping systems, such as sewage and steam. The *Gull Arrow* also sustained damage to its portside hull when the impact pushed the ship into the concrete wharf. On the portside, a 10-foot-high by 115-foot-long section of shell plating, between frames 42 and 79, was inset about 3 inches.

No fuel tank was breached and no fuel was released from the *Gull Arrow*. The damage to the *Gull Arrow* was estimated at $381,000.

[31] The gunwale is the upper edge of a vessel's side.

Figure 12. Damage to the *Gull Arrow*.

1.6.3 *Kirby 30406*

The bow (or rake) of the barge *Kirby 30406* was peeled back in the collision with the *Eagle Otome* (figure 13). The barge’s void space on its starboard-side rake was crushed, and about 5 feet of the rake had curled up under the hull plating of the *Eagle Otome*. The cargo tanks remained intact, and no aromatic concentrate product was released.

The damage to the *Kirby 30406* was estimated at $35,000.

Figure 13. Damage to *Kirby 30406*.

1.7 Vessel Information

1.7.1 *Eagle Otome*

The 810-foot-long, 138-foot-wide Aframax[32] tankship was a double-hull crude oil carrier, built in May 1994 as the *Neptune Otome* (renamed *Eagle Otome* in 2000) and registered in the Republic of Singapore. The tankship had 12 cargo tanks with a total cargo carrying capacity of 693,903 barrels. It was powered by a single 16,600-horsepower Mitsubishi Sulzer direct-reversible, slow-speed diesel engine, model 7RTA62, driving a single propeller. As mentioned earlier, the *Eagle Otome*'s steering system was a conventional electrohydraulic, double-ram, rapson-slide type, with one rudder. The *Eagle Otome*'s classification society was the American Bureau of Shipping. The tankship was owned by AET Tanker Holdings Sdn Bhd, headquartered in Malaysia.

1.7.2 *Gull Arrow*

The 597-foot-long, 95-foot-wide general cargo carrier (forest product carrier) was built in January 1982 and registered in the Bahamas. It was powered by a single 11,200-horsepower

[32] The term Aframax is derived from the Average Freight Rate Assessment tanker rate system. Aframax tankers range from 80,000 to 120,000 deadweight tons.

slow-speed diesel engine, model 6L67GFCA, manufactured by B&W Diesel. The ship had a deadweight of 38,787 tons, a gross tonnage of 25,846 tons,[33] and five bulk cargo hatches. The *Gull Arrow*'s classification society was Det Norske Veritas. The ship was owned by Gearbulk Shipowning Ltd., headquartered in Bermuda.

1.7.3 *Dixie Vengeance*

The 75-foot-long, 24-foot-wide vessel was a U.S.-registered canal towboat built in 1966 and modified in 1998. The *Dixie Vengeance* had a gross tonnage of 143 tons and was powered by twin medium-speed diesel engines, Cummins model KTA-38 MO, with ahead propulsion power of 1,700 horsepower. The *Dixie Vengeance* was not inspected by the Coast Guard, nor was it required to be. The two barges towed by the *Dixie Vengeance* were U.S.-registered and Coast Guard-inspected double-hull tank barges. *Kirby 30406* was 297 feet long and 54 feet wide and had a gross tonnage of 1,619 tons. *Kirby 28112* was 300 feet long and 54 feet wide and had a gross tonnage of 1,632 tons. Both barges had a draft of about 10 feet. The *Dixie Vengeance* and the barges were owned by Kirby Inland Marine, LLC, Houston, Texas.

1.8 Environmental and Waterway Conditions

At the time of the accident, the weather at the nearby Beaumont/Port Arthur Southeast Texas Regional Airport was recorded as 65 degrees F, overcast with no precipitation, and winds out of the southeast at 10 knots. Visibility was 6 miles. Nearby tidal currents were 0.9 knot flood at 1306 on January 23 and 1.7 knot ebb at 0405 on January 24. By about 2000 on January 23, the winds were out of the northwest.

1.9 Oil Spill and Recovery Efforts

1.9.1 Notifications of Response Organizations

About 0936, the *Eagle Otome* master radioed Coast Guard Sector Houston-Galveston on VHF radio channel 16[34] to report the accident. At 0938:43, the second pilot told the bridge team that he had notified VTS Port Arthur of the accident and the pollution in the water, and that he had suggested to VTS that the waterway be shut down in the area of the accident.

A Coast Guard petty officer witnessed the accident while on duty at the Coast Guard Marine Safety Unit (MSU) Boat Docks, located about 0.4 mile northeast of the accident location. Within minutes, two Coast Guard boat crews from the MSU Boat Docks launched to the scene. As the boat crews approached the vessels, they noted that the canal was covered in oil. After they determined that no one was injured, the boat crews withdrew to enforce a safety zone to prevent other vessels from entering the oiled section of the canal.

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[33] Deadweight tonnage is the cargo carrying capacity of a vessel, and gross tonnage is a measure of its internal volume, usually used for regulatory purposes.

[34] VHF channel 16 (156.8 MHz) is the international VHF/FM calling, reply, and safety channel. It may also be used for distress and urgency signals.

At 0939, the superintendent of the Port of Port Arthur telephoned VTS and confirmed that oil had spilled into the canal. At 0942, VTS sent a radio broadcast to mariners that the canal at the Port of Port Arthur was closed until further notice. A VTS supervisor also contacted MSU Port Arthur, which alerted its environmental protection and security assets. MSU Port Arthur also notified the Coast Guard Sector Houston/Galveston Situation Unit and the following agencies: Texas General Land Office, Louisiana Oil Spill Coordinator's Office, Louisiana Department of Environmental Quality, NOAA, U.S. Fish and Wildlife Service, and the U.S. Army Corps of Engineers (the Corps). Within the first hour following the accident, an ExxonMobil shipper's representative arrived on scene to provide technical expertise regarding specific hazards of the crude oil and the aromatic concentrate.

The bridge crew on board the *Eagle Otome* also began required notifications. About 10 minutes following the accident, the master notified AET's qualified individual [35] in Houston, who in turn alerted AET's assigned spill management team, Gallagher Marine Systems.[36] The qualified individual also notified AET's designated person ashore[37] and members of AET's emergency response team in Houston. About 1035, Gallagher Marine Systems activated AET's oil spill response organization, Marine Spill Response Corporation. Gallagher Marine Systems also notified the National Response Center, the Texas General Land Office, Louisiana State Police, and the Coast Guard captain of the port in Port Arthur. After AET's qualified individual met with AET's emergency response team in Houston, he traveled to Port Arthur, arriving shortly after 1300. Gallagher Marine Systems personnel were already on site, directing deployment of boom to corral the oil along the banks of the Sabine-Neches Canal.

The *Eagle Otome* bridge crew recorded in the bridge notebook the following additional notifications during the 2 hours after the accident:

- Notified the AET security officer
- Contacted the National Response Center, Washington, DC
- Radioed the *Gull Arrow* and the *Dixie Vengeance* to caution crews about the fire hazards associated with the crude oil and not to use lights
- Provided information about the accident to the primary and alternate qualified individuals
- Provided information to the Coast Guard by radio and telephone
- Provided information to the *Eagle Otome*'s port agent

[35] A qualified individual is a person designated to be notified in the case of an oil spill and who manages the response effort on behalf of the ship owner or operator.

[36] At the time of the accident, AET was in the process of transitioning its qualified individual responsibilities to Gallagher Marine Systems. Following the accident, Gallagher Marine Systems supplied qualified individual services to AET.

[37] The 1998 International Safety Management Code, established for the safe operation of ships and for pollution prevention, states in part that shipping companies should designate a person ashore with direct access to the company's top-level management. The designated person ashore is responsible for monitoring the ship's safety and pollution prevention aspects and for ensuring that shore-based support and resources are provided as required.

1.9.2 Unified Command

Because of the scale of the *Eagle Otome* oil spill, the Coast Guard formed a unified command,[38] initially located at MSU Port Arthur. The unified command comprised a Federal on-scene coordinator (FOSC),[39] who was Port Arthur's captain of the port and commanding officer of MSU Port Arthur; an incident commander, who was AET's qualified individual; a state on-scene coordinator (SOSC), who was a representative of the Texas General Land Office; a local on-scene coordinator (LOSC), who was a captain with the Port Arthur Fire Department; and a deputy incident commander, who was Kirby Inland Marine's qualified individual. Other agencies with on-scene representatives included NOAA, Texas Parks and Wildlife Division, Texas Department of Public Safety, and Texas Commission on Environmental Quality. The incident commander's actions were subject to the concurrence and oversight of the FOSC, the SOSC, and the LOSC.[40]

In addition, the Port Arthur police and fire departments set up a forward command post at the street entrance to the Port of Port Arthur. Together with personnel from the Coast Guard, the Jefferson County Emergency Management, KCS Railroad, and the Texas Department of Public Safety, the police and fire departments coordinated the evacuation of a section of Port Arthur impacted by the crude oil vapor (see section "1.9.4 Olmeca Crude Oil").

1.9.3 Safety Zone

At 1052, the Coast Guard established a safety zone along a 12-mile section of the Sabine-Neches Canal, starting at the Texas Island Intersection to the south. By the end of the day, the safety zone was expanded by 4 miles to the south, encompassing a 16-mile segment of the Sabine-Neches Waterway.

1.9.4 Olmeca Crude Oil

The *Eagle Otome*'s No. 1 center cargo tank, which had a capacity of 73,225 barrels, was loaded with 67,305 barrels of Olmeca crude oil at the time of the accident. Olmeca crude oil is a pale black liquid that contains a complex mixture of petroleum hydrocarbons. It has a flash point

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[38] A unified command operates on the principle of shared command response authorities at the Federal and state levels in response to a major pollution event. The current iteration of a unified command stems from Department of Homeland Security Presidential Directive 5.

[39] The FOSC holds the ultimate authority for all decision-making related to the response and is responsible for coordinating and directing Federal response efforts. The FOSC oversees and ensures the adequacy of the response actions and has the authority to take over, or federalize, the response if he or she determines that it is not being properly conducted by the responsible party.

[40] Key provisions of the Oil Pollution Act of 1990 (33 *United States Code* 2701 et seq.) include holding the owner of a vessel from which oil is discharged responsible for damages and costs associated with the removal of the discharge. If a discharge from a vessel poses a substantial threat to public health, welfare, or the environment, the FOSC directs all Federal, state, and private actions to remove the discharge. The vessel owner or operator must act in accordance with the national contingency plan, applicable area contingency plans, and vessel response plans. (Also see section "1.9.8 Vessel Response Plan.")

of less than 100 degrees F and an average specific gravity[41] of 0.826. As with other crude oil, Olmeca contains varying concentrations of hazardous substances, in particular hydrogen sulfide, as well as benzene, toluene, xylene, ethylbenzene, and polynuclear aromatic hydrocarbons. The U.S. Department of Transportation classifies Olmeca crude oil as a “Class 3” flammable liquid.[42] Potential acute health effects from exposure to high concentration levels of crude oil vapors include skin irritation, convulsion, cyanosis,[43] congestion, and hemorrhaging of lungs and internal organs.

1.9.5 Evacuation

Southeast winds carried vapors from the crude oil, mainly of hydrogen sulfide, along with an associated strong pungent odor, into downtown Port Arthur. The fire department’s air monitoring results revealed hydrogen sulfide levels at about 1 to 5 parts per million in the general area. The fire department measured the highest hydrogen sulfide concentration dockside next to the *Gull Arrow*, including one measurement of 100 parts per million.[44]

Exposure to high concentrations of hydrogen sulfide can cause headache, dizziness, internal bleeding, suffocation, brain damage, coma, and death. As a precaution, the Port Arthur police and fire dispatch initiated the Southeast Texas Alerting Network (STAN)[45] reverse 911 system to notify local residences and businesses near the accident location about the situation. The police and fire departments also established an exclusionary zone to the northwest of the accident location. The exclusionary zone, which included the Port of Port Arthur, was evacuated as a precaution, beginning shortly after 1100 (figure 14). The police and fire dispatch sent a second STAN reverse 911 message to all residences and businesses in this zone informing them to evacuate. Personnel from the police and fire departments also went door-to-door to ensure that all residents were aware of the evacuation.

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[41] Specific gravity is the density of a substance relative to the density of water. Substances with a specific gravity of less than 1.0 float, and those greater than 1.0 sink. Specific gravity is commonly used in environmental response to determine where in a body of water a released substance can be recovered: on the surface or at the bottom.

[42] A Class 3 flammable liquid has a flash point of not more than 141 degrees F. More information about Class 3 flammable liquids is available at 49 CFR 173.120.

[43] Cyanosis results from a lack of oxygen in the blood (as in carbon monoxide poisoning) and can ultimately cause death.

[44] The Occupational Safety and Health Administration considers a hydrogen sulfide concentration of 20 parts per million the permissible exposure limit, not to be exceeded for healthy adults in a work place. A concentration of 100 parts per million is considered immediately dangerous to life and health.

[45] STAN is a multifunction telephone messaging and notification system that gives industrial companies and local agencies the ability to provide the community with important, timely information about emergency incidents and other high-profile events occurring in Southeast Texas. In the event of an emergency that warrants activation, STAN’s ring-down system can place phone calls to home numbers providing information on what actions need to be taken. The alert can also be sent as a call or text message to cell phones or as an e-mail.

Figure 14. City map showing the neighborhood that received the initial STAN message about the oil spill and the neighborhood that was evacuated.

In total, about 136 of Port Arthur's approximately 55,000 residents were evacuated.[46] The Jefferson County Community Emergency Response Team and the American Red Cross established a shelter for the evacuees at a senior citizens' recreation center in Port Arthur. After several hours of continuous air quality monitoring, which indicated no concentrations of hydrogen sulfide within detection limits of air monitoring equipment, the evacuation was lifted at 1800 that same day. However, about 20 residents elected to remain in the shelter overnight because of the petroleum odor that remained in some areas.

[46] The residents were evacuated from an area between Houston Avenue to the south and Beaumont Avenue to the north and between 7th Street to the west and the waterway to the east. The evacuated area was about 0.147 square mile in size.

After the residential evacuation was lifted, the forward command post was demobilized about 1600 on January 24, and the response transitioned to cleanup operations. The fire department continued to monitor the air in the vicinity of the cleanup operations, while the police department maintained perimeter security.

1.9.6 Determination of Quantity Spilled

According to notes in the *Eagle Otome*'s bridge logbook, oil continued to discharge from the tankship from the time of the accident at 0935 until about 1012. About 1049, the *Eagle Otome*'s chief officer completed sounding the No. 1 center cargo tank and estimating the amount of oil that had flowed from it. He determined that a total of about 20,532 barrels (862,344 gallons) of oil had spilled from the cargo tank into the ballast tank, and about 11,000 barrels (462,000 gallons) of that amount flowed from the ballast tank into the water. About 1140, a Coast Guard representative at the forward command post received the spill estimate and reported it to MSU Port Arthur. A Coast Guard inspection team boarded the *Eagle Otome* at 1438 to confirm the tank soundings, among other activities. The chief officer, together with a Coast Guard marine inspector, recalculated the amount of oil spilled into the water to be about 10,097 barrels (424,074 gallons).[47] About 1946, the AET qualified individual confirmed to the Coast Guard the amount of oil contained in the No. 1 cargo tank before and after the accident. He later refined the calculation of the amount released into the water to be about 9,452 barrels, or about 396,984 gallons. His calculation took into account that about 11,041 barrels of oil had leaked from the No. 1 cargo tank into the *Eagle Otome*'s starboard ballast tank, and about 40 barrels of oil had spilled into the bow of the *Kirby 30406*.

Despite these lower release estimates by the Coast Guard and the qualified individual, the unified command decided to base its response on the original release estimate (11,000 barrels spilled into the water) that had been disseminated.

1.9.7 Environmental Response Operations

As required by the area contingency plan,[48] the response actions were conducted in accordance with the National Incident Management System.[49] Within this incident command organization, AET's spill management team served as chiefs, and Coast Guard personnel

[47] The *Eagle Otome* chief officer and the Coast Guard marine inspector used tank sounding quantities that were reported in units of gross standard volume, which includes volume correction factors for temperature, density, pressure, and American Petroleum Institute (API) gravity. Similar to specific gravity, API gravity is a measure of how heavy or light a petroleum liquid is compared to water. API gravity is used in petroleum shipping to provide a way to grade the oil and calculate the number of barrels based on metric tonnage. The API gravity of this shipment of Olmeca crude oil was measured as 39.80° API.

[48] The area contingency plan was developed by the Area Committee under the direction of the Federal on-scene coordinator. The Area Committee is a spill preparedness and planning body made up of Federal, state, and local agency representatives. More information can be obtained in Section 4202 of the Oil Pollution Act of 1990.

[49] The National Incident Management System, developed by the Federal Emergency Management Agency, provides a systematic approach to guide agencies at all levels of government as well as nongovernmental organizations and private sector organizations to work together to respond to, recover from, and mitigate the effects of incidents.

generally served as deputy chiefs while performing an oversight role. The organization evolved over time and was outlined in the daily incident action plans. The operations section was organized as follows:

- The protection and recovery branch was subdivided into three geographic divisions and was responsible for oil deflection, containment, and collection activities.
- The vessel decontamination and transit branch was responsible for reopening the waterway to commercial traffic.
- The air monitoring branch was responsible for detecting hydrogen sulfide, volatile organic compounds, and explosive atmospheres.
- The air operations branch provided aerial reconnaissance and photography to map the oil spill and assess resource needs. The crews of two chartered helicopters assisted with the reconnaissance and helped direct oil skimming operations.
- The waterway management branch was responsible for area security and enforcement of safety zones.
- The vessel salvage branch implemented vessel lightering[50] and firefighting plans for the *Eagle Otome* and the *Kirby 30406* barge.
- The wildlife recovery and rehabilitation branch responded to reports of injured wildlife and monitored 48-hour spill trajectory forecasts.
- An incident command post branch employed four field observers in each of the three geographic divisions that were responsible for validating response resource and oil location maps, oil recovery rates, and assessment of the spill response effectiveness.

1.9.8 Vessel Response Plan

Title 33 *Code of Federal Regulations* (CFR), Section 155, Subpart D, Tank Vessel Response Plans for Oil, requires that vessels carrying oil in bulk as cargo and operating on the navigable waters of the United States operate in compliance with a plan approved by the Coast Guard. The Texas Administrative Code also requires vessel owners and operators to submit certain information to the Texas General Land Office from their Coast Guard–approved vessel response plans. Response plan development and evaluation criteria for vessels carrying petroleum oil as cargo are contained in 33 CFR 155.1050, which sets forth the levels of equipment and response capability times that must be identified for planning purposes.

In October 2009, the Coast Guard approved AET’s 5-year vessel response plan that was in effect at the time of the accident. The plan covered 52 tankships owned or operated by AET, including the *Eagle Otome*. The plan addressed a worst-case discharge[51] for the *Eagle Otome* of

[50] Lightering involves offloading a vessel’s cargo onto another vessel.

[51] The worst-case discharge means a discharge of the vessel’s entire cargo in adverse weather conditions.

693,903 barrels, the tankship's total cargo capacity. AET's plan also outlined crew responsibilities, including a requirement that the master make an immediate determination of the danger to which the vessel is exposed and make all required notifications. The priorities identified following a collision included damage assessment by visual inspection; sounding of all tanks; comparing tank soundings to ullage[52] reports; sounding compartments and void spaces; and taking draft and trim readings. The plan also directed oil to be transferred away from the damage, if possible.

1.9.9 Oil Containment Measures

The primary oil spill response organization in the accident was Marine Spill Response Corporation, a national, nonprofit spill response organization funded by the Marine Preservation Association (MPA). Membership in the MPA entitles members to immediate access to spill response services. The *Eagle Otome*'s owner, AET, was a member of the MPA. About 1140 on the day of the accident, a Marine Spill Response Corporation representative arrived at the unified command. Contractors with the Marine Spill Response Corporation arrived on scene shortly after noon, about 2.5 hours after the accident. About 1235, the contractors began deploying oil boom around the *Eagle Otome*. With the assistance of later arriving crews, they also deployed upriver and downriver containment measures. Because of the high air concentration of hydrogen sulfide at the accident site, skimming operations could not begin until nearly 2200 that evening. About 2330, skimming near the vessels was again delayed because of high air concentration of hydrogen sulfide. Although the work stop near the vessels lasted about 4.5 hours, spill containment and recovery measures upriver and downriver from the accident site were not affected.

