Transportation Safety Board of Canada
Bureau de la sécurité des transports du Canada

MARINE TRANSPORTATION SAFETY INVESTIGATION REPORT M20C0188

COLLISION

General cargo vessels *Florence Spirit* and *Alanis*
Welland Canal, Ontario
11 July 2020

Canada

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Summary

On 11 July 2020, the general cargo vessels *Florence Spirit* and *Alanis* collided near mile 16 in the Welland Canal, Ontario. Both vessels sustained major damage to their hull structures. No injuries or pollution were reported.

1.0 FACTUAL INFORMATION

1.1 Particulars of the vessels

Table 1. Particulars of the vessels

Name	*Florence Spirit*	*Alanis*
International Maritime Organization (IMO) number	9314600	9468085
Official number	839979	4661
Port of registry	Hamilton	St. John’s
Flag	Canada	Antigua and Barbuda
Type	General cargo vessel	General cargo vessel
Gross tonnage	8935	9611
Length overall	136.43 m	138.07 m
Moulded breadth	21.2 m	21.0 m
Cargo	Coal in bulk (11 416 t)	Wind turbine towers (3204 t)
Design draft	8.364 m	8.0 m
Draft at the time of the occurrence	Forward 7.4 m, aft 7.8 m	Forward 6.1 m, aft 7.5 m
Displacement	17 873 t	17 971 t
Block coefficient based on draft at the time of the occurrence	0.76	0.801

Built	2004	2010
Propulsion	1 diesel engine of 4320 kW driving 1 controllable-pitch, left-handed propeller	1 diesel engine of 5400 kW driving 1 controllable-pitch, left-handed propeller
Crew	14	13
Owner	McKeil Marine	MS "Alina" Schifffahrtsgesellschaft mbH & Co. KG, Germany
Manager	McKeil Marine	Rambow Bereederungs GmbH & Co. KG, Germany
Classification society / recognized organization	Lloyd's Register	Bureau Veritas
Issuing authority for International Safety Management certification	Lloyd's Register	Bureau Veritas

1.2 Description of the vessels

1.2.1 *Florence Spirit*

The *Florence Spirit* (Figure 1) is a general cargo vessel built by the Kyokuyo Shipyard Corporation in Japan. The bridge, engine room, and accommodation spaces are located aft. The vessel has 4 cargo holds. The *Florence Spirit* is 1 of 3 sister ships.[1]

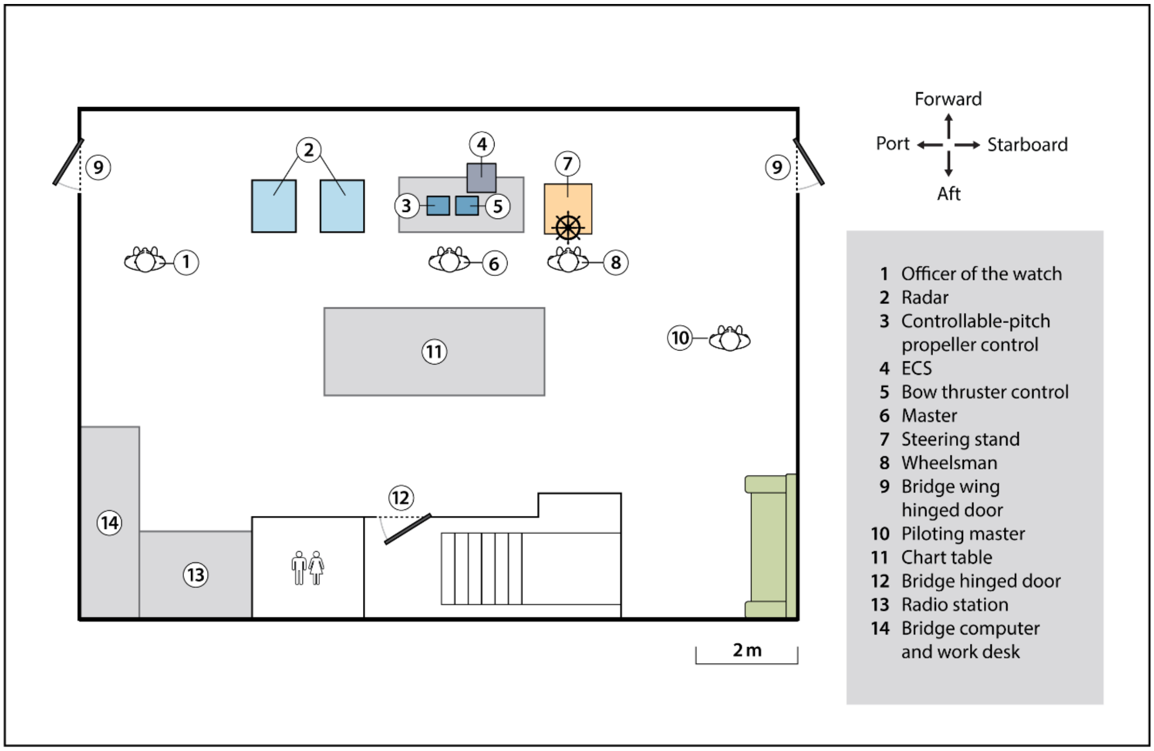
Figure 1. The Florence Spirit (Source: Rob Burdick)