Marine Spill Response Corporation maintained an inventory of response equipment, including the oil spill response vessel *Texas Responder*, which was stationed in Galveston, about 65 miles southwest of Port Arthur. The 210-foot-long vessel, equipped with oil boom, support boats, and oil skimming equipment, arrived on site shortly after 0400 on January 24. A second oil spill response vessel, the *Gulf Responder*, arrived on scene on January 25. Within 12 hours of the accident, Marine Spill Response Corporation had six oil skimming units and 32,000 feet of oil boom on scene. Within 60 hours of the accident, 35 oil skimming units were on scene with a skimming capacity of 53,620 barrels/day and 63,800 feet of oil boom. In total, the resources deployed in the Port Arthur spill included about 1,000 oil spill response contractor personnel, 200 incident command post personnel, 114 skimmer boats, 12 large skimmer assets, 160,000 feet of oil boom, 400,000 feet of sorbent boom and snare, 83 vacuum trucks, and two helicopters.

Ebbing tidal currents in the waterway carried the oil south about 8 miles. The bulk of the spilled oil was confined to a 16-mile section of the Sabine-Neches Waterway. On-water oil skimming operations continued until February 7. Cleanup of about 96 percent of the affected waterway was completed by February 10. The remaining area was monitored for evidence of oil leaching from the river banks.

[52] Ullage is the measurement of empty space available in a cargo or ballast tank.

The unified command determined that spill recovery operations were complete on February 24, 2010. The incident commander reported that about 32 percent of the total oil released in the accident was removed from the waterway in the spill recovery effort.[53]

1.9.10 Coast Guard Marine Board of Investigation and Public Hearing

The Coast Guard convened a formal investigation of the accident (known as a Marine Board of Investigation). In accordance with 46 CFR Part 4, after a preliminary investigation, testimony is received under oath in a public hearing, with all designated parties in attendance. The NTSB's investigator in charge participated in the preliminary investigation and the public hearing, the latter of which took place in Port Arthur, March 9 through 11, 2010, and he was permitted to ask questions and evaluate material admitted as evidence. (For samples of testimony provided at the hearing, see sections "1.15 SETWAC Protocol and Sabine Pilots Association Guidelines" and "1.16 Jefferson and Orange County Board of Pilot Commissioners."

1.10 Waterway Information

1.10.1 Sabine-Neches Waterway

The Sabine-Neches Waterway is a 64-mile-long waterway along the border between Texas and Louisiana. From the south at the Gulf of Mexico, the waterway comprises the Sabine Pass Channel, the Port Arthur Canal, the Sabine-Neches Canal, and the lower Neches River just south of Beaumont. The shoreline along the Sabine-Neches Waterway comprises man-made structures (such as the Sabine Pass) and mud banks with marshes. The waterway is maintained by the Corps and is dredged to a controlling depth[54] of 40 feet. The waterway is bordered on the west by Jefferson and Orange counties, Texas, and, at its most southern end, by Cameron Parish, Louisiana.

1.10.2 Sabine-Neches Canal

The midsection of the Sabine-Neches Waterway is the approximately 12-mile-long, 400- to 450-foot-wide Sabine-Neches Canal. The Sabine-Neches Canal shares this section of the waterway with the Gulf Intracoastal Waterway, which enters from the west at the Texas Island Intersection and exits the waterway to the east at the intersection with the Neches River.

In 2008, 2,538 tankships and 23,336 towing/tug vessels transited inbound and outbound in the Sabine-Neches Canal. Crude oil shipments accounted for the majority of tonnage through the waterway.[55] Terminals along the waterway include the Port of Port Arthur and the Port of Beaumont

[53] Of the remaining amount of spilled oil, about one-third evaporated from the surface of the water, and the rest dispersed in the water column and through other weathering processes.

[54] Controlling depth is the deepest ship draft that a channel can accommodate; it restricts safe use of the channel to deep drafts of less than that amount. Controlling depth is based on mean lower low water, which is the average of all lowest water levels for tidal days over a period of usually 19 years.

[55] *Waterborne Commerce of the United States, Calendar Year 2008*, Report Number CEIWR-WCUS-08-2 (Washington DC: Department of the Army Corps of Engineers, 2010).

as well as 14 petroleum refineries, a liquid natural gas facility, chemical plants, and bulk/break-bulk terminals that use vessel and barge transportation to move crude oil, petroleum products, liquid and dry chemicals, steel, and dry bulk cargo.[56]

1.10.3 NTSB Calculations of Missouri Bend

NTSB investigators examined channel dimensions to determine if the Sabine-Neches Canal is wide enough at Missouri Bend for vessels the size of the *Eagle Otome*. Using the beam and length of the *Eagle Otome*, the calculations[57] showed that although the minimum turn radius at Missouri Bend is within preliminary guidelines provided by the Corps for channel design,[58] the channel width at Missouri Bend is less than the Corps' suggested minimum for a vessel the size of the *Eagle Otome*. Using the Corps' preliminary guidelines, NTSB investigators calculated that the *Eagle Otome* ideally needs a canal width in the range of 414 to 463 feet at Missouri Bend, as opposed to the actual canal width of 400 feet.

NTSB investigators contacted the Corps about the channel dimensions at Missouri Bend. A Corps director responded that no strict Corps design criteria exist for navigation channel width. The director further stated that the Corps' preliminary guidelines are conservative, the width guidance provided in the engineering manual can usually be reduced, and many shipping channels in the United States are narrower than what the Corps' guidelines stipulate.[59] The Corps uses simulation studies in the planning, design, construction, operation, and maintenance of navigation channels. In 2002, the Corps conducted simulations in the Sabine-Neches Waterway. However, the director stated that no simulation was conducted at Missouri Bend.

The Corps manual states that increasing the width of a channel in a turn can affect the alignment of the current pattern, which can lead to ship steering problems. In addition, increasing the channel width can change shoaling[60] tendencies as well as the rate and location of shoaling areas. Each widening project must be evaluated for local effects of currents, wind, waves, and visibility on ship piloting. (Also see section "1.18.1 Accidents in the Sabine-Neches Waterway.")

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[56] *Study for the Economic Impact of Maintenance Dredging and Economic Impact of Deepening and Widening of the Sabine-Neches Waterway* (Martin Associates, Lancaster, Pennsylvania; Commissioned by the Jefferson County Waterway and Navigation District, 2006).

[57] The calculations, along with a kinematics parameter extraction study, are available in the NTSB public docket.

[58] The Corps published general channel design guidelines in an August 2004 engineering manual titled, "Hydraulic Design of Deep-Draft Navigation Projects." The guidelines are not specific to the Sabine-Neches Waterway and provide only general design guidance. The engineering manual clarifies that final channel designs should be developed through ship navigation studies that incorporate simulation tests with local pilots.

[59] In the past decade, concern has been raised about the increasing size of ships in static-width waterways. See W. Gray and others, "Channel Design and Vessel Maneuverability – Next Steps: When Ships Get Too Big For Their Ditches," *Marine Technology*, Volume 40, Issue 2, April 2003, available at <http://www.usna.edu/naoe/channel/final.pdf>.

[60] Shallowing as a result of sediment accumulation at the bottom.

1.10.4 Ports and Waterways Safety Assessment

The Coast Guard established the ports and waterways safety system (PAWSS) in the late 1990s to address the needs of waterway users and to place greater emphasis on partnering with the marine industry to reduce risk in the marine environment. Part of the PAWSS involved the Coast Guard's promptly establishing a "national dialogue group" of maritime and waterway community stakeholders representing all major sectors of the U.S. and foreign-flag marine industry. The Coast Guard, in conjunction with the national dialogue group, then developed a ports and waterways safety assessment (PAWSA), a risk assessment process that identifies major waterway safety hazards, estimates risk levels in a qualitative sense, evaluates potential mitigation measures, and sets the stage for implementation of selected measures to reduce risk. The Coast Guard conducts PAWSAs by convening a select group of waterway users and stakeholders in a 2-day workshop to address these issues. Participation of local Coast Guard officials is required before and throughout the workshop.

A PAWSA was conducted for the Port of Port Arthur in September 1999. In accordance with a national PAWSA model, the participants identified deep-draft vessels as contributing twice as much risk as shallow-draft vessels. Traffic density, visibility conditions, meeting arrangements, and waterway complexity were also identified as high risk. The participants identified VTS, which in 1999 was not in place in Port Arthur, as having the greatest potential for mitigating waterway risks. As a result of the PAWSA, VTS Port Arthur was established in 2005.

1.11 VTS Port Arthur

The Sabine-Neches Waterway is monitored by VTS Port Arthur, located at MSU Port Arthur, about 6 miles from the accident location. Certain vessels transiting the Sabine-Neches Waterway are required to check in with VTS at various points, and both the *Eagle Otome* and the *Dixie Vengeance* did so. VTS provides three primary services:

- Information, including position, identity, and intentions of vessels operating in the VTS area; meteorological information; aids to navigation status; traffic congestion; and waterway restrictions.

- Navigational assistance, at the request of the vessel operator, by providing information about the operator's own vessel, such as course and speed; position in the waterway relative to the channel axis; landmarks; aids to navigation or other landmarks; and the positions, intentions, and identities of surrounding traffic.

- Traffic organization, including advance planning and notification of movements, congestion, and waterway restrictions. Prioritization of movements and mandatory position reporting could be required as well as establishing speed limits to aid the flow of traffic.

VTS services to mariners are primarily advisory. VTS watchstanders at Port Arthur monitor VHF radio channels 13, 16, and 1A (alpha) and communicate daily with Sabine pilots and others by way of radio communication. At any given time, VTS watchstanders may be monitoring multiple vessels in their sectors of responsibility, displayed electronically on computer screens (figure 15). VTS watchstanders do not monitor one target to the exclusion of other marine traffic unless circumstances warrant it or a vessel operator requests VTS to do so. The primary navigational tools on which VTS operators rely are AIS data received from the vessel and the radar return from various radar-receiving stations located along the waterway. AIS and radar data are combined and received on VTS screens about every 2 to 10 seconds, depending on the transmitting vessel's speed. As a result, the information that is displayed on the VTS screens is delayed by that amount of time.

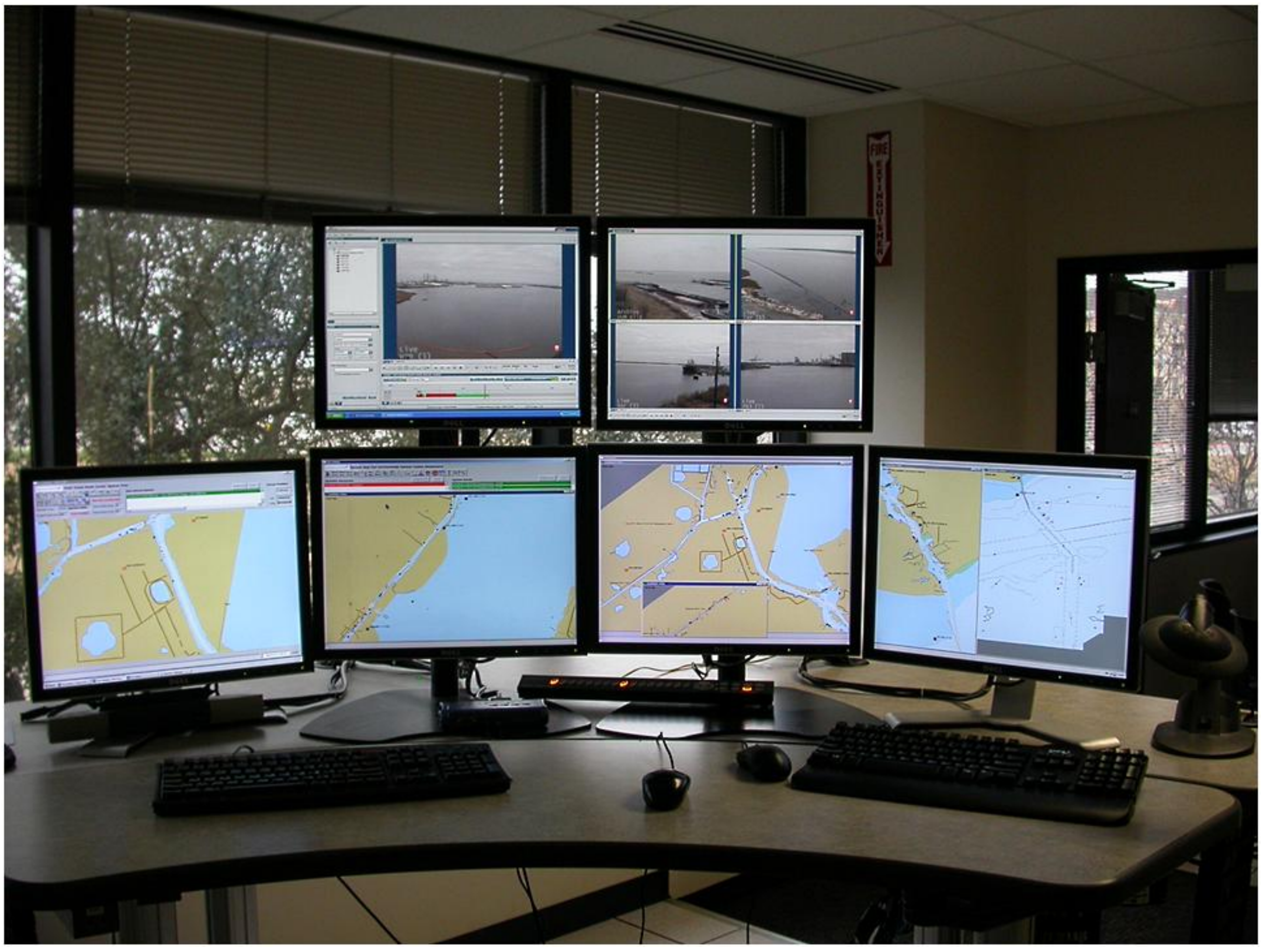

Figure 15. Data screens at VTS Port Arthur. The VTS video cameras did not capture any footage of the accident, only the *Eagle Otome*'s transit through the Texas Island Intersection.

On the morning of January 23, 2010, a VTS Port Arthur watchstander was monitoring the approximately 40-mile-long southern section of the Sabine-Neches Waterway in which the *Eagle Otome* was transiting (from the Sabine Fairway anchorage to just past the accident location). He told investigators that he became aware of the *Eagle Otome*'s inbound approach just before 0900, about 10 minutes after beginning his watch, when the tankship was approaching the Texas Island Intersection. The *Eagle Otome*'s AIS was transmitting data about every 3 to 4 seconds, showing the tankship's name, speed, destination, transited path, draft, and pilot designators. The VTS watchstander recalled that, about the same time, he also saw AIS data from the *Dixie Vengeance* appear on his screen as the towboat entered the northern portion of his monitoring sector in the area near the schoolhouse. Both vessels' names, speeds, and destinations appeared on his computer chart displays.

The VTS watchstander told investigators that from the start of his shift to the time of the accident, radio communication was light. He did not recall hearing any conversation between the *Eagle Otome* and the *Dixie Vengeance* nor any communication from the *Eagle Otome* to VTS during this time.[61]

The watchstander told investigators that he first became aware of the accident when the *Dixie Vengeance* master called VTS to report it. Before that, the watchstander only knew that the two vessels were approaching each other from opposite directions in the waterway near the Port of Port Arthur and near the *Gull Arrow*. He stated that at no point during the *Eagle Otome*'s transit did he think that the tankship might be having a problem. He stated that he felt that the arrangement of the two vessels meeting in that area of the canal was acceptable.

1.12 Personnel Information

1.12.1 Sabine Pilots

First Pilot. The first pilot, age 44, who had navigational control of the *Eagle Otome* at the time of the accident, was a 1988 graduate of the Texas Maritime Academy in Galveston, Texas, where he earned a B.S. in marine transportation. In 1989, he obtained a Coast Guard-issued third mate's unlimited license.[62] After graduating, he worked for a dredging company for about 1 year. He worked for Coastal Tank Ships during the next decade, advancing his license and eventually sailing in a higher rating and advancing in rank. He received his master's unlimited license in March 1997 and became a pilot with the Sabine Pilots Association in July 2006. Before becoming a Sabine pilot, he trained for 2 years with other pilots in the association, repeatedly riding along and training on vessels of increasing length, draft, and tonnage. During his 2-year pilot training, he made at least 500 transits through the Sabine-Neches pilotage area. The first pilot told investigators that he completed training in bridge resource management (BRM)[63] in 1999 and that he had also taken other courses required to maintain his Coast Guard license, such as radar observer classes. The first pilot stated that he had also attended training that was not required by the Coast Guard, such as advanced shiphandling simulator training, and training in shipmaneuvering and docking at the Sabine Pass liquid natural gas terminal.

[61] VTS watchstanders do not specifically listen for any set of exchanges; they monitor multiple frequencies and broadcasts from the entire monitoring sector. The VTS watchstander on the day of the accident was not required to specifically monitor the exchanges between the *Eagle Otome* and the *Dixie Vengeance*; none of those exchanges were directed to VTS.

[62] An unlimited license means any vessel tonnage on any ocean.

[63] BRM is the effective use by a vessel's bridge team of all available resources—information, equipment, and personnel—to safely operate a vessel. BRM was developed to help operators enhance the quality of teamwork and to recognize and mitigate the consequences of operator errors. (Also see sections "1.17 Bridge Resource Management" and "2.3 Division of Piloting Duties; Breakdown in Bridge Resource Management.")

The first pilot had piloted the *Eagle Otome* on one previous occasion and had also piloted similar-sized ships. He had an unblemished record before the accident, with no incidents or accidents in several years of working in the Sabine-Neches Waterway.

Following the accident, the first pilot submitted to the Coast Guard a work/rest schedule for the previous days. According to the schedule, he reported for work mid-morning on Tuesday, January 19. He completed his piloting assignment about 1650, went home, and fell asleep about 2330. The following day, Wednesday, January 20, the first pilot reported waking up about 0745. Because the waterway was closed that day due to fog, he had no job assignments. He went to bed about 2300. The following day, Thursday, January 21, the first pilot reported waking up about 0700 and beginning work mid-morning. He completed his piloting assignment about 1852, returned home, and had dinner. He reported lying in bed and watching television, beginning about 2000. At 2200, he was called for a job assignment. About 0015 the following morning, Friday, January 22, the first pilot boarded a vessel at the Sabine Fairway anchorage and brought it to the ExxonMobil facility in Beaumont. He completed the assignment about 0813 and returned home, where he went to bed about 1015. According to the first pilot, he slept until 1700. He then made dinner, checked on his work status, and was back in bed about 2100. At 0230 on the day of the accident, Saturday, January 23, he was called for the *Eagle Otome* pilotage assignment. He boarded the tankship at the Sabine Fairway anchorage about 0530.

First Pilot's Medical Condition. In April 2008, the first pilot was assessed at a sleep clinic for a sleep disorder. He underwent a polysomnography (sleep study) for severe snoring and daytime fatigue, conditions that had reportedly been manifest for 3 to 5 years.[64] The results led to a diagnosis of obstructive sleep apnea (OSA).[65] In a followup polysomnography, the first pilot was able to sleep effectively with a continuous positive airway pressure (CPAP) device,[66] and he was prescribed CPAP to treat his condition. In subsequent doctor's visits, the first pilot reported that he felt rested in the morning after using the CPAP device but did not use it every night because he found the face mask uncomfortable. After the accident, the first pilot told investigators that he had not used the CPAP device in at least the 4 days before the accident.

The first pilot's last medical evaluation[67] before the accident was completed in February 2009. At that time, the CG-719K form[68] did not require mariners or their health

[64] The results revealed a sleep efficiency of 96.8 percent, a latency to initial sleep of 1 minute, and an apnea + hypopnea index of 26.1 events per sleeping hour, that is, his sleep was disrupted an average of 26.1 times per hour due to insufficient oxygen, all indicating moderate to severe obstructive sleep apnea.

[65] See section "1.13 Fatigue" for additional information about OSA.

[66] CPAP uses air pressure delivered through a mask or nasal device to keep the individual's airway open and oxygen supplied during sleep.

[67] The Coast Guard is responsible for the medical certification of all U.S.-licensed mariners. Regulations at 46 CFR 12.02-17(e) require that pilots of vessels of 1,600 gross tons or more have a yearly medical examination and provide the Coast Guard with the results. Applicants for the licensed and qualified ratings (other than pilots of vessels of 1,600 gross tons or more) must have a medical examination every 5 years. Other than the frequency of examinations, the medical examination and certification requirements for pilots is the same as for other licensed and qualified ratings. Any licensed physician, physician assistant, or nurse practitioner can perform the medical examination, using the guidelines contained in NVIC 04-08.

[68] Part of the evaluation requires the mariner and the examining health care provider to complete a Coast Guard-issued form, CG-719K, to detail the mariner's medical conditions.

practitioners to disclose a diagnosis of a sleep disorder; information about the first pilot's OSA diagnosis and prescribed treatment was not noted on the 719K for that examination[69] (for more information, see section "1.13 Fatigue").

Second Pilot. The second pilot, age 47, who boarded the *Eagle Otome* at the Sabine Pass, graduated from the Texas Maritime Academy in 1985 with a degree in marine transportation and a Coast Guard–issued third mate's license. The first decade after graduation, he worked in the dredging industry and then worked for about 5 years in the offshore oil-drilling industry before becoming a Sabine pilot in 1999. Like the first pilot, he had trained for 2 years before becoming a pilot, as required by the Jefferson and Orange County Board of Pilot Commissioners. He had also previously transited on the *Eagle Otome* and a sister ship. The most recent BRM training course he had completed before the accident took place in 1998.

The second pilot's most recent physical exam before the accident took place in November 2009.

The second pilot also submitted a work/rest schedule to the Coast Guard following the accident. He stated in the schedule that he did not recall what hours he had slept in the 3 days leading up to the accident but that he had received between 6 and 8 hours of sleep each 24-hour period and that the quality of sleep was good. On Wednesday, January 20, he did not work because of the waterway fog closure. On Thursday, January 21, he was called for a piloting assignment about 1000 and completed the work about 1345. About 1315 that same day, he was called for a subsequent piloting assignment, which he completed about 2100. The following day, Friday, January 22, he was called for a piloting assignment about 0530 and completed the work about 1530. The following day, which was the accident day of Saturday, January 23, the second pilot was called about the *Eagle Otome* piloting assignment about 0530, and he boarded the tankship at Sabine Pass about 0750.

1.12.2 *Eagle Otome*

Master. The master, an Indian national, age 35, received a license as third mate in 1998 and then sailed exclusively on board AET vessels in increasingly higher-ranked officer positions. He obtained his master's certificate of competency from India in May 2005. He had worked as master on board two other AET ships for 11 months before the accident. In December 2009, he became master of the *Eagle Otome*. He had made about 10 previous transits on the Sabine-Neches Waterway on board vessels about the size of the *Eagle Otome*. He had also previously transited the Sabine-Neches Waterway on the *Eagle Otome* and recalled having transited previously with the first pilot.

The master completed a BRM training course in March 2009. His most recent physical examination before the accident took place in December 2009.

The master stated that he generally slept well and had a full night's rest during each of the 3 nights before the accident, when the *Eagle Otome* was at anchor at the Sabine Fairway

[69] The subsequent version of the 719K (released in November 2009) inquires about diagnosed sleep apnea. The first pilot reported his diagnosis in the medical evaluation conducted after the accident, in February 2010.

anchorage in the Gulf of Mexico. According to a work/rest schedule that he provided to the Coast Guard following the accident, he went to bed at midnight and rose about 0700 on Wednesday, January 20. On Thursday, January 21, he went to bed about 2300 and rose about 0730. On Friday, January 22, he went to bed about 2200 and rose about 0430 on the morning of the accident to prepare for the pilot boarding and the transit into Beaumont.

Helmsman. The helmsman, an Indian national, age 26, had been an able bodied seaman for 3 years and an ordinary seaman for 4 years before that. He had served on the *Eagle Otome* for nearly 9 months and had made four previous transits in the accident area, each one on board the *Eagle Otome* serving as helmsman. On the day of the accident, he came on duty at 0730. He told investigators that he had never experienced a problem with the tankship's handling.

1.12.3 *Dixie Vengeance*

Master. The towboat master, age 52, told investigators that he had been in the maritime industry for about 10 years and had worked for the towboat operator, Kirby Inland Marine, LLC, for 8 of those years. He had received all his recent mariner training through the company. He held a license as master of towing vessels issued in March 2007 and had worked on board the *Dixie Vengeance* since February 2009. On the day of the accident, he was working the 0600–1200 and 1800–2400 watches.

The towboat master provided a work/rest schedule following the accident. According to the schedule, he had slept about 9 hours during each of the four 24-hour periods leading up to the accident. He reported that he obtained this sleep in 4-hour and 5-hour segments in each 24-hour period because of the watch schedule on the vessel.

1.12.4 VTS Personnel

Watchstander. The VTS watchstander on the day of the accident, age 46, had worked at VTS Port Arthur for nearly 3 years after completing a 3- to 4-month training period. The training consisted of ship-handling knowledge, rules of the road,[70] and area familiarization for identification of facilities, waterways, and channel depths. In addition, he stood 2 months of supervised watches under a VTS training director. He also attended a ship simulator facility to gain familiarization with bridge watchstanding and shiphandling and participated in vessel ride-along programs to become familiar with shipboard operations and aspects of transiting the Sabine-Neches Waterway.

The VTS watchstander told investigators that he worked 12-hour shifts. On the day of the accident, he reported to work about 0845. The day before, on January 22, he worked a shift beginning at 0600. Before that, he had been off from work for 3 days. He told investigators that he had slept about 7 hours during each of the 4 nights before the accident.

[70] Navigation Rules and Regulations: International Navigational Rules Act of 1977 and the Inland Navigation Rules Act of 1980, 33 CFR Subchapter E.

Supervisor. The VTS supervisor on the day of the accident, age 37, had worked at VTS Port Arthur for about 4.5 years after transferring from VTS Houston. He told investigators that he worked 12-hour shifts, and, on the day of the accident, he started at 0600. He estimated that he had slept about 8 hours during each of the 2 nights before the accident. He had been off-duty for 2 days before that and told investigators that he generally slept well.

1.13 Fatigue

1.13.1 Background

Fatigue and its effects on human performance and transportation safety have received considerable attention in recent years. Although most people consider fatigue "as an outcome state, [that is] feeling tired or sleepy,"[71] researchers seek more precise definitions. One widely accepted definition terms fatigue as "a biological drive for recuperative rest."[72] That is, sleep deprivation results in a biological need for restorative sleep and a subjective state of sleepiness.

1.13.2 Causes of Fatigue

The fundamental causes of fatigue are related to the physiological effects of sleep loss, circadian disruption, extended hours of wakefulness, and sleep disorders. Although a variety of factors may have some moderating effects on fatigue, these four physiological fatigue factors are scientifically well-established as the primary underlying mechanisms. Typically, 8 hours of sleep per night will provide most people enough rest to avoid being fatigued the next day,[73] although some may need more sleep and some can sleep less without being fatigued. In general, the less sleep one obtains in any given regular sleep period, the more fatigued one will subsequently become. There are multiple reasons individuals may not obtain sufficient sleep. Insomnia, working long hours, or staying up late all lead to insufficient sleep and thus fatigue.

Circadian rhythms are generated by an internal biological clock located in the brain that controls the 24-hour cycle of physiological systems. For example, within each 24-hour period, people are programmed to be awake during the day and asleep at night. Circadian influences extend to all human systems, beyond regular sleep and wake times, including 24-hour body temperature, digestive, and endocrine rhythms. A person's circadian "clock" is generally programmed for its lowest point between about 0300 and 0500, during which time physiological and mental functioning is reduced. A second circadian low generally occurs between about 1500 and 1700.

[71] L. Di Milla and others, "Demographic Factors, Fatigue, and Driving Accidents: An Examination of the Published Literature," *Accident Analysis and Prevention*, vol. 43 (2011), pp. 516–532.

[72] A. Williamson and others, "The Link Between Fatigue and Safety," *Accident Analysis and Prevention*, vol. 43 (2011), pp. 498–515.

[73] M.M. Mallis, S. Banks, and D.F. Dinges, "Aircrew Fatigue, Sleep Need, and Circadian Rhythmicity." In E. Salas and D. Maurino (Eds.), *Human Factors in Aviation* (2nd Edition), pp. 401–436 (Burlington, Massachusetts: Academic Press, 2010).

Because it is difficult to rapidly change circadian rhythms, most people cannot quickly alter their sleep schedules from one day to the next without experiencing the effects of fatigue. Rather, circadian rhythms adjust slowly to new sleep schedules. The greater the difference between the old and new schedules, the longer the adjustment time needed; substantial schedule changes generally necessitate several days to a week of adjustment time. Thus, a person attempting to work during a period when, up to that point, he or she had been sleeping, will very likely be fatigued.[74]

Medically related sleep disorders can lead to fatigue as well, with OSA the most commonly diagnosed sleep disorder. The airways of OSA individuals become obstructed during sleep, causing loud snoring and, more importantly, breathing interruptions that disrupt sleep, interruptions of which the individuals are often unaware. The more severe the OSA, the more numerous the breathing interruptions and the more likely the individuals are to experience daytime fatigue. OSA is diagnosed through polysomnography, during which the patient sleeps under controlled conditions with key physiological parameters measured to determine quality and quantity of sleep.

Obesity and high blood pressure increase the risk for OSA, and in 2002, a review of the epidemiology of the condition estimated that about 7 percent of the U.S. population has at least moderate OSA.[75] Untreated OSA has been linked to daytime sleepiness, impaired vigilance, mood disturbances, and cognitive dysfunction.[76] As with fatigue in general, individuals with untreated OSA are at higher risk of transportation accidents than those without the condition.[77] Even mild OSA, when untreated, causes performance deficits that can affect safety. Researchers noted the following:[78]

> Pretreatment personal and public health ramifications [of OSA] include increased risk for motor vehicle crashes, occupational injuries, and decreased quality of life. Performance deficits during neuropsychological testing can be documented with even mild [OSA]. With a frequency of 15 apneas-hypopneas per hour of sleep, the decrement is equivalent to that associated with 5 years of aging. [CPAP is considered] the treatment of choice for most patients with [OSA].

[74] Williamson and others, pp. 498–515.

[75] T. Young, P.E. Peppard, and D.J. Gottlieb, "Epidemiology of Obstructive Sleep Apnea: A Population Health Perspective," *American Journal of Respiratory and Critical Care Medicine*, vol. 165 (2002), pp. 1217-1239.

[76] H.C. Kim and others, "Sleep-Disordered Breathing and Neuropsychological Deficits: A Population-Based Study," *American Journal of Respiratory and Critical Care Medicine*, vol. 156 (1997), pp. 1813–1819.

[77] J. Teran-Santos, A. Jimenez-Gomez, and J. Cordero-Guevara, "The Association Between Sleep Apnea and the Risk of Traffic Accidents," Cooperative Group Burgos-Santander, *New England Journal of Medicine*, vol. 340, no. 11 (1999), pp. 847–51.

[78] E.J. Olson and others, "Obstructive Sleep Apnea-Hypopnea Syndrome," *Mayo Clinic Proceedings*, vol. 78 (2003), pp. 1545–1552.

1.13.3 Fatigue and Cognitive Performance

Fatigue's adverse effects on cognitive performance are particularly relevant to transportation safety because operator effectiveness in contemporary transportation systems depends largely on cognitive rather than physical skills. The adverse effects of fatigue on cognitive performance have been demonstrated.[79] Research has shown that fatigued individuals perform more poorly on measures of vigilance, reaction time, selective attention (the ability to focus on a task while avoiding distraction), logical reasoning, and visual search, among others—all skills that contribute to the quality of a person's performance as a transportation system operator. In one study, sleep-deprived individuals showed evidence of cognitive impairment equivalent to those with positive blood alcohol levels,[80] that is, individuals with 24 hours of sustained wakefulness were comparably impaired on measures of cognitive performance to individuals with blood alcohol levels of 0.10 percent. A later study, comparing the performance of subjects at various levels of sleep deprivation with the performance of subjects at various levels of alcohol impairment, noted that even as little as 2 hours of sleep loss resulted in cognitive performance decrement equivalent to that of consuming two or three beers, or having an average breath alcohol level of 0.045 percent. The subjects' performance with regard to memory, vigilance, and reaction time worsened with increasing sleep loss, closely matching and in some cases exceeding the impairment resulting from alcohol consumption.[81]

1.13.4 Fatigue and Transportation Safety

Because of the adverse effects of fatigue on cognitive skills and the importance of cognitive skills to operator effectiveness, fatigued individuals have been found to be at higher risk of accidents.[82] In 1995, the NTSB examined the role of fatigue in a segment of highway accidents (single-vehicle, heavy truck accidents) and found that a number of sleep-related factors contributed to the accidents.[83] Although motor vehicle and truck operators have been the primary focus of fatigue-related transportation safety research, a link between operator fatigue and accidents has been noted in other transportation modes as well.[84]

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[79] See (a) M. Blagrove, C. Alexander, and J.A. Horne, "The Effects of Chronic Sleep Reduction on the Performance of Cognitive Tasks Sensitive to Sleep Deprivation," *Applied Cognitive Psychology*, vol. 9 (1995), pp. 21–40; (b) M. Gillberg and T. Akerstedt, "Sleep loss and performance: No 'safe' duration of a monotonous task," *Physiology and Behavior*, vol. 64 (1998), pp. 599–604.

[80] D. Dawson and K. Reid, "Fatigue, alcohol, and performance impairment," *Nature*, vol. 388 (1997) p. 235.

[81] T. Roehrs and others, "Ethanol and Sleep Loss: A 'Dose' Comparison of Impairing Effects," *Sleep*, 26, (2003), pp. 981–985.

[82] See (a) Teran-Santos; (b) M.H. Smolensky and others, "Sleep Disorders, Medical Conditions, and Road Accident Risk," *Accident Analysis and Prevention*, vol. 43 (2011) pp. 533–548; (c) J.A. Horne and L.A. Reyner, "Sleep Related Vehicle Accidents," *British Medical Journal*, vol. 310 (1995), pp. 565–567.

[83] *Factors that Affect Fatigue in Heavy Truck Accidents*, Safety Study NTSB/SS-95/01 (Washington, DC: National Transportation Safety Board, 1995).

[84] See (a) S. Folkard, "Transport: Rhythm and Blues," Westminster Lecture on Transport Safety (London: Parliamentary Advisory Council for Transport Safety, 2000); (b) J. Dorrian and others, "The Effects of Fatigue on Train Handling During Speed Restrictions," *Transportation Research, Part F* (2006), pp. 243–257.

The NTSB has identified fatigue as a factor in at least two highly visible marine accidents. The NTSB determined that the March 24, 1989, grounding of the vessel *Exxon Valdez* on Bligh Reef,[85] an accident that caused extensive pollution and environmental destruction to the waters of Prince William Sound, Alaska, was caused, among other factors, by the "failure of the third mate to properly maneuver the vessel because of [his] fatigue and excessive workload … ." The NTSB also found that the June 23, 1995, grounding of the passenger vessel *Star Princess*, also in Alaskan waters, was fatigue related.[86] It determined that the probable cause of that accident was the pilot's "poor performance, which may have been exacerbated by chronic fatigue caused by sleep apnea." Because the NTSB does not investigate all major maritime accidents that occur in the United States and because some accident investigators place less emphasis on investigating fatigue than do others, fatigue likely has played a role in the cause of other marine accidents as well.

1.13.5 Mitigating and Preventing Fatigue in Transportation

Given the complexities of contemporary transportation systems, a systematic approach to fatigue mitigation and prevention is widely considered to be the most effective approach to manage the adverse effects of fatigue on the performance of transportation system operators. The fundamental parameters of such an approach include (1) proper scheduling and effective hours of service rules, (2) operator education, and (3) diagnosis and treatment of sleep disorders.

The Coast Guard rule governing rest and duty periods is found at 46 CFR 15.1111(a). The rule states:

> Each person assigned duty as officer in charge of a navigational or engineering watch, or duty as a rating forming part of a navigational or engineering watch, on board any vessel that operates beyond the Boundary Line shall receive a minimum of 10 hours of rest in any 24-hour period.

Further, 46 CFR 15.1111(b) states:

> The hours of rest required under paragraph (a) of this section may be divided into no more than two periods, of which one must be at least 6 hours in length.

Laws specified in 46 *United States Code* 8104 (n) pertain to tankships and crewmembers on tankers. The law states:

> On a tanker, a licensed individual or seaman may not be permitted to work more than 15 hours in any 24-hour period or more than 36 hours in any 72-hour period, except in an emergency or a drill. In this subsection, "work" includes any

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[85] *Grounding of the U.S. Tankship* Exxon Valdez *on Bligh Reef, Prince William Sound near Valdez, Alaska, March 24, 1989.* Marine Accident Report NTSB/MAR-90/04 (Washington, DC: National Transportation Safety Board, 1990).

[86] *Grounding of the Liberian Passenger Ship* Star Princess *on Poundstone Rock, Lynn Canal, Alaska, June 23, 1995*. Marine Accident Report NTSB/MAR-97/02 (Washington, DC: National Transportation Safety Board, 1997).

administrative duties associated with the vessel whether performed on board the vessel or offshore.

As a signatory to the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) of the IMO, the United States, through the Coast Guard, agreed to adhere to and enforce STCW rules, rules that apply to foreign-flagged vessels operating in U.S. waters (such as the *Eagle Otome*), and to U.S.-flagged vessels operating beyond the boundary line on seagoing voyages. U.S.-flagged vessels that operate in U.S. waters are subject to Coast Guard rules and U.S. laws but not to STCW requirements.

The IMO recently revised its STCW work/rest requirements, and these revisions are scheduled to take effect in 2012. The new STCW rules (A-VIII/1) mandate that watchstanders, that is, officers in charge of a watch, or those with "a rating forming part of a watch" must have 10 hours of rest in any 24-hour period and 77 hours of rest in any 7-day period. Hours of rest may be divided into no more than two periods, one of which must be at least 6 hours long. As with Coast Guard rules, exceptions to these rules apply to emergencies or "other overriding operational conditions."

The Sabine Pilots Association, although not a regulatory entity, established a rest period policy for its members. The policy stated that Sabine pilots must have a mandatory rest period of 8 hours after

- Completing a single piloting assignment on board a vessel with a deep draft of 33 feet or greater, heading to or from the sea buoy at the Sabine Fairway anchorage, and starting or ending above the Neches River intersection;

- Completing a second piloting assignment, and fewer than 8 hours passed between the completion of the first job and the assignment to the second job; and

- Any single assignment lasting 12 hours or more.

The rest period begins at the completion of the qualifying assignment, and pilots are not eligible for subsequent assignments until after at least 8 hours have passed.

In a July 5, 2011, e-mail, the Jefferson and Orange Board of Pilot Commissioners ("the commission") informed the NTSB that it does not oversee hours of service issues for the Sabine Pilots Association. Rather, the commission noted that it is primarily concerned with pilot training, standards of pilot selection, and commissioning and recommissioning pilots as their licenses expire and need to be renewed. The commission believes that the Sabine Pilots Association is responsible for enforcing hours of service compliance issues for its pilots.