The bridge is equipped with all of the required navigational equipment, including propulsion and bow thruster controls, an electronic chart system (ECS), and 3 cm and 10 cm radars (Figure 2). A 3-face rudder angle indicator is mounted on the bridge ceiling above the radars. The rudder angle indicator is graduated to depict the full range of rudder

1 The *Florence Spirit*'s sister ships are the *Longwave* (IMO 9287314) and the *NACC Argonaut* (IMO 9287302).

movement of 70° to port and starboard. The vessel also has an automatic identification system (AIS), a differential global positioning system (DGPS), and an echo sounder. A voyage data recorder is also installed on board.

Figure 2. Diagram showing the Florence Spirit's bridge layout (Source: TSB)



The *Florence Spirit* has a lower pintle high-efficiency fishtail rudder. It is the only vessel in McKeil Marine's fleet with this type of rudder. The rudder is made of steel and has a surface area of 14.85 m^2. It is paired with a rotary vane steering gear[2] that is capable of turning the rudder up to 70° to both port and starboard. The system is equipped with mechanical stoppers at 71.5°. The vessel also has a 550 kW tunnel bow thruster. The *Florence Spirit*'s manoeuvring characteristics[3] are available in Appendix A.

1.2.2 *Alanis*

The *Alanis* (Figure 3) is a general cargo vessel built by the Jiangxi Jiangzhou Shipyard in China. It is designed to carry containers, heavy cargoes, and cargoes in bulk. The vessel has 3 cargo holds and 2 cranes located on the vessel's port side. The engine room and accommodation spaces are located aft. The vessel has a 500 kW tunnel bow thruster.

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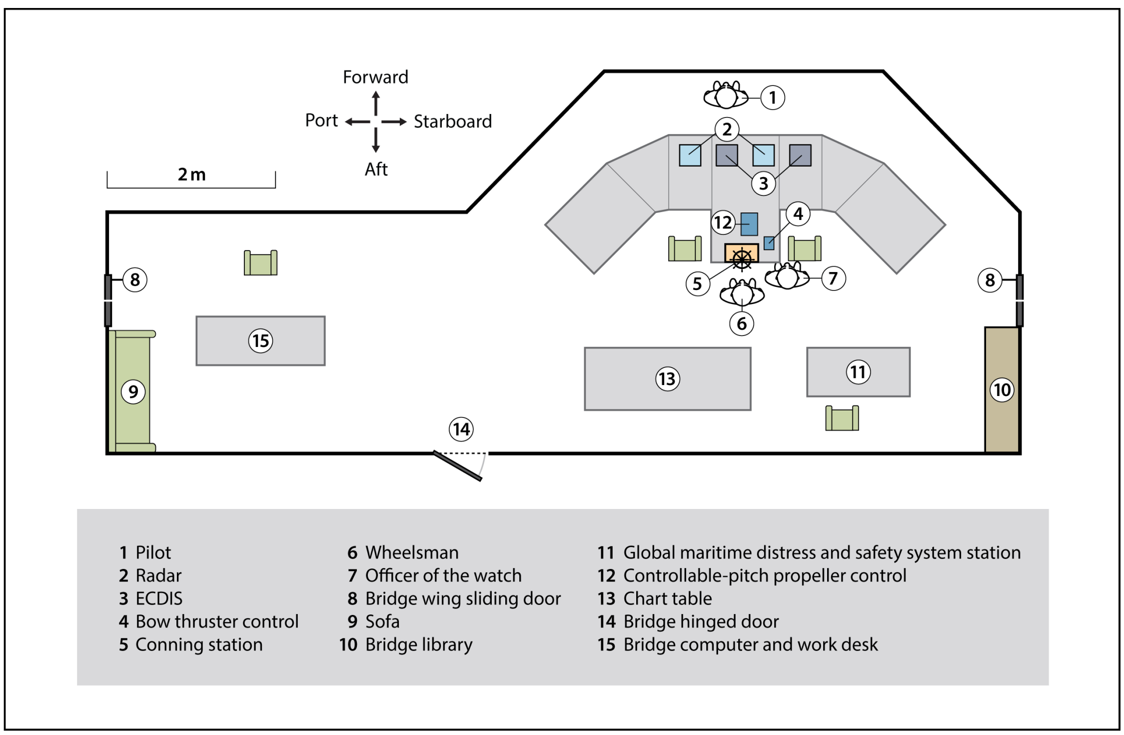
2 Prior to the occurrence, the steering gear had last been tested on 22 June 2020, and the steering movement times were found to be satisfactory.