In a June 22, 2011, e-mail, the American Pilots' Association (APA; the national trade association of professional maritime pilots) informed the NTSB that "under current U.S. Coast Guard legal interpretations" Coast Guard hours of service rules do not apply to state pilots conning tankships such as the *Eagle Otome*. The Coast Guard, independently of the APA, reiterated this view in a July 19, 2011, e-mail to the NTSB. The Coast Guard noted that it did not consider the *Eagle Otome* pilots to be members of the ship's crew. The pilots, the Coast Guard said, were operating under the authority of Texas and not under Coast Guard requirements, adding that "at present, state v. Federal pilotage requirements is an established legal issue."

Major transportation modes in the United States have established hours of service rules and regulations for their operators. For example, in August 2011, the Federal Railroad Administration upgraded its hours of service rules to include provisions for the disruptive effect that working through nighttime hours has on circadian rhythms. The Federal Aviation Administration (FAA) recently initiated the process of upgrading its hours of service rules, contained in 14 CFR Parts 117 and 121. Among the provisions of the proposed upgrade is an accounting for circadian effects on (aviation) pilots' performance by requiring additional rest, or reduced hours of service, for flights beginning in what would be pilots' circadian low periods.

Further, the FAA proposed an alternative to hours of service rules—fatigue risk management systems (FRMS)—in which airlines work with the FAA to develop tailored scheduling rules according to the routes they operate and their particular needs. For example, international flights crossing multiple time zones can lead to disruptions in pilots' circadian rhythms. Airlines may propose different scheduling requirements for its international pilots than for its domestic pilots to take into account the fatiguing effects of rapid transmeridian flight, commonly referred to as "jet lag," on pilot performance.

In a November 20, 2010, letter to the FAA, the NTSB supported the FAA's efforts to upgrade its hours of service rules. In particular, the NTSB supported the FAA's efforts to promote adoption of an FRMS to mitigate fatigue, noting that it was "encouraged by the proposed rules' recognition of FRMS as a way for both [airline] operators and the FAA to make informed decisions about operator-specific exemptions to the rule to address unique operational challenges." In addition to endorsing an FRMS in its proposed rulemaking, on August 3, 2010, the FAA issued an advisory circular on the subject, titled "Fatigue Risk Management Systems for Aviation Safety" (AC 120-103), which provides guidance to develop an FRMS. Further, in July 2011, the International Civil Aviation Organization, with the International Air Transport Association and the International Federation of Air Line Pilots' Associations, issued an FRMS implementation guide for airlines. The guide defined an FRMS as "a data-driven means of continuously monitoring and managing fatigue-related safety risks, based upon scientific principles and knowledge as well as operational experience that aims to ensure relevant personnel are performing at adequate levels of alertness."

Educating operators about the adverse effects of fatigue on their performance can reduce the risk of fatigue to transportation safety as well. The FAA uses all three elements of fatigue prevention by requiring air transport carriers to establish fatigue education programs for their crews and is developing an advisory circular to guide carriers on developing acceptable fatigue training programs.

The Coast Guard has also endorsed operator education regarding the adverse effects of fatigue. On March 21, 2008, it issued Navigation and Inspection Circular (NVIC)[87] 02-08,

[87] The Coast Guard uses NVICs to disseminate information and advisory material to the marine industry. Although the NVIC guidance is not enforceable, the industry usually makes an effort to comply with it. NVICs are sometimes used to disseminate information that will subsequently be proposed as regulations.

describing for vessel owners and operators parameters of an effective crew endurance management system (CEMS). CEMS is the Coast Guard's program, implemented by vessel owners and operators, to educate mariners on fatigue mitigation and prevention strategies. Also, as discussed in the following section, the Coast Guard recently upgraded its requirement for mariners to demonstrate proper and effective treatment for diagnosed sleep disorders.

1.13.6 Coast Guard Restrictions and Waiver

In October 2008, the Coast Guard upgraded its medical oversight system and issued NVIC 04-08 to inform mariners and health care practitioners of its revised medical standards. NVIC 04-08 also provided health care practitioners with guidance and recommended tests to use when conducting a medical examination for Coast Guard licensure requirements, including the issuance of limitations and conditions on mariner licenses. The new standard required mariners diagnosed with sleep disorders to

> Submit [to the Coast Guard] all pertinent medical information and current status report from a qualified sleep medicine specialist. Include sleep study with a polysomnogram, use of medications and titration study results. If surgically treated, [mariner] should have post operative polysomnogram to document cure or need for further treatment.

If the information provided to the Coast Guard indicates that a diagnosed sleep disorder is being successfully treated (for example, by the prescription and use of a CPAP device), the Coast Guard will grant the mariner a waiver and renew his or her license, provided that the mariner adheres to the conditions of the waiver. With regard to OSA, a waiver would require the mariner to provide evidence of "daily or nightly use of the CPAP device for sleep prior to operating under the authority of the credential." The waiver also requires the mariner to annually provide the Coast Guard a "sleep specialist evaluation and evidence of compliance through submission of compliance log or maintenance of wakefulness testing (MWT)."[88]

1.14 Sabine Pilots Association

1.14.1 Organization

The two pilots who were on board the *Eagle Otome* at the time of the accident were members of the Sabine Pilots Association, as are all compulsory state-licensed pilots who navigate ships entering the Sabine-Neches Waterway from foreign ports. Sabine pilots have serviced the local waterways since 1881, and the association's stated goal is to provide smooth and effective pilotage service to the local shipping industry. At the time of the accident, the Sabine Pilots Association headquarters was located in Groves, Texas, just north of Port Arthur. At Sabine Pass, where the second pilot boarded the *Eagle Otome* on the day of the accident, the association maintained a continuously staffed pilot station with four pilot boats. On the day of the accident, 14 pilots were on duty.

[88] MWT evaluates a person's ability to stay awake during the day. The test normally follows an overnight polysomnography and is conducted in four sleep trials spaced 2 hours apart.

The Sabine Pilots Association has no regulatory authority and considers its members to be independent contractors to the ship operators. At the time of the accident, 29 state-licensed pilots were members of the Sabine Pilots Association. The president of the association is elected annually by the pilot members from their current membership and represents the association at the national APA. The Sabine Pilots Association is a member of the Southeast Texas Waterways Advisory Council, or SETWAC (see sections "1.15 SETWAC Protocol and Sabine Pilots Association Guidelines" and "1.16 Jefferson and Orange County Board of Pilot Commissioners.").

1.14.2 Pilot Training

When an applicant is approved to serve as a pilot, he or she begins a 2-year pilot training program.[89] The applicant serves as an apprentice pilot during the first year and is assigned to one of the state-licensed pilots who will oversee the apprentice pilot's progress through the program. The apprentice pilot also serves with different pilots each week in a variety of pilotage assignments. About halfway through the first year of training, the apprentice pilot is given a few weeks off from the pilot rotation to prepare for the Federal license exam. During the exam, apprentice pilots in the Sabine Pilots Association are questioned about the pilotage waters in the Sabine-Neches Waterway and other information. On successfully completing the exam, the apprentice pilot returns to the pilotage rotation and resumes hands-on training. At the end of the first year, the Sabine Pilots Association recommends the apprentice pilot to the Jefferson and Orange County Board of Pilot Commissioners, and if no Sabine pilot makes an adverse recommendation about the apprentice pilot, he or she becomes a "deputy" pilot and begins the deputy year, which is the second and final year of training before becoming a full pilot licensed by the state of Texas.

During the second year, the deputy pilot gradually takes on assignments involving larger tonnage and draft. Although the deputy pilot works mostly alone during the second year, his or her performance continues to be evaluated by other association pilots. Halfway through the second year, the deputy pilot attends a simulator course using both electronic simulation and scaled-down model ships in a maneuvering basin. The course focuses on shiphandling but also on simulated emergencies involving power and rudder failures, all designed to acquaint the deputy pilot with possible real-life emergencies. On successfully completing the simulator course, the deputy pilot returns to rotation training to finish the year. At the end of the second year, if the performance was satisfactory, the deputy pilot becomes a Texas state pilot with the approval of the Jefferson and Orange County Board of Pilot Commissioners.

1.15 SETWAC Protocol and Sabine Pilots Association Guidelines

Because the size of vessels transiting in the Sabine-Neches Waterway began to increase in the 1970s, local parties involved in the waterway's management determined to implement increased safety measures. The parties formed SETWAC, which became a safety committee for the ports and waters of the Sabine-Neches Waterway. Members included marine terminal

[89] The Jefferson and Orange County Board of Pilot Commissioners establishes the training standards for local pilots, and the Sabine Pilots Association arranges for pilots in training to meet these standards.

operators, ship companies, shipping agents, shipyard and repair facilities, directors of local ports, emergency response management, the Corps, and the Sabine Pilots Association. The Coast Guard is a nonvoting member, and the Jefferson and Orange County Board of Pilot Commissioners, although not a member, has an open invitation to attend the SETWAC meetings.

SETWAC members developed policies to facilitate the "safe and secure movement of commerce" in the Sabine-Neches Waterway. The policies were contained in a printed document titled, "Ship Traffic Operating Protocol for the Sabine-Neches Waterway" (see appendix B, "SETWAC protocol"). Three of the policies listed in the SETWAC protocol were the following:

- Vessels with a length of 875 feet or greater, vessels with a beam of 125 feet or greater, and vessels with a deadweight of 85,000 metric tons or greater will only move during daylight hours above the Texas Island Intersection. The *Eagle Otome*'s deadweight was 95,663 metric tons, and its beam was 138 feet; thus, the tankship was restricted to transiting north of the Texas Island Intersection only during daylight hours.

- [Two vessels] with a combined beam that equals or exceeds one-half the channel width will not meet day or night.

- Vessels with an overall length of 860 feet or greater and vessels with a beam of 120 feet or greater must have two pilots on board when transiting the Sabine-Neches Waterway. At 810 feet in length, the *Eagle Otome* was just under the length specification, but its 138-foot-wide beam meant that the SETWAC protocol called for a second pilot.

The Sabine Pilots Association also developed guidelines pertaining to pilotage. Following their inception, the guidelines underwent some transformation; however, the most recent document version, dating from the early 1990s, was called "Guidelines Governing Aboard Vessels Requiring Two Pilots When Transiting the Sabine-Neches Waterway" ("piloting guidelines"; see appendix C). The Sabine Pilots Association designated the two-pilot piloting area of the Sabine-Neches Waterway into five areas. The first and most southern of these areas, piloting area A, stretched (from south to north) from the boarding station at Sabine Pass to beacon 40, located near the Texas Island Intersection. The next area, piloting area B, stretched from south to north, from beacon 40 near the Texas Island Intersection to the "schoolhouse" just north of the Port of Port Arthur. In piloting area A, the Sabine Pilots Association specified that "pilot no. 1" have navigational control and "pilot no. 2" handle radio communication and miscellaneous tasks.[90] In piloting area B, the guidelines specified that "pilot no. 2" have the conn and that "pilot no. 1" handle the radio and miscellaneous tasks. The piloting guidelines also stated, "Both pilots shall be on the navigation bridge of the vessel and either shall be ready, willing, and able to assume command of navigation of the vessel at all times. The above

[90] The association defined "radio" as listening to and handling all radio communications relating to traffic, safety, and position-reporting requirements during the vessel's transit through the waterway. "Miscellaneous" tasks included assisting the conning pilot if requested, providing information regarding dense traffic conditions, watching for clearance or obstructions, arranging for tugs, briefing the ship's master of mooring arrangements, and providing any other assistance to the conning pilot and the ship's master as requested.

guidelines as set by the Sabine Pilots should not be construed as limiting the assigned pilots in the exercise of their good judgment."

After the accident, the president of the Sabine Pilots Association testified at the Coast Guard hearing on the accident that "it is incumbent upon the individual commissioned pilots that they comply with the protocol and any other policies." He also stated that the piloting guidelines served as "the initial framework and blueprint" for establishing the two-pilot system and that, in the approximately two decades or so since the piloting guidelines were drafted, pilot practices had evolved

> … to speak specifically to the swap of the conn or the changeover, the way it's done now is pretty standardized and it's handed down in the training program too as to when each pilot will relieve the other and that … basically evolved in order to accomplish the main element of the system and that was to equitably apportion the transit time between the two individuals.

The pilot association president stated that he thought that the evolution of the piloting guidelines had improved area pilotage and that he was comfortable with the idea that individual pilots applied the guidelines with some variation.[91]

Both of the *Eagle Otome* pilots also testified at the Coast Guard hearing. They indicated that the division of duties specified in the piloting guidelines were not followed as a matter of practice. Also during the hearing, the second pilot reviewed AIS imagery of the *Eagle Otome* commencing the turn at Missouri Bend. On seeing the tankship's position in the canal, the second pilot commented that it appeared that the *Eagle Otome* "may have gotten too deep into the bend." The second pilot also said that, to initiate turns in the waterway, he would input rudder commands of 10 or 20 degrees.

1.16 Jefferson and Orange County Board of Pilot Commissioners

U.S. law gives each state the authority to regulate and administer pilotage requirements for vessels engaged in foreign trade. The state or local pilot commissions set the minimum service and training requirements for state pilots. Usually, but not always, state pilot commissions require that state pilots, in addition to their state pilot license, also hold the appropriate Coast Guard Federal pilot license (endorsement) for the waterway in which they work.[92] According to the Texas Transportation Code, Section 69.015, the Jefferson and Orange County Board of Pilot Commissioners ("the commission") has exclusive jurisdiction over pilot services provided in Jefferson and Orange counties, including stops and landing places on navigable streams fully or partially located in the commission's jurisdiction.

Twenty-four states and two U.S. territories oversee their pilots through pilot oversight organizations. The role of the oversight organizations has historically been to protect the public

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[91] Hearing testimony by the president of the Sabine Pilots Association is available in the NTSB public docket for this accident.

[92] Holding a Federal pilot license also requires that the licensee complete the annual Coast Guard medical examination discussed in the section "1.12.1 Sabine Pilots; First Pilot's Medical Condition."

interest by ensuring that the pilots that navigate vessels in local waters are qualified to do so. As was noted in a recent article, “Together, the 24 state systems [and two territories] comprise a national program of navigation safety regulation and environmental protection.”[93] The oversight organizations enforce pilot practices through their authority to license pilots. In general, oversight organizations investigate pilot-related incidents and accidents and address pilot deficiencies identified in their or the Coast Guard’s investigations by suspending or revoking pilot licenses or by requiring the pilots in question to participate in additional training. The application of oversight differs between the various organizations. For example, one developed and applied medical standards—independent of the Coast Guard’s—for the pilots it oversees. Another established hours of service rules for its pilots. Also, members of the various oversight organizations differ in their backgrounds. They include active and retired pilots, attorneys, port facility owners, and those with no background in marine operations. In many states, pilot oversight organizations, in addition to their pilot oversight duties, also establish the rates for piloting services to be collected from ship owners and operators.

Pilots have typically formed associations within each pilot oversight jurisdiction to represent their interests, to serve as liaisons to ship owners to facilitate scheduling and fee collection for pilot services, to schedule and dispatch pilots, and to establish training protocols and apprenticeship practices to conform to oversight organization requirements. The pilot associations, which have no regulatory authority, often participate in local waterway activities to promote safety and best pilot practices. The pilot associations also contribute to the APA, which represents their interests and promotes pilot safety on a national and international level. No comparable national organization exists for local pilot oversight organizations.’

In the public hearing that the Coast Guard convened following the *Eagle Otome* accident, the chairman of the Jefferson and Orange County Board of Pilot Commissioners quoted part of Texas Transportation Code, Section 69.017, with respect to the commission’s duties:

> … establish the number of pilots necessary to provide adequate pilotage service for Jefferson and Orange County ports, establish pilotage rates, make recommendations to the governor about any pilot whose license should not be renewed or should be revoked, adopt rules and issue orders to pilots and vessels when necessary to secure efficient pilot services, provide penalties to persons who are not pilots who operate vessels in and out of the port, establish times when pilot services are available, approve any changes to the locations of pilot stations, examine pilots and determine … the qualifications of applicants for deputy pilot, examine qualifications for full … pilot, and reexamine full … pilots for renewal, investigate complaints about pilots from industry or the public, investigate pilot conduct in marine casualties as defined by the U.S. Coast Guard, consider pilot association applications for rate changes, adopt necessary rules for the regulation of pilots under the Texas transportation statute.[94]

[93] P.G Kirchner and C.L. Diamond, “Unique Institutions, Indispensible Cogs, and Hoary Figures: Understanding Pilotage Regulation in the United States,” *University of San Francisco Maritime Law Journal*, vol. 23 (2010), pp. 168–205.

[94] The hearing testimony by the chairman of the Jefferson and Orange County Board of Pilot Commissioners is available in the NTSB public docket for this accident.

The members of the commission are appointed by the governor of Texas. At the time of the accident, the commission had five members of various backgrounds, none of them with maritime experience. In the postaccident Coast Guard hearing, the commission chairman indicated that he owned marine facilities on the Sabine-Neches Waterway and had served on the commission since 2001. The *Eagle Otome* accident was the first accident that the commission had investigated since his appointment.[95] The chairman also remarked that this was the first accident since 1979 that had resulted in an oil spill in the Sabine-Neches Waterway. He stated that the commission would investigate accidents when the Coast Guard or the pilots reported them to the commission and that the commission would investigate any incident involving a pilot. To his knowledge, no such incident had previously occurred during his tenure. The chairman also stated that he had a standing invitation to attend SETWAC's meetings but had not attended one since his term began in 2001.

The chairman told NTSB investigators that the commission was not a party to the Sabine Pilots Association's piloting guidelines or other guidelines pertaining to ship operations in the Sabine-Neches Waterway and that the commission was not aware of the piloting guidelines until they were introduced as evidence during the postaccident Coast Guard hearing 6 weeks after the accident. The chairman stated that, in general, he understood the reason for the two-pilot guidelines to be waterway safety.

1.17 Bridge Resource Management

BRM is the effective use by a vessel's bridge team (masters, officers, crew, and pilots) of all available resources—information, equipment, and personnel—to safely operate the vessel. BRM, as well as that of crew resource management in aviation from which BRM originated, was developed to help operators enhance the quality of teamwork and to recognize and mitigate the consequences of operator errors. Researchers noted that crew resource management training was "designed to improve teamwork … by applying well-tested tools (e.g., performance measures, exercises, feedback mechanisms) and appropriate training methods (e.g., simulators, lectures, videos) targeted at specific content (i.e., teamwork knowledge, skills, and attitudes)."[96] One of the principles of BRM is that everyone on the bridge should understand his or her responsibilities and be able to freely and professionally communicate observations about the vessel's progress to others on the bridge.

Both pilots on board the *Eagle Otome* had taken BRM training; however, their most recent training before the accident took place more than a decade earlier, in the late 1990s.

[95] The commission's findings and recommendations based on this accident are available in the NTSB public docket for this accident. In part, the commission recommended that Sabine pilots train in BRM and that the Sabine Pilots Association submit revised piloting guidelines to the commission for review and approval.

[96] P. O'Connor and others. "Crew Resource Management Training Effectiveness: A Meta-Analysis and Some Critical Needs." *The International Journal of Aviation Psychology*, 18 (2008), pp. 353–368.

Since 1974, the NTSB has investigated several accidents in which breakdowns in BRM caused or contributed to the accident.[97] (Also see section "1.18.2 Accidents Involving Two Pilots On Board.")

1.18 Previous NTSB Action

1.18.1 Accidents in the Sabine-Neches Waterway

The NTSB has investigated three previous accidents in the Sabine-Neches Waterway. Two of the accidents, one in 1979[98] and the other in 1980,[99] involved explosions and fires on board tankships. The third accident, which occurred on February 25, 1979, involved a collision between the inbound tankship S/T *Mobil Vigilant* and the outbound tankship S/T *Marine Duval* near Beaumont.[100] Each vessel had a Sabine pilot on board. As a result of its investigation, the NTSB made six recommendations. Safety Recommendation M-80-36 requested that the Coast Guard, in conjunction with the U.S. Army Corps of Engineers and the Sabine Pilots Association, assess traffic control guidelines with respect to maneuvering of large vessels in restricted channels, and, if necessary, revise the guidelines. The NTSB also issued Safety Recommendations M-80-37 through -41 to the Sabine Pilots Association, addressing pilot communication, operation, scheduling, and use of bridge electronic equipment. Safety Recommendation M-80-36 was classified "Closed—Acceptable Action" in August 1981. Safety Recommendations M-80-37 through -41 were classified "Closed—Unacceptable Action" in February 1984 because of the lack of response from the association. In the three decades since Safety Recommendations M-80-36 through -41 were issued, various safety developments have been established that have helped resolve the issues raised in the recommendations. For example, VTS has been implemented, the NTSB and pilot associations across the country communicate regularly with each other, and improved policies have been put in place regarding ship operation in the Sabine-Neches Waterway.

[97] Recent examples include (a) *Allision of Bahamas-Registered Tankship M/T* Axel Spirit *with Ambrose Light, Entrance to New York Harbor, November 3, 2007*, Marine Accident Report NTSB/MAR-09/02 (Washington, DC: National Transportation Safety Board, 2009); (b) *Grounding of Hong Kong-Registered Containership* New Delhi Express*, New York Harbor, Kill Van Kull Waterway, April 15, 2006*, Marine Accident Brief NTSB/MAB-07/02 (Washington, DC: National Transportation Safety Board, 2007); (c) *Allision of Liberia-Registered Fruit Juice Carrier M/V* Orange Sun *with U.S.-Registered Dredge* New York, *Newark Bay, New Jersey, January 24, 2008.* Marine Accident Report NTSB/MAR-09/03. Washington, DC: National Transportation Safety Board, 2009).

[98] *Liberian Tank Vessel M/V* Seatiger *Explosion and Fire, Sun Oil Terminal, Nederland, Texas, April 19, 1979*, Marine Accident Report NTSB/MAR-80/12 (Washington, DC: National Transportation Safety Board, 1980).

[99] *Explosion and Fire on Board the U.S. Tankship* Monticello Victory*, Port Arthur, Texas, May 31, 1981*, Marine Accident Report NTSB/MAR-81/14 (Washington, DC: National Transportation Safety Board, 1981).

[100] *Collision of S/T* Mobil Vigilant *and S/T* Marine Duval *on the Neches River, near Beaumont, Texas, February 25, 1979*, Marine Accident Report NTSB/MAR-80/08 (Washington, DC: National Transportation Safety Board, 1980).

1.18.2 Accidents Involving Two Pilots On Board

On April 15, 2006, the 853-foot-long containership *New Delhi Express* grounded in the Kill Van Kull waterway in New York Harbor.[101] The ship was inbound to Port Newark, New Jersey, after completing a transatlantic voyage from Gibraltar. Two local pilots were on board. One of them, a Sandy Hook pilot, boarded the ship outside New York Harbor and navigated the vessel to the Kill Van Kull waterway. The other pilot, a docking pilot with the Metro Pilots Association, was to bring the ship to the dock at Port Newark. The NTSB concluded, in part, that the two pilots did not adequately communicate with each other about the passage into port. Specifically, the docking pilot who had the conn leading up to the grounding did not clearly communicate to the other pilot and the master his intended maneuvers in a narrow and challenging portion of the waterway near the Bayonne Bridge. As a result of the *New Delhi Express* accident, the NTSB issued Safety Recommendation M-07-3 to state pilot commissions whose harbor pilots work with docking pilots:

> Require your harbor and docking pilots to take part in recurrent joint training exercises that emphasize the concepts and procedures of bridge resource management.

Following a favorable response from the majority of the state pilot commissions, Safety Recommendation M-07-3 was classified "Closed—Acceptable Action" in October 2009.

1.18.3 Pilot Commission Communication

In its investigation of the November 3, 2007, allision of containership M/V *Cosco Busan* with the San Francisco–Oakland Bay Bridge,[102] the NTSB concluded that regular communication among pilot oversight organizations about pilot-related performance data and best practices would enhance the ability of those organizations to effectively oversee pilots. As a result, the NTSB issued Safety Recommendation M-09-5 to the Coast Guard:

> Establish a mechanism through which representatives of pilot oversight organizations collect and regularly communicate pilot performance data and information regarding pilot oversight and best practices.

The Coast Guard did not concur with M-09-5, stating in a July 2009 response that "pilot oversight organizations have not expressed a desire or need to collect and regularly communicate pilot performance data." The Coast Guard further stated that the APA provided enough mechanisms for information exchange among various pilot organizations. Because of the Coast Guard's decision not to implement M-09-5, the NTSB classified the recommendation

[101] *Grounding of Hong Kong-Registered Containership* New Delhi Express, *New York Harbor, Kill Van Kull Waterway, April 15, 2006*, Marine Accident Brief NTSB/MAB-07/02 (Washington, DC: National Transportation Safety Board, 2007), available at http://www.ntsb.gov.

[102] *Allision of Hong Kong-Registered Containership M/V* Cosco Busan *with the Delta Tower of the San Francisco–Oakland Bay Bridge, November 7, 2007*, Marine Accident Report NTSB/MAR-09/01 (Washington, DC: National Transportation Safety Board, 2009), available at http://www.ntsb.gov.

"Open—Unacceptable Response" in November 2009, pending further response from the Coast Guard.

1.18.4 Change in Mariner Medical Condition

Also as a result of the *Cosco Busan* accident investigation, the NTSB concluded that the Coast Guard's system of medical oversight of mariners lacked a requirement for mariners to report changes in their medical status between medical evaluations (required annually for pilots and every 5 years for non-pilot mariners). As a result of this finding, the NTSB issued Safety Recommendation M-09-4 to the Coast Guard:

> Require mariners to report to the Coast Guard, in a timely manner, any substantive changes in their medical status or medication use that occur between required medical evaluations.

The Coast Guard concurred with the intent of the recommendation but stated that to require all mariners to report changes in their medical condition would require a regulatory change, which the Coast Guard believed would be met with resistance. The Coast Guard stated that it was reviewing options to address the issue. In November 2009, the NTSB classified Safety Recommendation M-09-4 "Open—Acceptable Response."

1.18.5 Hours of Service Rules

In 1999, the NTSB recommended that the Coast Guard change its hours of service rules for U.S. mariners. In a June 1999 letter to the Coast Guard, the NTSB noted that research showed that "insufficient sleep, irregular and unpredictable schedules, [and] working during low points in the circadian rhythm" can "affect … performance." Safety Recommendation M-99-1 asked the Coast Guard to:

> Establish within 2 years scientifically based hours-of-service regulations that set limits on hours of service, provide predictable work and rest schedules, and consider circadian rhythms and human sleep and rest requirements.

In e-mails from the Coast Guard to the NTSB, the Coast Guard stated its belief that providing voluntary educational and guidance programs to mariners would meet the intent of this regulation. However, the NTSB did not agree, citing its belief that a regulatory response, together with voluntary guidance programs, was needed. As a result of the Coast Guard's response, the NTSB classified Safety Recommendation M-99-1 "Open—Unacceptable Response" in November 2007.

1.18.6 Obstructive Sleep Apnea

As a result of experience with OSA in all transportation modes, including marine accidents involving mariners with OSA,[103] the NTSB issued safety recommendations to multiple

[103] (a) *Collision of Staten Island Ferry* Andrew J. Barberi*, St. George, Staten Island, New York, October 15, 2003*, Marine Accident Report NTSB/MAR-05/01 (Washington, DC: National Transportation Safety Board, 2005);

modal agencies in October 2009, including Safety Recommendations M-09-14, -15, and -16 to the Coast Guard:[104]

> Modify Form 719K (Merchant Mariner Physical Examination Report) to elicit specific information about any previous diagnoses of OSA and about the presence of specific risk factors for that disorder. (M-09-14)
>
> Implement a program to identify licensed mariners subject to the Navigation and Vessel Inspection Circular on Medical and Physical Evaluation Guidelines for Merchant Mariner Credentials (NVIC 04-08) and who are at high risk for OSA, and require that those mariners provide evidence through the medical certification process of having been appropriately evaluated and, if treatment is needed, effectively treated for that disorder before being granted unrestricted medical certification. (M-09-15)
>
> Develop and disseminate guidance for mariners, employers, and physicians regarding the identification and treatment of individuals at high risk of OSA, emphasizing that mariners who have OSA that is effectively treated are routinely approved for continued medical certification. (M-09-16)

With regard to Safety Recommendation M-09-14, the Coast Guard was in the process of revising the 719K form to ask specifically about sleep apnea[105] when the NTSB made the recommendation. At that time, the NTSB had seen a draft of the revised form and noted that the revisions included a specific question about OSA and other sleep disorders. However, the draft form did not include any questions about symptoms of OSA, such as snoring or daytime sleepiness. Because the NTSB did not believe that the Coast Guard's revisions to the 719K form were substantial enough, the NTSB issued Safety Recommendation M-09-14.

In March 2010, the Coast Guard partially concurred with Safety Recommendation M-09-14 and said that it would confer with the Merchant Mariner Medical Advisory Committee as to what modifications should be made to the 719K form to best address OSA. As a result, the NTSB classified M-09-14 "Open—Acceptable Response" in July 2010.

The Coast Guard also partially concurred with Safety Recommendation M-09-15 in March 2010 but stated that it could not impose additional requirements on mariners simply for being identified at risk for OSA or for any other condition. The Coast Guard did offer to change NVIC 04-08 to improve the ability of medical practitioners to address potential OSA cases. Again, the Coast Guard stated that it would confer with the Merchant Mariner Medical Advisory

(b) *Grounding of the Liberian Passenger Ship* Star Princess *on Poundstone Rock, Lynn Canal, Alaska, June 23, 1995*, Marine Accident Report NTSB/MAR-97/02 (Washington, DC: National Transportation Safety Board, 1997), both available at http://www.ntsb.gov.

[104] The letter containing Safety Recommendations M-09-14 through -16, dated October 20, 2009, is available on the NTSB's website at http://www.ntsb.gov.

[105] The Coast Guard's revision of the form was based, in part, on NTSB recommendations related to the 2003 *Andrew J. Barberi* accident and the 2007 *Cosco Busan* accident.

Committee as to appropriate changes to NVIC 04-08. As a result of the Coast Guard's response, the NTSB classified M-09-15 "Open—Acceptable Alternate Response" in July 2010.

The Coast Guard concurred with Safety Recommendation M-09-16 and, in March 2010, stated that it was drafting an alert to mariners, employers, and physicians about the risks of OSA. As a result of the Coast Guard's action, the NTSB classified M-09-16 "Open—Initial Response Received" in July 2010.

As of the date of this report, the Coast Guard was reviewing how it might implement the three recommendations. It has not yet drafted the alert to mariners recommended in M-09-16.

1.19 Postaccident Action

Following the accident, the *Eagle Otome*'s operating company, AET, notified the NTSB that the company had elected to take certain corrective and preventive measures. For example, AET determined that all of its ships would immediately start using escort tugboats northward from the Texas Island Intersection. AET also covered and marked the "engine emergency stop" button on all its vessels' engine control consoles. Senior AET deck officers also attended river transit simulator training.

The Sabine Pilots Association also notified the NTSB of some corrective measures that it had taken following the accident. In a December 2010 letter, the president of the pilot association stated, in part, that after the accident both of the *Eagle Otome* pilots had attended BRM refresher training with emergency shiphandling simulation. He also stated that the entire Sabine Pilots Association was to attend this refresher training as soon as scheduling would permit, which he anticipated would be in the first quarter of 2011 (NTSB investigators confirmed that this training was completed in February 2011). The president confirmed that AET had increased the use of tugboat assistance for loaded tankships in the 400-foot-wide section of the waterway and that the pilot association fully supported AET's initiative to do so. With respect to the piloting guidelines, the president stated that the association was in the process of revising and updating the document so that it would more closely reflect how the two-pilot system was being conducted.

2. Analysis

This analysis begins with a summary of the accident sequence, followed by a brief discussion of factors that were neither causal nor contributory to the accident and then a discussion of factors that were found to have caused or contributed to the accident.

2.1 Accident Summary

The *Eagle Otome* was en route from Pajaritos, Mexico, to an ExxonMobil facility in Beaumont, Texas, with a load of crude oil. About 0530 on January 23, 2010, a pilot from the Sabine Pilots Association boarded the *Eagle Otome* at the Sabine Fairway anchorage off the coast of Texas to begin the transit up the Sabine-Neches Waterway to Beaumont. About 0750, a second Sabine pilot boarded the tankship, as called for by the Sabine Pilots Association, which had established a two-pilot guideline in the waterway for vessels greater than 120 feet in width. The transit was uneventful for about the next hour and a half. About 0910, the *Eagle Otome* entered a section of the waterway called the Sabine-Neches Canal, where the waterway narrowed to about 400 feet. About 0922, the tankship needed to complete about a 32-degree turn to starboard at a location referred to as Missouri Bend. The first pilot, who had the conn, was on the radio speaking with the master of the towboat *Dixie Vengeance*, which was outbound in the canal about 2.6 miles north of the *Eagle Otome* and would be meeting the tankship near the Port of Port Arthur. When the radio exchange ended about 0923, the *Eagle Otome* had entered Missouri Bend but the first pilot had not yet ordered the starboard turn. At 0923:54, the first pilot ordered "hard to starboard," and the tankship began to make its way through Missouri Bend. At 0924:11, the first pilot gave rudder orders to ease the turn. However, the *Eagle Otome* continued the starboard motion despite the pilot's easing the rudder. The first pilot characterized this starboard motion as the first of four sheering events. When the tankship's starboard bow came in close proximity to the east bank of the canal, it turned back toward the center of the canal, sheering to port this time, despite the first pilot's rudder orders to counteract it. The *Eagle Otome* sheered toward the west bank of the canal and, about 0929, passed close to the west foundation of the Dr. Martin Luther King, Jr. Memorial Bridge in Port Arthur. As the *Eagle Otome* approached the west bank of the canal, the cushion of water at the bow forced the ship to starboard, sheering toward the east bank of the canal despite the first pilot's rudder orders to counteract it. The first pilot again attempted to prevent the bow from turning back when it began to interact with the east bank. However, a final sheering event occurred, forcing the *Eagle Otome* toward the west bank of the canal, where the general cargo vessel *Gull Arrow* was berthed at the Port of Port Arthur. About 0935, the *Eagle Otome*'s bow collided with the *Gull Arrow*'s starboard side. Seconds later, the forward of the two barges that were being pushed by the *Dixie Vengeance* collided with the starboard side of the *Eagle Otome*. The second pilot and the master on the *Eagle Otome*, as well as the *Dixie Vengeance* master, all reported the accident to the Coast Guard.

Following the accident, NTSB investigators tested the mechanical systems on both the *Eagle Otome* and the *Dixie Vengeance*, and all inspected systems were found to be in proper working order. Postaccident toxicological testing, which was performed on all the pertinent crewmembers on the three accident vessels as well as on the VTS watchstander and the VTS supervisor, was negative for the presence of alcohol or illegal drugs. The weather at the time of the accident was calm and clear with light winds and visibility of about 6 miles. Nothing in the weather conditions would have encumbered navigation. The NTSB therefore concludes that weather, mechanical failure, and illegal drug or alcohol use were not factors in the accident.

The area of the Sabine-Neches Canal where the *Eagle Otome* and the *Dixie Vengeance* were going to meet each other was narrow, about 400 feet wide. Transiting and meeting in this area required considerable vigilance. However, safe meeting and passing of vessels the size of the *Eagle Otome* with smaller vessels can be—and is—accomplished on a near-daily basis in the Sabine-Neches Canal. Postaccident photos of the accident location clearly show that the *Dixie Vengeance* was keeping to the right of the center of the canal. The towboat master did so to allow the *Eagle Otome* as much space as possible to transit on the towboat's port side. The *Dixie Vengeance* master was navigating as agreed to by radio communication with the first pilot. The NTSB therefore concludes that the vessel meeting arrangement agreed to by the towboat master and the first pilot was appropriate and was not a factor in the accident.

The watchstanding personnel at VTS Port Arthur had AIS and radar imagery available to monitor the Sabine-Neches Waterway and provide guidance to marine operators. However, the accident area was displayed only as a small portion of the total area shown on the VTS watchstanders' screens. Therefore, the sheering of the *Eagle Otome* that began after Missouri Bend would have been nearly imperceptible on the VTS screens unless the watchstanders considerably enlarged the display of that section of the canal. From the watchstanders' perspective, there was no reason to do so. Also, because of the nature of AIS transmission, the information available to VTS watchstanders was delayed by several seconds. Although VTS monitored the waterway, the watchstanders could not have prevented or mitigated the results of the accident because the information available to them did not indicate a problem with the movement of the *Eagle Otome*. The NTSB therefore concludes that personnel at VTS Port Arthur played no role in the accident.

2.2 Navigation

About 0914, as the *Eagle Otome* was approaching the Texas Island Intersection, the first pilot made a security call inquiring about any outbound traffic near the bridge at the Port of Port Arthur. The *Dixie Vengeance* master promptly responded and stated that his towboat was about 3 miles from the bridge. The two pilots were conversing with each other at the time, and neither acknowledged the call from the *Dixie Vengeance*.

The navigational sequence of events that led to the accident began at Missouri Bend. At this turn in the Sabine-Neches Canal, the *Eagle Otome* needed to make about a 32-degree turn to starboard. As the tankship approached Missouri Bend about 0923, the first pilot who had navigational control was on the radio with the master of the towboat *Dixie Vengeance* discussing meeting arrangements. He had not yet given the order to turn the *Eagle Otome*, and the tankship's rudder was still at midship when he responded to the *Dixie Vengeance* master's radio call announcing his location. The piloting guidelines established by the Sabine Pilots Association stated that radio communication and other miscellaneous tasks should be handled by "pilot no. 2"—in this case, the second pilot—so that the pilot with the conn could focus on navigation. Nevertheless, the first pilot was conducting the radio calls during the transit, and he did not give the rudder order at Missouri Bend until after he had concluded the 45-second radio conversation with the *Dixie Vengeance* master. The NTSB therefore concludes that, contrary to pilot association guidelines, the first pilot on the *Eagle Otome* was conducting a radio call at a critical point in the waterway, and the radio call interfered with his ability to fully focus on conning the vessel.

When the first pilot finished the call with the towboat master, he ordered “hard to starboard” to commence the turn. A hard rudder order when maneuvering Aframax tankships is not uncommon in and of itself. However, the turn at Missouri Bend is only about 32 degrees, and hard to starboard is a large rudder order for such a relatively mild turn. Moreover, the first pilot had initiated all of his previous turns that morning with a maximum rudder order of 20 degrees, as opposed to hard rudder, even though some of those earlier turns in the waterway necessitate larger course changes than Missouri Bend. Postaccident analysis of the *Eagle Otome*’s S-VDR data revealed that bank effect at Missouri Bend had already begun the bow’s movement to starboard before the first pilot’s rudder order had taken effect. The hard to starboard rudder order—which was excessive at that point—therefore likely indicated the first pilot’s realization that the *Eagle Otome* was “too deep into the bend.” Although the tankship exited Missouri Bend without incident, a sheering sequence had begun, which the first pilot was unable to correct. From this point forward in the transit, his efforts to arrest the sheering were ineffective (also see section “2.4 Fatigue”). The NTSB therefore concludes that the first pilot’s failure to correct the sheering motions that began after his late turn initiation at Missouri Bend led to the accident.

When the second sheering event occurred while the vessel was approaching the Dr. Martin Luther King, Jr. Memorial Bridge, causing the *Eagle Otome* to cross the canal from the east bank to the west, the pilots’ comments indicated that they both were aware of the sheering problem: At 0928:13, the first pilot asked the second pilot, “Is she gonna come back?” Six seconds later, the second pilot answered, “Might.” At this point, the two pilots could have alerted the *Dixie Vengeance* of the increasing danger that the sheering posed to vessels upriver, as several minutes remained before the *Eagle Otome* was to meet them. However, the pilots did not do so.