3 The *Florence Spirit* was formerly known as the *Arklow Willow*. The manoeuvring characteristics document on board (Appendix A) still used this former name.

Figure 3. The Alanis (Source: Rambow Bereederungs GmbH & Co. KG)

The bridge is equipped with all of the required navigational equipment, including a navigation console that contains the conning station, propulsion controls, 3 cm and 10 cm radars, and an electronic chart display and information system (ECDIS) (Figure 4). The vessel is equipped with a DGPS and an AIS. A voyage data recorder is also installed on board.

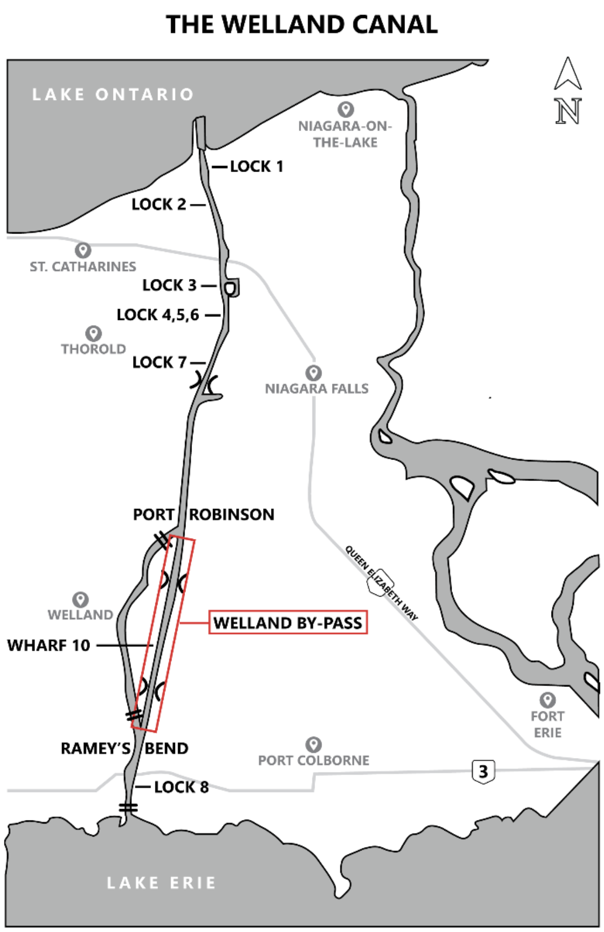
Figure 4. Diagram showing the Alanis's bridge layout (Source: TSB)



1.3 Description of the Welland Canal

The Welland Canal is located in the western section of the St. Lawrence Seaway and links Lake Ontario and Lake Erie via a series of 8 locks (Figure 5). During the 2019 season, the Welland Canal was open from 22 March 2019 to 08 January 2020, and 3186 vessels transited it during this period.[4] The maximum allowable vessel beam is 23.77 m, and the maximum allowable vessel length is 225.5 m. The nominal allowable vessel draft is 8.08 m.

Figure 5. The Welland Canal (Source: Third party, with TSB modifications)



The St. Lawrence Seaway is managed jointly by the St. Lawrence Seaway Management Corporation (SLSMC) and the United States St. Lawrence Seaway Development Corporation. The SLSMC manages vessel traffic in the Welland Canal via Seaway Traffic Control.

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4 St. Lawrence Seaway Management Corporation and Saint Lawrence Seaway Development Corporation, "The St. Lawrence Seaway 2019 Traffic Report," at https://greatlakes-seaway.com/wp-content/uploads/2020/03/traffic_report_2019_en.pdf (last accessed 04 October 2021).

Vessels transiting the Welland Canal may meet other vessels transiting in the opposite direction at certain locations along the canal. The SLSMC has designated some locations as no-meeting areas, and Seaway traffic controllers also have the authority to prohibit meetings at certain locations.[5] Vessels may make meeting arrangements if needed, and Seaway traffic controllers may assist with these arrangements upon request.