In the radio conversation between the first pilot and the towboat master about 5 minutes earlier, the *Dixie Vengeance* master offered to facilitate the meeting, stating, at 0923:42, “If I need to speed up or slow down to make it easy on both of us, let me know.” Still, despite the two pilots’ realization that they did not have full control of the *Eagle Otome* and despite knowing that the *Dixie Vengeance* master was willing to do what he could to facilitate the meeting if asked, neither pilot alerted him of the situation. At 0933:14, a full 5 minutes after the two pilots likely recognized the sheering problem, the first pilot finally said to the second pilot, “Will you talk to this next tow?” Eleven seconds later, at 0933:25, the second pilot answered, “What do you want me to tell them? Just one whistle or look out here we come?” The first pilot answered, “One, yeah, look out, the one there is *Vengeance*.” Yet despite the first pilot’s instruction that the second pilot alert the *Dixie Vengeance,* the second pilot did not make the radio call. Almost 1 minute later, at 0934:16, the *Dixie Vengeance* master radioed asking, “Inbound ship lookin’ okay?” Despite his inquiry, the towboat master received no response, and the first definitive sign that the *Eagle Otome* was experiencing problems came from his seeing the tankship’s anchor drop. At that point, it was too late for him to stop the towboat and avoid the tankship. Had the *Dixie Vengeance* master received a radio warning when the *Eagle Otome* was sheering near the bridge or shortly thereafter, which was about 5 minutes before the accident, he could have reacted sooner. As it was, he was able to reduce the towboat’s speed by only about 2 knots in the

1 minute from when he saw the tankship's anchor drop to the time of the collision. The NTSB therefore concludes that, had the *Eagle Otome* pilots alerted the *Dixie Vengeance* master of the sheering problem, the force of the collision between the *Eagle Otome* and the *Dixie Vengeance* tow would have been lessened or the collision might have been avoided altogether.

2.3 Division of Piloting Duties; Breakdown in Bridge Resource Management

To enhance safety in the Sabine-Neches Waterway as tankship sizes increased, SETWAC established a ship traffic protocol in the early 1980s which, in part, called for two onboard pilots on large ships in the waterway. The Sabine Pilots Association also established guidelines regarding the duties and responsibilities of its pilots, including who should have the conn in what segment of the waterway. The piloting guidelines were detailed in a printed document called "Guidelines Governing Aboard Vessels Requiring Two Pilots When Transiting the Sabine-Neches Waterway." The intent of the piloting guidelines seemed to be that the Sabine Pilots Association wanted its pilots to form navigation teams. This intent was commendable; the use of teams in operating complex systems, such as navigating large vessels in narrow waterways, is preferable to using single operators. Researchers have noted the following:[106]

> Teams have become the strategy of choice when organizations are confronted with complex and difficult tasks. Teams are used when errors lead to severe consequences; when the task complexity exceeds the capacity of an individual; when the task environment is ill-defined, ambiguous, and stressful; when multiple and quick decisions are needed; and when the lives of others depend on the collective insight of individual members [p. 540].

The use of two operators to navigate large vessels on the Sabine-Neches Waterway is consistent with human factors principles. That is, given the complexity of the task, the use of teams on the waterway would enable pilots to share navigation-related tasks so that one pilot does not become overloaded. For example, while one pilot focuses on vessel navigation tasks, the other pilot communicates with nearby vessels. Teams also enable pilots to monitor each other's performance to reduce errors and their consequences, which is consistent with good BRM practice. However, at the time the *Eagle Otome* accident occurred, the Sabine pilots were not consistently applying the piloting guidelines in their operations. As a result, the first pilot had the conn in the accident area when the second pilot should have. More significantly, when the first pilot should have been focusing on the upcoming turn at Missouri Bend at about 0923, he—not the second pilot, as should have been the case when the first pilot had the conn—was conducting the radio call with the *Dixie Vengeance* master. When the second pilot was needed to assist the first pilot after the radio communication, he was not prepared to do so because he had not been sufficiently engaged in the navigation. The two pilots had both attended BRM training; however, their most recent training before the accident was in the late 1990s. Leading up to the accident, neither pilot appeared to take full advantage of having an experienced and equal colleague on the bridge. The second pilot allowed himself to lose situational awareness by reading the newspaper and disengaging from performing radio and miscellaneous duties specified in the piloting

[106] E. Salas, N.J. Cooke, and M.A. Rosen, "On Teams, Teamwork, and Team Performance: Discoveries and Developments," *Human Factors*, vol. 50 (2008), pp. 540–547.

guidelines. The first pilot chose to conduct both the conning and miscellaneous duties by himself, and thus did not use all of the resources that were available to him. The NTSB concludes that although both pilots completed BRM training, they failed to apply the team performance aspects of BRM to this operation. The NTSB therefore recommends that governors of states and territories in which state and local pilots operate require local pilot oversight organizations that have not already done so to implement initial and recurring BRM training requirements.

According to the president of the Sabine Pilots Association, individual variation on the piloting guidelines was permissible and, in his opinion, may even have improved the pilotage in the Sabine-Neches Waterway. However, adhering to the Sabine Pilots Association guidelines that non-conning pilots handle radio and miscellaneous tasks could have allowed the first pilot to focus exclusively on navigation. The NTSB concludes that the *Eagle Otome* pilots did not follow Sabine Pilots Association guidelines with respect to division of duties while under way. The NTSB therefore recommends that the Sabine Pilots Association take action to ensure that its member pilots follow its guidelines with respect to division of duties and responsibilities of pilots.

In the Coast Guard's hearing on the accident, the chairman of the Jefferson and Orange County Board of Pilot Commissioners stated that the commission's duties included, in part, establishing the number of pilots necessary for safe pilotage in the area and establishing rules for the pilots to follow. However, the commission chairman was unaware of the piloting guidelines that the Sabine Pilots Association had had in place for about 20 years. To ensure the highest levels of safety, the commission should have been aware of best practices in the waterway, ensured that the practices were documented, and ensured that the local pilots' duties and behaviors met the intent of the documented guidelines (see section "2.4 Fatigue").

2.4 Fatigue

The totality of the evidence indicates that, at the time of the accident, the first pilot was subject to the fatiguing effects of insufficient sleep from a combination of untreated OSA, extended wakefulness, and disrupted circadian rhythms. Throughout the series of sheers that began at Missouri Bend, the first pilot's engine and helm orders were either insufficient or not applied preemptively enough to counter and stop the sheering. In other words, during the sheering events, he was "behind," rather than ahead of, the tankship's motions; quicker and more aggressive rudder and engine inputs were needed.

The ability to correct the sheering required the very cognitive skills most susceptible to the adverse effects of fatigue: vigilance, perception, judgment, and reaction time, among others. These cognitive skills were needed to enable the first pilot to determine not only what was happening to the ship he was navigating, but to predict the effects of his commands on the vessel's future path in the waterway. His failure to properly interpret and project the *Eagle Otome*'s path based on his steering and engine commands can be directly attributed to fatigue. Therefore, the NTSB concludes that the first pilot's fatigue adversely affected his ability to predict and stop the *Eagle Otome*'s sheering.

The first pilot had been diagnosed with moderate to severe OSA following a polysomnography in 2008 and was subsequently prescribed a CPAP device to treat the condition. However, he found the CPAP uncomfortable and did not use it consistently, testifying that he had not used it in at least the 4 days before the accident. Given the severity of his diagnosed sleep disorder, not using the CPAP would have led to his being fatigued.

In addition to untreated OSA, the first pilot maintained a fatigue-inducing schedule in the 2 days before the accident. Although the Sabine Pilots Association sought to reduce the effects of fatigue by establishing a rest period policy, the policy itself was insufficient to prevent fatigue among the pilots. It did not address (1) circadian rhythms, (2) time on task, or (3) extended wakefulness, all factors well-documented to be fatigue-inducing.

Sabine Pilots Association members, like those of other pilot associations, can work at any hour during a 2-week duty period, after which they are allotted 2 weeks off duty. During their on-duty periods, the association assigns piloting jobs in order, so that after a pilot completes one rotation, that pilot is then the last to be assigned until all other pilots ahead of him or her in the rotation have been assigned piloting jobs. As a result, pilots working less than 12 hours can be called to report for duty any time in a 24-hour period. Further, by this policy, a pilot can report for duty less than 8 hours after completing a transit as long as the first transit took place on board a vessel with a draft of less than 33 feet and lasted less than 12 hours.

Because it does not consider time of day, the Sabine Pilots Association rest period policy allows pilots to be assigned piloting jobs at any hour, day or night, during their 2-week duty period. Further, the policy does not fully address time on task or periods of extended wakefulness. Thus, as was true with the first pilot on the *Eagle Otome*, a pilot can complete an 8-hour+ transit on a relatively shallow-draft vessel and then be called for a 10-hour+ commitment only 3 hours after completing the first. In short, the rest period policy of the Sabine Pilots Association, although well intended, does not prevent fatigue.

The first pilot had maintained a day-awake, night-asleep schedule for at least 3 days during the week before the accident. Two days before the accident, he awoke about 0700, reported for duty about 1000, and was off duty at 1852. Just over 3 hours later, about 2200, he was called for another piloting assignment that he began shortly after midnight and finished at 0813 the day before the accident. These consecutive piloting assignments resulted in extended wakefulness, insufficient sleep, and disruption to circadian rhythm because the first pilot (1) was awake continuously for at least 27 hours, receiving no sleep when he should have slept 8 hours, and (2) worked through the night when his circadian rhythms were used to sleeping.

After completing the second consecutive piloting assignment the day before the accident, the first pilot then went to bed about 1015, rose about 1700, and remained awake but off duty until 2100 when he went to bed. Although he was in bed for much of the day before the accident, the quality of the sleep he received would almost certainly have been poor because (1) he did not treat his OSA and (2) he was attempting to sleep during a period when he had ordinarily been awake. Even if he had used the CPAP that day, his circadian rhythms, which were consistent with being awake in this period, would likely have prevented him from accruing a full 6 hours and 45 minutes of restorative sleep during the period he was in bed (1015 to 1700). As noted, he went to bed again at 2100 but was called at 0230 the morning of the accident and reported for duty at 0530, where he continued on duty until the accident.

The first pilot was therefore awake during a period when his circadian rhythms corresponded to times of lower performance, times when he would ordinarily have been in his deepest sleep. In the 48 hours before the accident, the schedule that he maintained was in and of itself fatigue-inducing. As a result, the first pilot was subject to fatigue from multiple sources: untreated OSA, circadian disruption, and extended wakefulness, making him highly susceptible to the adverse effects of fatigue on his cognitive performance and at higher risk of involvement in an accident. In effect, none of the three fundamental parameters of fatigue prevention was in place in this accident. The first pilot's sleep disorder was not treated, he was not given formal training on the adverse effects of fatigue, and no effective hours of service rules were in place to prevent fatigue-inducing schedules. Therefore, the NTSB concludes that the combination of untreated OSA, disruption to his circadian rhythms, and extended periods of wakefulness that resulted from his work schedule caused the first pilot to be fatigued at the time of the accident.

The Sabine Pilots Association's rest period policy was intended to prevent pilot fatigue; however, because it had shortcomings, the policy was nevertheless ineffective. Further, no regulatory body with pilot oversight authority had rules or regulations in place that could have precluded the adverse effects of fatigue-inducing scheduling practices from impairing the very cognitive skills that the pilots needed most to effectively navigate vessels through the Sabine-Neches Canal. Therefore, the NTSB concludes that no effective hours of service rules were in place that would have prevented the Sabine pilots from being fatigued by the schedules that they maintained.

The Jefferson and Orange County Board of Pilot Commissioners asserted that its authority only extended to pilot licensing and pilot training. The commission's lack of scheduling rules created a void that permitted fatigued pilots to perform safety-critical duties in a busy, challenging waterway. Such a void in a complex transportation system poses a threat to property, ecosystems, and the lives of those in and near the waterway. Researchers have suggested criteria—such as time of day, circadian rhythms, duration of opportunity for sleep, sleep quality, predictability, sleep debt, time on task, and short breaks—to evaluate the efficacy of hours of service rules.[107] Although it can be argued that not all of the criteria are appropriate to a fatigue mitigation and prevention regulatory scheme, these criteria can be used as a standard of comparison against which regulations can be assessed, and most hours of service rules in place today meet at least several of these criteria. However, because no regulatory body had established effective hours of service rules that Sabine pilots were required to follow, the pilots were at risk for fatigue in all of the suggested criteria, highlighting the safety hazard posed by the regulatory vacuum that existed. Without effective hours of service rules and education in fatigue management, there was little to mitigate the effects of fatigue among the Sabine pilots except for Coast Guard medical oversight of mariner sleep disorders. Therefore, the NTSB concludes that the absence of an effective fatigue mitigation and prevention program among the pilots operating under the authority of the Jefferson and Orange County Board of Pilot Commissioners created a threat to the safety of the waterway, its users, and those nearby.

[107] C.B. Jones and others, "Working Hours Regulations and Fatigue in Transportation: A Comparative Analysis," *Safety Science*, vol. 43 (2005), pp. 225–252.

The circumstances of this accident illustrate the important role that hours of service rules play in preventing fatigue in transportation. The NTSB's concern about effective hours of service rules led it to issue Safety Recommendation M-99-1 to the Coast Guard calling for it to upgrade its hours of service rules to reflect advances in the science of sleep. The NTSB has been disappointed with the Coast Guard's response to M-99-1, particularly in light of the extensive research demonstrating the adverse effects of fatigue that has been gathered since the NTSB issued the recommendation. Other Federal transportation regulators, such as the FAA, have made considerable progress toward preventing fatigue by establishing or initiating scientifically based hours of service rules. The NTSB has consistently disagreed with the Coast Guard's position that mariner education and medical oversight are sufficient to prevent mariner fatigue because this position is not based on research in general and research in transportation safety in particular.

At this time, a sufficient amount of experience has been gained to provide regulators with knowledge about the benefits of an FRMS to prevent fatigue-inducing scheduling practices. A recent study provides several illustrations of the application of FRMSs to transportation settings.[108] The FAA has stated that this approach would meet the intent of its proposed rulemaking changes to implement effective, scientifically based hours of service programs to prevent schedule-induced fatigue, and the NTSB has supported this approach. Pilot commissions and the Coast Guard may consider this method as an acceptable means of implementing hours of service rules effective in preventing fatigue.

The statement by the Jefferson and Orange County Board of Pilot Commissioners—that it deals primarily with pilot training and pilot re-commissioning—appears to meet the letter, but not the spirit, of its regulatory responsibilities. As Kirchner and Diamond note, "State pilotage systems not only license pilots and oversee their professional activities (as the Coast Guard does for Federal pilots), they also seek to ensure that each port in the state has a reliable, expert pilot operation … ."[109] The commission's charter calls for it to "adopt rules and issue orders to pilots and vessels when necessary to secure efficient pilot services," a responsibility that gives the commission the authority to regulate the safety of pilot actions and performance. Pilot oversight organizations should use the power that the governors of their states and territories have given them to fully regulate practices that enhance the safety of their waterways. To enhance safety in the Sabine-Neches Waterway, the commission could have been aware of and enforced the intent of the two-pilot guidelines that the Sabine Pilots Association developed for piloting large vessels through the Sabine-Neches Waterway and played an active role in SETWAC. The commission could also have implemented a fatigue mitigation and prevention program to educate pilots about fatigue and require that fatigue-preventing hours of service rules govern pilot schedules. The commission's lack of familiarity with the Sabine Pilots Association's two-pilot guidelines further illustrates that the commission did not take an active role to ensure waterway safety through establishing safety rules and piloting oversight. Therefore, the NTSB concludes that the Jefferson and Orange County Board of Pilot Commissioners should have more fully exercised its authority over pilot operations on the Sabine-Neches Waterway by becoming aware of and enforcing the Sabine Pilots Association's two-pilot guidelines and implementing a fatigue mitigation and

[108] P. Gander and others, "Fatigue Risk Management: Organizational Factors at the Regulatory and Industry/Company Level," *Accident Analysis and Prevention,* vol. 43 (2011), pp. 573–590.

[109] Kirchner and Diamond, pp. 168–205.

prevention program among the Sabine pilots. The NTSB therefore recommends that the Jefferson and Orange County Board of Pilot Commissioners develop and implement (1) a system to monitor its state-licensed pilots so that the commission can verify the execution of policies, procedures, and/or guidelines necessary for safe navigation, and (2) a fatigue mitigation and prevention program among the Sabine pilots.

The NTSB is concerned that other pilot oversight organizations, like the Jefferson and Orange County Board of Pilot Commissioners, may not be exercising their authority to ensure the safety of our nation's waterways by effectively overseeing the activities and work schedules of local pilots. In the interests of safety, therefore, organizations that oversee pilots must ensure that sufficient regulations are in place so that pilots follow best practices for safety. Because most pilots are required to have Coast Guard licenses, Coast Guard oversight of mariner medical standards is already in place to reduce the risk of fatigue from sleep disorders. However, the circumstances of this accident suggest that pilot oversight organizations may lack regulations that promote the highest level of safe practices among their pilots, including hours of service rules that prevent fatigue-inducing scheduling. Therefore, the NTSB recommends that governors of states and territories in which state and local pilots operate ensure that local pilot oversight organizations effectively monitor and, through their rules and regulations, oversee the practices of their pilots to promote and ensure the highest level of safety. In addition, the NTSB recommends that governors of states and territories in which state and local pilots operate require local pilot oversight organizations that have not already done so to implement fatigue mitigation and prevention programs that (1) regularly inform mariners of the hazards of fatigue and effective strategies to prevent it, and (2) promulgate hours of service rules that prevent fatigue resulting from extended hours of service, insufficient rest within a 24-hour period, and disruption of circadian rhythms.

The circumstances of this accident also suggest that pilot oversight organizations differ in their awareness of the fatiguing effects of poor scheduling practices. In the *Cosco Busan* investigation, where it was evident that pilot oversight organizations did not systematically and regularly communicate with each other and did not have the ability to readily access a database of pilot incidents and accidents, the NTSB concluded that regular meetings of oversight organizations and a regularly accessible database would enhance the oversight effectiveness of these organizations.

No mechanism is currently in place for pilot oversight organizations to regularly communicate with each other to learn of safety issues that their colleagues are encountering and of ways to address those issues. In addition, pilot oversight organizations that maintain databases of pilot incidents and accidents have access only to their own pilots' activities. These databases provide insufficient sample sizes to portray the true picture of safety trends that would be available in a nationwide database. The Coast Guard does maintain a database of marine accidents and incidents, but it (1) is not restricted to pilots but includes all mariners, (2) is only available by request to the Coast Guard and a response to a database request necessitates extensive Coast Guard effort due to manpower and resource limitations, and (3) requires considerable expertise and database knowledge to fully exploit. Because of these limitations, the NTSB issued Safety Recommendation M-09-5 to the Coast Guard in the belief that only the Coast Guard had the resources and the objective commitment to marine safety to establish a nationwide communication mechanism. However, the Coast Guard declined to act on the recommendation, stating that (1) pilot oversight organizations have not expressed a need for such suggestions and (2) the APA "provides sufficient mechanisms of information exchange among pilot organizations."

This accident indicates that a need exists for both regular communication and a readily accessible database of nationwide pilot incidents and accidents that could reveal to pilot oversight organizations particular hazards—for example, fatigue-inducing scheduling—that jeopardize the safety of the waterways they oversee and allow them to discuss with each other these safety hazards and methods to address them. Moreover, the association that the Coast Guard identifies as best suited to carry out the intent of Safety Recommendation M-09-5, the APA, is not a pilot oversight organization and represents the interests of only one segment of U.S. marine operations, pilots on local waterways. The APA does not represent the interests of vessel operators, vessel owners, vessel flag states, classification societies, the IMO, other waterway users, the waterway ecosystems, or the neighbors of the waterways. By contrast, the Coast Guard, as a U.S. government agency, oversees civilian marine operations to ensure the safety of our nation's waterways and to protect the marine environment. Therefore, the NTSB concludes that the Coast Guard is the organization with the resources, capabilities, and expertise best suited to (1) enhance communication among pilot oversight organizations and (2) establish an easy-to-use and readily available database of pilot incidents and accidents. Given the Coast Guard's response, the NTSB classifies Safety Recommendation M-09-5 "Closed—Unacceptable Action/Superseded." The NTSB recommends that the Coast Guard facilitate and promote regular meetings for representatives of pilot oversight organizations to communicate information regarding pilot oversight and piloting best practices. In addition, the NTSB recommends that the Coast Guard establish a database of publicly available pilot incidents and accidents and make the database easy to use and readily available to all pilot oversight organizations.

2.5 Medical Oversight

The first pilot did not report his OSA diagnosis on his subsequent 719K form, dated February 2009, nor was he required to do so because the version of the form in effect at that time did not specifically ask about the diagnosis of sleep disorders. The Coast Guard's subsequent version of the 719K form, released in November 2009, does inquire about sleep disorders, and the first pilot disclosed his OSA diagnosis during his subsequent medical certification in February 2010. The Coast Guard requires mariners with OSA waivers to annually submit evidence of compliance with their treatment plans. The NTSB is pleased with the changes that the Coast Guard has made in its medical oversight system of mariners. As currently implemented and practiced, the system should prevent mariners with diagnosed sleeping disorders from performing safety-related duties without demonstrating that they are effectively treating their disorders.

In 2009, the NTSB issued Safety Recommendation M-09-4, which would require mariners to report to the Coast Guard any significant medical changes that occur between mandatory medical evaluations. Had M-09-4 been implemented, the first pilot on the *Eagle Otome* would have been required to promptly notify the Coast Guard of his OSA diagnosis in 2008, but he ultimately did not report it until nearly 2 years later, after the accident. Because of the loophole that currently exists in the Coast Guard's medical reporting system, the NTSB reiterates M-09-4 in this report.

2.6 Whistle Alert and General Alarm

Leading up to and at the time of the accident, the master of the berthed *Gull Arrow* was on the bridge checking on the installation of a new radar. He heard several blasts of the *Eagle Otome*'s whistle, sounded by the first pilot, which made him aware of the impending collision. The *Dixie Vengeance* master also heard the tankship's whistle blasts. At that point, the *Gull Arrow* master sounded his ship's general alarm. Doing so was prudent and facilitated alerting crewmembers and longshoremen, who were offloading cargo from the ship, about the danger. Security video footage from the dock where the *Gull Arrow* was berthed shows the personnel reacting to the warning.

In the NTSB's investigation of the January 24, 2008, allision of the fruit juice carrier M/V *Orange Sun* with the dredge *New York*,[110] the NTSB concluded that the pilot and the master on board the juice carrier should have sounded the ship's whistle to attempt to warn the *New York* crew of the impending accident. The pilot had made five radio calls on VHF channel 13 to attempt to warn the *New York* crew but had received no acknowledgement that the crew had heard his calls. The NTSB concluded that sounding the *Orange Sun* whistle would have been prudent in using all available resources to alert people in harm's way. Because the first pilot on the *Eagle Otome* did sound 12 blasts of the tankship's whistle, which were heard and acted on, the NTSB concludes that the first pilot's sounding the *Eagle Otome*'s whistle and the *Gull Arrow* master's sounding the cargo vessel's general alarm were prudent and effective.

2.7 Oil Spill Response

Within minutes of the accident and resulting oil spill, boat crews with MSU Port Arthur established a safety zone around the three vessels, and VTS Port Arthur broadcasted an alert to mariners that the canal in that area was closed. About 1 hour after the accident, the Coast Guard established a safety zone along a 12-mile section of the Sabine-Neches Waterway. Local police and fire department assets notified residents and businesses in the affected area of the accident and also went door-to-door to ensure their safe evacuation. The *Eagle Otome*'s vessel response plan was also enacted efficiently. The Coast Guard quickly assembled an on-scene unified command, and oil spill response organizations formed an effective joint team to tackle the spill. The numbers of contracted oil spill response resources that the ship owner deployed to the accident scene were in accordance with the assets identified in the vessel response plan. The NTSB therefore concludes that the accident response and oil spill recovery efforts were timely and effective.

2.8 Waterway Risk Analysis

More than 11 years have passed since the last PAWSA was conducted for the Port of Port Arthur. Because of the evolving and increasing traffic density in the Sabine-Neches Waterway, a new PAWSA could help identify new or changed risk factors and assess how VTS may have influenced conditions since its establishment.

[110] *Allision of Liberia-Registered Fruit Juice Carrier M/V* Orange Sun *with U.S.-Registered Dredge* New York, *Newark Bay, New Jersey, January 24, 2008*, Marine Accident Report NTSB/MAR-09/03 (Washington, DC: National Transportation Safety Board, 2009).

Moreover, NTSB investigators' initial calculations that assessed the channel width at Missouri Bend together with the *Eagle Otome*'s dimensions indicate that the Sabine-Neches Canal is narrower at Missouri Bend than what the Corps' preliminary guidelines stipulate for channel width and vessels of that length and beam. The Corps has made clear that its guidelines, on which NTSB investigators based their calculations, are conservative, that the width guidance can usually be reduced, and that many channels in the United States are narrower than the guidelines suggest. The Corps uses simulation studies to aid in determining final channel configuration. Although a simulation study was conducted in the Sabine-Neches Waterway in 2002, the Corps did not conduct such a study of Missouri Bend, and according to a Corps director, it is not clear what effect the results of a simulation study of Missouri Bend would have had on the channel width in that location.

The circumstances of this accident suggest that the margin of safety in the Sabine-Neches Waterway—particularly in its narrow sections, such as the Sabine-Neches Canal where the accident occurred—may be insufficient, and the NTSB is concerned that the turn dimensions at Missouri Bend may be inadequate for large ships. Moreover, as indicated in an NTSB kinematics parameter extraction study, the hydrodynamic forces in the area of Missouri Bend and the Port of Port Arthur can become excessive, and the channel dimensions leave little margin for operator error. Given the hazardous substances carried on board some of the vessels in the waterway, any increased risk of collision is of concern. The risk could be mitigated by certain strategies. For example, greater restriction on meeting arrangements could be applied. Another example would be for large ships to employ tugboats when transiting in narrow sections of the waterway (as the *Eagle Otome* operating company AET chose to do following the accident). Although large vessels have been transiting the waterway for years without incident, the NTSB nevertheless concludes that the dimensions of the Sabine-Neches Waterway may pose an unacceptable risk, given the size and number of vessels transiting the waterway. The NTSB therefore recommends that the Coast Guard conduct a PAWSA for the Sabine-Neches Waterway, determine from that whether the risk is unacceptable, and if so, develop risk mitigation strategies.

2.9 Control Design

The master of the *Eagle Otome* tried to increase the tankship's propulsion from 65 to a total of 90 rpm, or from full ahead to navigational full ahead, in an attempt to avoid striking the *Gull Arrow*. However, when the master attempted to press the button that would have enabled him to do this, he inadvertently pressed an adjacent button—the "manual emergency stop" button—in the group of identically shaped buttons on the engine control console. As a result, instead of increasing the propulsive power, the opposite occurred: the engine stop order reduced rather than increased the engine rpm. NTSB investigators determined that the master's error did not contribute to the accident because, at the same time, the first pilot ordered the anchor dropped to try to stop the vessel anyway. Without the help of the anchor, the *Eagle Otome* would have needed about 2,625 feet to come to a stop, and less than 500 feet separated the *Eagle Otome* and the *Gull Arrow* at that point.

Although the engine stop order did not lead to the accident, the master's error was a common one in which the operator intends to accomplish one action but instead causes another, an error referred to as a "slip."[111] This type of error, which includes such common ones as typographical errors, is highly influenced by the design of the particular control. The NTSB has long been interested in control design in transportation and its relationship to operator errors that lead to accidents.[112] Although commonly accepted human factors guidelines for control design have been available for several decades to reduce the incidence of design-induced errors, and although such guidelines are required to be applied to aircraft control design, vessel designers continue to design critical component controls without employing these guidelines.

For example, one standard human factors reference[113] lists six different ways controls can differ: location, shape, size, color, labeling, and mode of operation. The greater the difference among controls in at least the first three of these factors, the less likely an operator in a stressful situation will be to inadvertently command the wrong action by activating the wrong control. The buttons on the *Eagle Otome*'s engine control console were not required to meet commonly accepted human factors design principles. In fact, they were located adjacent to each other and were the same size and shape, contrary to standard human factors design principles.

The IMO took action on this issue in 1998, when its Maritime Safety Committee issued MSC Circular 834, "Guidelines for Engine-Room Layout, Design and Arrangement." However, these guidelines were advisory only. Similarly, the vessel classification society American Bureau of Shipping has developed guidelines for the design of critical vessel controls and displays and has distributed these guidelines to its customers and the marine community. However, the American Bureau of Shipping does not mandate its guidelines in the vessels it surveys. The potential safety issue illustrated by the error made by the *Eagle Otome* master stems not from a dearth of information about the need for human factors guidance in control design or from a lack of such guidance itself. Rather, it stems from the absence of a requirement to apply such guidelines in the design and manufacturing of critical vessel controls. The NTSB therefore concludes that commonly accepted human factors principles were not applied to the design of the *Eagle Otome*'s engine control console, which increased the likelihood of error in the use of the controls. The NTSB therefore recommends that the Coast Guard work through the IMO to encourage the application of human factors design principles to the design and manufacture of critical vessel controls.

2.10 Use of Vessel Name in Radio Communication

During the NTSB's investigation of the *Cosco Busan* accident in San Francisco, California, investigators confirmed that at no point during the underway radio communication between the pilot and VTS was the ship referred to by its name. Instead, the pilot and VTS simply used the pilot's designator, "Romeo," as identification. The *Cosco Busan*'s master and bridge crew were Chinese, and the master later told investigators that he was uncertain as to what ship the radio communication was referring. He said that without hearing his vessel's name

[111] D.A. Norman, *The Design of Everyday Things* (New York: Doubleday, 1988).

[112] See, for example, *Design Induced Landing Gear Retraction Accidents in Beechcraft Baron, Bonanza, and Other Light Aircraft*, Aviation Special Study NTSB/SR-80/01 (Washington, DC: National Transportation Safety Board, 1980).

[113] M. Helander, *A Guide to Human Factors and Ergonomics* (2nd edition) (Boca Raton, Florida: CRC Press, 2006).

during radio communication, it was difficult to discern whether the exchange was "private conversation" as opposed to operational and vessel-specific, and hearing the vessel name would have clarified that the communication pertained to him. During the *Cosco Busan* investigation, the NTSB also confirmed that in most U.S. ports, VTS uses the vessel's name in radio communication, but that in a few ports—including the Port of Oakland, from which the *Cosco Busan* departed—VTS and the pilots used the pilot designator or other terms as identification. As a result of this finding, the NTSB issued Safety Recommendation M-09-2 to the Coast Guard:

> Revise your vessel traffic service policies to ensure that vessel traffic service communications identify the vessel, not only the pilot, when vessels operate in pilotage waters.

In a July 2009 response, the Coast Guard responded that it concurred with the intent of the recommendation and that it would review VTS's radiotelephone practices to determine whether nationwide communication protocols should be developed. As a result, the NTSB classified Safety Recommendation M-09-2 "Open—Acceptable Response" in November 2009.

Following the *Eagle Otome* accident, the VTS Port Arthur supervisor confirmed to NTSB investigators that VTS Port Arthur uses the vessel name when communicating by radio. However, the first pilot on board the *Eagle Otome* did not refer to the ship by name in his radio communication with the *Dixie Vengeance* master. According to the Federal Communications Commission's "Bridge-to-Bridge Communication Procedure" at 47 CFR 80.331, the vessel name should be used in radio communication that takes place on designated navigational frequencies. The *Dixie Vengeance* master referred to his vessel by name but did not ask the first pilot for the name of the tankship. During the radio communication leading up to the accident, the *Dixie Vengeance* master referred to the *Eagle Otome* only as "inbound ship." This was similar to the way in which the first pilot had referred to the ship in his earlier radio communication with the towboat master ("first of two inbound tankers").

As the Chinese master of the *Cosco Busan* indicated, radio communication in a foreign language may be difficult for a bridge crew to comprehend, especially if the crew is not specifically concentrating on it. Considerable radio exchange can take place during the course of a long transit (between pilot and dispatcher, pilot to pilot, and general vessel-to-vessel communication) and frequently does not pertain to the navigation of that specific vessel at that exact moment. A bridge crew is therefore more likely to heed and take action when its vessel's name is called out. Had the *Eagle Otome* master and bridge crew heard the *Dixie Vengeance* master ask, "*Eagle Otome* lookin' okay?" as opposed to "Inbound ship lookin' okay?" they might have questioned the pilots about the call or answered the towboat master themselves when the pilots did not. The *Eagle Otome* master, an Indian national, did not indicate in postaccident interviews that he was uncertain whether the radio communication pertained to his vessel, nor does evidence indicate that the first pilot's not using the vessel's name was a factor in the accident. Nevertheless, the NTSB concludes that consistent use of a vessel's name in radio communication can help avoid confusion and enhance bridge team coordination. The NTSB recommends that the American Pilots' Association advise its members to consistently identify vessels by name in bridge-to-bridge radio communication, as required by the Federal Communications Commission.

3. Conclusions

3.1 Findings

Note: The order in which these findings are listed below is different from their order in the analysis section. This is intentional.

1. Weather, mechanical failure, and illegal drug or alcohol use were not factors in the accident.

2. The vessel meeting arrangement agreed to by the towboat master and the first pilot was appropriate and was not a factor in the accident.

3. Personnel at Vessel Traffic Service Port Arthur played no role in the accident.

4. The *Eagle Otome* pilots did not follow Sabine Pilots Association guidelines with respect to division of duties while under way.

5. Although both pilots completed bridge resource management training, they failed to apply the team performance aspects of bridge resource management to this operation.

6. Contrary to pilot association guidelines, the first pilot on the *Eagle Otome* was conducting a radio call at a critical point in the waterway, and the radio call interfered with his ability to fully focus on conning the vessel.

7. Had the *Eagle Otome* pilots alerted the *Dixie Vengeance* master of the sheering problem, the force of the collision between the *Eagle Otome* and the *Dixie Vengeance* tow would have been lessened or the collision might have been avoided altogether.

8. The combination of untreated obstructive sleep apnea, disruption to his circadian rhythms, and extended periods of wakefulness that resulted from his work schedule caused the first pilot to be fatigued at the time of the accident.

9. The first pilot's failure to correct the sheering motions that began after his late turn initiation at Missouri Bend led to the accident.

10. The first pilot's fatigue adversely affected his ability to predict and stop the *Eagle Otome*'s sheering.

11. No effective hours of service rules were in place that would have prevented the Sabine pilots from being fatigued by the schedules that they maintained.

12. The absence of an effective fatigue mitigation and prevention program among the pilots operating under the authority of the Jefferson and Orange County Board of Pilot Commissioners created a threat to the safety of the waterway, its users, and those nearby.

13. The Jefferson and Orange County Board of Pilot Commissioners should have more fully exercised its authority over pilot operations on the Sabine-Neches Waterway by becoming

aware of and enforcing the Sabine Pilots Association's two-pilot guidelines and implementing a fatigue mitigation and prevention program among the Sabine pilots.

14. The Coast Guard is the organization with the resources, capabilities, and expertise best suited to (1) enhance communication among pilot oversight organizations and (2) establish an easy-to-use and readily available database of pilot incidents and accidents.

15. The first pilot's sounding the *Eagle Otome*'s whistle and the *Gull Arrow* master's sounding the cargo vessel's general alarm were prudent and effective.

16. The accident response and oil spill recovery efforts were timely and effective.

17. The dimensions of the Sabine-Neches Waterway may pose an unacceptable risk, given the size and number of vessels transiting the waterway.

18. Commonly accepted human factors principles were not applied to the design of the *Eagle Otome*'s engine control console, which increased the likelihood of error in the use of the controls.

19. Consistent use of a vessel's name in radio communication can help avoid confusion and enhance bridge team coordination.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the collision of tankship *Eagle Otome* with cargo vessel *Gull Arrow* and the subsequent collision with the *Dixie Vengeance* tow was the failure of the first pilot, who had navigational control of the *Eagle Otome*, to correct the sheering motions that began as a result of the late initiation of a turn at a mild bend in the waterway. Contributing to the accident was the first pilot's fatigue, caused by his untreated obstructive sleep apnea and his work schedule, which did not permit adequate sleep; his distraction from conducting a radio call, which the second pilot should have conducted in accordance with guidelines; and the lack of effective bridge resource management by both pilots. Also contributing was the lack of oversight by the Jefferson and Orange County Board of Pilot Commissioners.

4. Recommendations

4.1 New Recommendations

As a result of this accident investigation, the National Transportation Safety Board makes the following safety recommendations:

To the U.S. Coast Guard:

Conduct a ports and waterways safety assessment for the Sabine-Neches Waterway, determine from that whether the risk is unacceptable, and if so, develop risk mitigation strategies. (M-11-13)

Work through the International Maritime Organization to encourage the application of human factors design principles to the design and manufacture of critical vessel controls. (M-11-14)

Facilitate and promote regular meetings for representatives of pilot oversight organizations to communicate information regarding pilot oversight and piloting best practices. (M-11-15)

Establish a database of publicly available pilot incidents and accidents and make the database easy to use and readily available to all pilot oversight organizations. (M-11-16)

To the Jefferson and Orange County Board of Pilot Commissioners:

Develop and implement (1) a system to monitor your state-licensed pilots so that your commission can verify the execution of policies, procedures, and/or guidelines necessary for safe navigation, and (2) a fatigue mitigation and prevention program among the Sabine pilots. (M-11-17)

To the Sabine Pilots Association:

Take action to ensure that your member pilots follow your guidelines with respect to division of duties and responsibilities of pilots. (M-11-18)

To governors of states and territories in which state and local pilots operate:

Ensure that local pilot oversight organizations effectively monitor and, through their rules and regulations, oversee the practices of their pilots to promote and ensure the highest level of safety. (M-11-19)

Require local pilot oversight organizations that have not already done so to implement fatigue mitigation and prevention programs that (1) regularly inform mariners of the hazards of fatigue and effective strategies to prevent it, and (2) promulgate hours of service rules that prevent fatigue resulting from extended hours of service, insufficient rest within a 24-hour period, and disruption of circadian rhythms. (M-11-20)

> Require local pilot oversight organizations that have not already done so to implement initial and recurring bridge resource management training requirements. (M-11-21)

To the American Pilots' Association:

> Advise your members to consistently identify vessels by name in bridge-to-bridge radio communication, as required by the Federal Communications Commission. (M-11-22)

4.2 Previous Recommendations Reiterated in This Report

To the U.S. Coast Guard:

> Require mariners to report to the Coast Guard, in a timely manner, any substantive changes in their medical status or medication use that occur between required medical evaluations. (M-09-4)

4.3 Previously Issued Recommendation Classified in This Report

To the U.S. Coast Guard:

> Establish a mechanism through which representatives of pilot oversight organizations collect and regularly communicate pilot performance data and information regarding pilot oversight and best practices. (M-09-5)

Safety Recommendation M-09-5 (previously classified "Open—Unacceptable Response") is classified "Closed—Unacceptable Response/Superseded" by M-11-15 and M-11-16 in section "2.4 Fatigue" of this report.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

DEBORAH A.P. HERSMAN
Chairman

CHRISTOPHER A. HART
Vice Chairman

ROBERT L. SUMWALT
Member

MARK R. ROSEKIND
Member

EARL F. WEENER
Member

Adopted: September 27, 2011

Member Sumwalt filed the following concurring statement on October 3, 2011. He was joined by Chairman Hersman, Vice Chairman Hart, and Members Rosekind and Weener.

Member Sumwalt, Concurring:

For vessels traversing the Sabine-Neches Canal with a beam width of 120 feet or greater, there is a local requirement for two pilots to be on board. This requirement was put in place a number of years ago, ostensibly to provide an extra margin of safety, by having one pilot backing up and assisting the other pilot.

According to Sabine Pilots Association guidelines, "both pilots shall be on the navigation bridge of the vessel and either shall be ready, willing and able to assume command of navigation of the vessel at all times."

Piloting a ship is very much a cognitive task – the pilot issues orders to the helmsman, then monitors to see that those orders are properly carried out, and finally, watches to ensure the ship responds as desired. It is an iterative process that involves active monitoring of orders, inputs, and response.

In order for the inactive pilot to be "ready, willing and able to assume command of navigation of the vessel at all times," that pilot would need to be actively engaged by listening, monitoring, and watching. Instead, the second pilot on board the *Eagle Otome* was resting and reading the newspaper during the *Eagle Otome*'s passage through the Sabine-Neches Canal. He told investigators that his first indication of a potential problem was when the first pilot asked, "Is she gonna come back?"

I firmly believe that if the second pilot had been more actively engaged in backing up and assisting the first pilot with pilotage duties instead of conducting non-pertinent activities, he could have provided valuable input which may have prevented the accident.

Those entrenched in the marine piloting profession may retort that this practice of doing non-pertinent activities such as reading is "just the way it is done" when two pilots are on board. Perhaps so, but I rhetorically ask: Just because it is always done, does this mean it is acceptable? Is it professional? Shipping companies pay large sums of money to have two pilots on board. That requirement is founded on the basis of safety; it is not for the purpose of allowing one pilot to read the newspaper while navigating a narrow channel.

I urge those who defend this practice to rethink your position. Generally speaking, the pilots of U.S. ports and waterways do an outstanding job; that said, is it time to raise the bar to an even higher level?

5. Appendixes

Appendix A

The Coast Guard notified the NTSB's communications center of the accident about 1130 eastern standard time on January 23. On January 25, three NTSB investigators arrived on scene about 1800 central standard time. The accident investigation was led by the Coast Guard with the NTSB participating. The NTSB's on-scene investigation concluded on February 3, 2010. No NTSB Board Member launched to the accident site.

The NTSB's investigator-in-charge returned to Port Arthur for the Coast Guard's public hearing on the accident, which took place March 9 through 11, 2010.

Appendix B

The ship traffic operating protocol, developed by SETWAC, in effect at the time of the accident:

SHIP TRAFFIC OPERATING PROTOCOL FOR THE SABINE-NECHES WATERWAY

THIS VOLUNTARY SHIP TRAFFIC OPERATING PROTOCOL (the "Protocol"), is made and entered into as of November 20, 2009, by and between the Southeast Texas Waterways Advisory Council (SETWAC) and the Sabine Pilots Association, collectively, the "Parties".

WITNESSETH:

WHEREAS, the Texas Transportation Code sets forth the compulsory Pilotage requirements in those waterways encompassing the Sabine-Neches waterway;

WHEREAS, Chapter 25 of Title 33 U.S. Code (Ports and Waterways Safety Program) and the regulations set forth in Title 33 of the Code of Federal Regulations endows the U.S. Coast Guard Captain of the Port with the authority to manage those navigable waterways of the United States within that Captain of the Port's defined boundaries;

WHEREAS, the charter of the Southeast Texas Waterways Advisory Council (SETWAC) allows regional stakeholders including but not limited to Port Authorities, shipping agents, marine terminals and the Sabine Pilots Association to develop policies and procedures for the safe and secure movement of commerce in the Sabine and Neches rivers and their approaches; and

WHEREAS, the aforementioned authorities permit stakeholders to provide advice and guidance to the applicable regulatory authorities – consistent with the Federal Advisory Committee Act – and the following protocol is intended to enhance navigation safety, define best practices and establish an equitable and fair approach to vessel traffic management consistent in accordance with the goals and intent of the Port and Waterways Safety Act:

NOW THEREFORE, in consideration of the mutual agreement of the shipping industry, waterway stakeholders, and with support of the U. S. Coast Guard and SETWAC, the following Protocol shall be administered by the Sabine Pilots Association.

VESSEL TRAFFIC COORDINATION

For vessels requiring or requesting a State Pilot, the Sabine Pilots will coordinate vessel movements in the waterway utilizing best vessel dispatch procedures consistent with overall efficiency and safety of the waterway. This shall include the coordination of such efforts with Vessel Traffic Service (VTS) Port Arthur as set forth in the VTS Port Arthur User Manual. In order for the Pilot Dispatch Office to do this, it is very important that the Pilot Office be kept well informed of expected vessel arrival and sailing times.

- The following procedure should be followed as closely as possible to enable the Pilot Office to make the most efficient use of the waterway in an effort to reduce delays. Advise the Pilot office as far in advance as possible but not less than four hours of any vessel's ETA and destination, along with its deep fresh water draft, air draft, length, beam, and DWT.
- Keep the pilot office abreast of any changes in ETA.
- When a vessel is in port, give notice as soon as possible, but not less than two hours of the vessel's ETS and deep fresh water draft.

The Pilots have agreed to, upon reasonable request, make available information to all impacted stakeholders as to the expected traffic schedule and any events that might cause delays.

NOTHING IN THIS AGREEMENT SHALL BE CONSTRUED AS LIMITING THE EXERCISE OF A PILOT'S GOOD JUDGMENT.

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TURNING BASINS

In order for the limitations on vessel movements to be kept at a minimum, it was agreed to utilize the turning basins at FINA and SUN OIL for the meeting of two vessels when circumstances make it unsafe for the vessels to meet. Based upon the pilots' discretion and vessel traffic flow, and in coordination with the Vessel Traffic Service, the inbound or outbound vessel will utilize the basins and allow the other vessel(s) passage. It is understood that tugs will be required to hold the vessel in the turning basins during this operation. The Pilot office will advise interests involved as to times vessels can be handled in these situations. If these basins are utilized properly, while perhaps causing a temporary delay in some cases, time on the inbound or outbound vessels can be gained. It is agreed that designated turning basins normally will not be used for anchorage. Vessels will vacate the basins as soon as possible.

VESSEL MOVEMENT AND MEETING LIMITATIONS

Vessels with any of the following criteria will move during daylight hours only above TEXAS ISLAND intersection.

- Vessels with a deadweight of 85,000 metric tons or greater
- Vessels with a LOA of 875 feet or longer
- Vessels with a beam of 125 feet or greater

Vessels with any of the above criteria may be shifted at any time to a nearby anchorage or adjacent dock at the discretion of the Pilot Office.

Vessels with a combined beam that equals or exceeds one-half the channel width will not meet day or night.

Vessels 85,000 metric deadweight tons or more will not meet vessels of either 30,000 metric deadweight tons or more, or 25 foot draft or more above TEXAS ISLAND intersection.

Vessels 85,000 metric deadweight tons or more will not meet vessels of 30,000 metric deadweight tons or more with a draft of 30 feet or more, above buoys 29 and 30.

Vessels 48,000 metric tons or more with a draft of 30 feet or more will not meet above buoys 29 and 30.

Vessels with a combined draft of 70 feet or more will not meet between the Neches River intersection and daybeacon #40 (Smith's Bluff) at night. Vessels with a combined draft of 65 feet or more will not meet above daybeacon #40 at night.

Meeting in bends should be avoided whenever possible or practical.

Vessels with a beam equal to or greater than one-half the width of the channel will move during daylight hours only in the Sabine River (200' wide Federal Channel leading to Orange).

DRAFT LIMITATIONS

The Federal waterway project depth currently allows vessels to transit with a maximum 40 foot draft. However, the most recent US Army Corp of Engineer's Hydrographic report, prevailing weather, and tidal conditions will govern the Sabine Pilot policy on maximum draft limitations.

NOTHING IN THIS AGREEMENT SHALL BE CONSTRUED AS LIMITING THE EXERCISE OF A PILOT'S GOOD JUDGMENT.

CHECK POINTS

Notwithstanding VTS reporting points as set forth in the VTS Users Manual, vessels shall report to the Pilot Office at the below listed check points as well as upon departure from a berth or anchorage. The dispatcher will use this information to ensure compliance with the above provisions of this agreement.

1. Sabine Bank Buoy, “SB”, Lat 29-25N Long 93-40W;
2. Buoys 29 and 30: Lat 29-36N Long 93-48W;
3. Daybeacon #40 on Sabine-Neches Canal; Mesquite Point;
4. Port Arthur turning basin;
5. Daybeacon #65; Neches River Intersection;
6. Daybeacon #40 in the Neches River.
7. Daybeacon #22 on the Sabine River at Orange Cut.

GENERAL GUIDELINES FOR VESSELS REQUIRING TWO PILOTS

Definitions: A Two Pilot Vessel is any vessel that meets either or both of the following criteria:

- Length Over All (LOA) of 860 feet or more.
- Beam of 120 feet or more.

Certain non-descript vessels, drill rigs, dead tows, etc. shall be considered by the Pilots on an individual basis to determine if two pilots are necessary.

In witness whereof, this agreement is executed the date first set forth herein.

SETWAC REP

[redacted]

Chairman-SETWAC

SABINE PILOTS ASSOC. REP

[redacted]

President-Sabine Pilots Assoc.

NOTHING IN THIS AGREEMENT SHALL BE CONSTRUED AS LIMITING THE EXERCISE OF A PILOT'S GOOD JUDGMENT.

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Appendix C

The Sabine Pilots Association guidelines in effect at the time of the accident:

GUIDELINES

GOVERNING ABOARD VESSELS REQUIRING TWO PILOTS WHEN TRANSITING THE SABINE NECHES WATERWAY

DEFINITIONS:

Conning means the pilot is in charge of piloting the vessel;

a) By directing the helmsman to turn the ship's rudder for steering, altering the course or maneuvering the vessel as, in his judgement, the existing circumstances and conditions dictate.

b) By directing the engines to operate in a way, so that, safe speeds are maintained at all times, as the vessel transits the waterway.

c) At times of reduced visibility he (the conning pilot) determines actions to be taken under the existing circumstances and conditions.

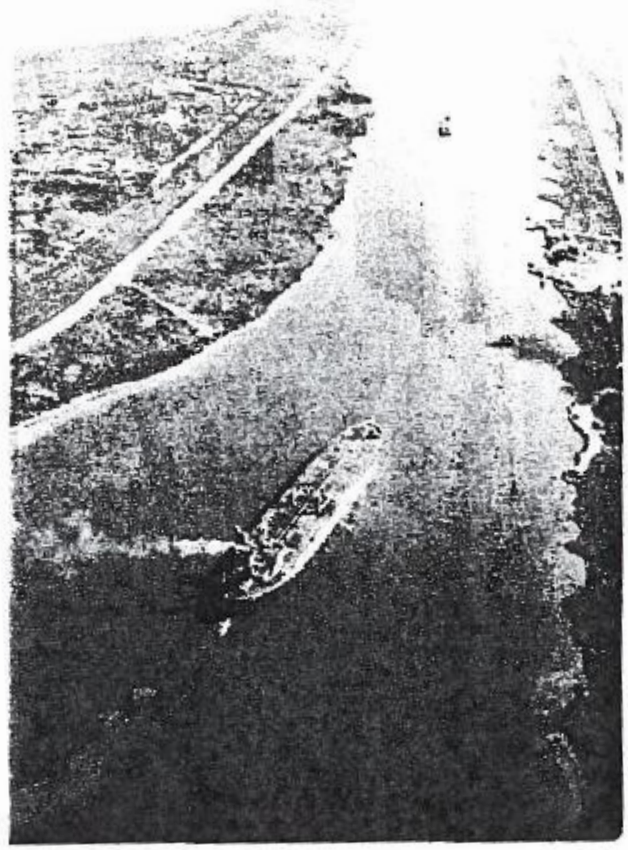
Radio Communications means the pilot must listen and handle all the radio communications relating to traffic, safety and position reporting established requirements, as the vessel transits the waterway.

Miscellaneous means:

a) Assist the pilot conning the vessel per his request.

b) Assist by providing information whenever dense traffic conditions prevail. Watch for clearance of traffic or other objects been obstructed by vessel's size or construction.

c) Inspect ship's particulars, arrange for tugs, brief the Captain of mooring arrangements. Provide any other assistance to the conning pilot and the master of the ship as requested.



INBOUND FROM SEA
DUTIES AND RESPONSIBILITIES OF PILOTS

PILOTING AREA	PILOT NO.1	PILOT NO.2
a) From Boarding Station to Beacon #40 (Port Arthur Canal)	Conning	Radio/Miscellaneous
b) From Beacon #40 (Port Arthur Canal) to School House (Chk. Pt. #3)	Radio/Misc.	Conning
c) From School House to Beacon #20 (FINA Highlines)	Conning	Radio/Misc.
d) From Beacon #20 (FINA Highlines) to SUN Terminal #5 included	Radio/Misc.	Conning & Docking
e) From SUN Terminal #5 to any destination above SUN #5	Conning & Docking	Radio/Misc.

OUTBOUND FOR SEA
DUTIES AND RESPONSIBILITIES OF PILOTS

PILOTING AREA	PILOT NO.1	PILOT NO.2
a) From Beaumont to SUN Terminal #5 (Chk. Pt. #5)	Radio/Misc.	Undock/Turn/Conn
b) From SUN Terminal #5 to Neches River Intersection	Undock/Turn/Conn	Radio/Misc.
c) From Neches River Intersection to Texas Island Intersection	Radio/Misc.	Undock/Turn/Conn
d) From Texas Island Intersection to Pilot Station	Undock/Turn/Conn	Radio/Misc.

Both pilots shall be on the navigation bridge of the vessel and either one shall be ready, willing and able to assume command of navigation of the vessel at all times.
The above guidelines as set by the Sabine Pilots should not be construed as limiting the assigned pilots in the exercise of their good judgement.

Appendix D

Timeline of events on the day of the accident and section of navigation chart 11342 showing the times of certain commands leading up to the accident, as recorded by the *Eagle Otome*'s S-VDR:

0524 The first pilot boards the *Eagle Otome* and takes the conn at the Sabine Fairway anchorage in the Gulf of Mexico.

0750 The second pilot boards the *Eagle Otome* at Sabine Pass in the Sabine-Neches Waterway.

0800 The second pilot takes the conn.

0904 The first pilot takes the conn.

0910 The *Eagle Otome* enters the Texas Island Intersection, a 38-degree turn to starboard, with a rudder order of starboard 20.

0914:34 The first pilot initiates a security call via VHF radio, announcing the *Eagle Otome*'s location and inquiring about outbound traffic near the bridge in Port Arthur.

0914:56 The *Dixie Vengeance* master answers the first pilot's security call, announcing that he is outbound with two loads about 3 miles north of the bridge.

0923:05 The *Dixie Vengeance* master announces his location (about 2 miles north of the bridge) via VHF radio, and he and the first pilot on the *Eagle Otome* engage in a 45-second conversation.

0923 The *Eagle Otome* enters Missouri Bend, a 32-degree turn to starboard, with the rudder at midship.

0923:54 The first pilot orders "hard to starboard" to initiate the turn at Missouri Bend.

0925 The *Eagle Otome* exits Missouri Bend, and the first sheering event occurs (to starboard, with the *Eagle Otome* near the east bank).

0928 The second sheering event occurs (to port, near the bridge, with the *Eagle Otome* close to the bridge's westside foundation).

0933 The third sheering event occurs (to starboard, with the *Eagle Otome* close to the east bank).

0933:35 The first pilot orders full ahead.

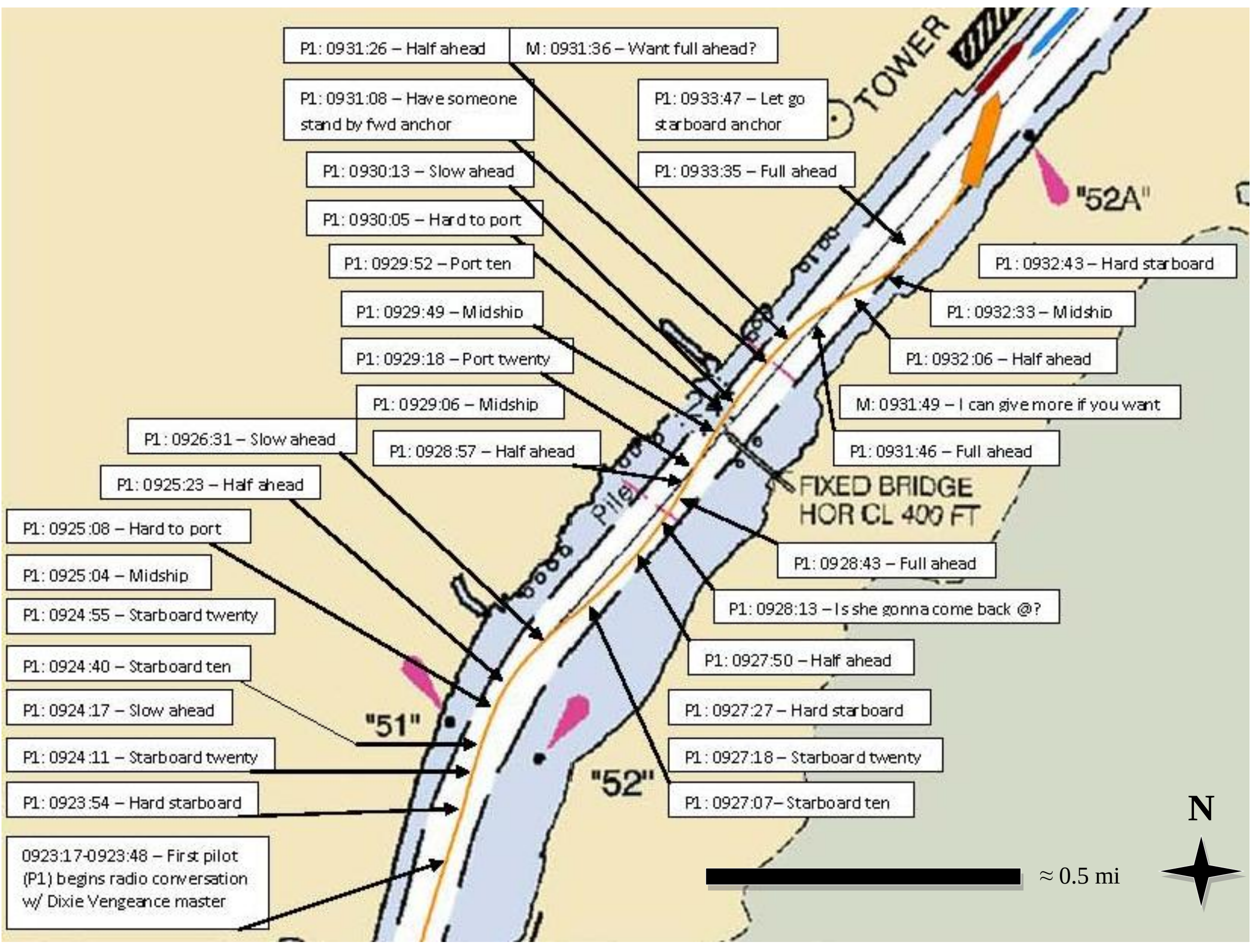
0933:46 The master tries to activate "navigational full ahead" and inadvertently presses the "manual emergency stop" button. (The master is able to restart the engine about 45 seconds later, and, as directed by the first pilot, then puts the engine full astern.)

0933:47 The first pilot orders the starboard anchor dropped.

0934 The fourth sheering event occurs (to port, toward the *Gull Arrow*, berthed at the Port of Port Arthur).

0934:20–25 The *Dixie Vengeance* master sees the *Eagle Otome*'s anchor drop and hears warning blasts from its whistle (sounded by the first pilot). He puts his engines full astern and sounds the towboat's emergency alarm.

0935 The *Eagle Otome* strikes the *Gull Arrow*; seconds later, the forward of the two barges pushed by the *Dixie Vengeance* strikes the *Eagle Otome*.



P1: First pilot

M: *Eagle Otome* master