The SLSMC has a handbook that prescribes speed limits for different parts of the Seaway. The speed limit for the Welland Canal is 6 knots, with the exception of the Welland By-Pass, where the speed limit is 8 knots.[6,7] The Welland By-Pass is a relatively straight 13.4 km section of the canal between Port Robinson and Ramey's Bend (Figure 5). The By-Pass has a navigable width of 106.7 m and a water depth of 9.1 m. Vessels are permitted to meet in the Welland By-Pass.

In 2004–2005, speed tolerances were introduced to allow vessels to increase their speed above the established speed limit for a limited duration to accommodate special manoeuvres for safe navigation. The degree of tolerance depends on a vessel's particulars, navigation conditions, and environmental conditions.

In areas where speed tolerances are in effect, the highest speed that a vessel is allowed to transit (the maximum speed limit + the speed tolerance) is commonly referred to as the "maximum permissible speed" by Seaway Traffic Control, as well as mariners who regularly transit the Seaway, although this term is not defined in Seaway documentation. At the time of the occurrence, the Welland By-Pass had a speed tolerance of 1.9 knots above the published maximum speed limit of 8 knots, for a maximum permissible speed was 9.9 knots.

1.4 History of the voyage

1.4.1 *Alanis*

On 09 July 2020, the *Alanis* departed Montréal, Quebec, Canada, bound for Duluth, Minnesota, U.S. On 11 July at 0055,[8] the *Alanis* arrived at Lock 1 of the Welland Canal. Due to a traffic backlog[9] in the canal, the *Alanis* remained secured at Lock 1 until 0720, at which time the vessel was able to proceed upbound in the canal. By about 1330, the *Alanis* was departing from Lock 7. The bridge team on the *Alanis* at that time consisted of a Great Lakes

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5 St. Lawrence Seaway Management Corporation, *Seaway Handbook*, "Joint Practices and Procedures Respecting the Transit of Ships on the St. Lawrence Seaway" (March 2020), Part 3: Seaway Navigation, section 31: Meeting and passing, p. 21.

6 Ibid., Schedule II: Table of Speeds, p. 50.

7 The main factors that were taken into consideration when establishing the speed limit were navigation safety, the water column available in the channel, the integrity of the infrastructure, and prevention of erosion of the canal banks.

8 All times are Eastern Daylight Time (Coordinated Universal Time minus 4 hours).

9 The day before, 10 July 2020, a power outage had resulted in the Welland Canal closing to vessel traffic for around 10 hours, causing a traffic backlog.

Pilotage Authority (GLPA) pilot, a wheelsman, and the second officer, who was the officer of the watch.

Upon departing Lock 7, the *Alanis* proceeded at reduced speed in order to time meetings with the *Florence Spirit* and 2 other vessels in the area between Port Robinson and Ramey's Bend.

1.4.2 *Florence Spirit*

On 10 July 2020, the *Florence Spirit* departed Toledo, Ohio, U.S., bound for Saguenay, Quebec, Canada. On 11 July at 0925, the vessel arrived at Wharf 16 in Port Colborne, Ontario, and was delayed there due to the traffic backlog in the Welland Canal. At 1325, the crew completed the pre-departure checklist, which involved testing the vessel's steering system and the main engine, among other things. All systems were found to be in good working order.

At 1446, the *Florence Spirit* departed Wharf 16 and proceeded downbound toward Lock 8. At this time, the vessel was being steered in follow-up mode[10] with 2 steering gear pumps in use. The bridge team consisted of the master, a wheelsman, and the second officer, who was the officer of the watch. A piloting master was also on the bridge for the purpose of training the master. The piloting master, an employee of McKeil Marine, held a GLPA pilotage certificate that authorized him to conduct company vessels in compulsory pilotage areas. The piloting master was training the master to obtain a pilotage certificate at the piloting master level. The master was on his 12th of 15 training trips required to obtain this certificate.[11]

At 1523, a Seaway traffic controller called the master of the *Florence Spirit* on the very high frequency (VHF) radiotelephone and asked for the vessel's estimated time of arrival (ETA) at the basin south of Lock 7 if the vessel was proceeding at the maximum permissible speed. After discussing the traffic controller's question with the piloting master, the master replied to the traffic controller that it would take 1 hour and 30 minutes to get to the basin. At this time, the master was attempting to manoeuvre the vessel out of Lock 8 but was encountering hydrodynamic forces that were causing the vessel to move sideways in the lock, which impeded its departure and delayed its transit to Lock 7.

At 1527, while the *Florence Spirit* was still in Lock 8, the pilot on the *Alanis* and the master of the *Florence Spirit* started to communicate using an instant messaging program about the upcoming meeting of the vessels in the Welland By-Pass. The master of the *Florence Spirit*

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10 Follow-up mode is the most common way to steer a vessel in restricted waters. In follow-up mode, the rudder responds to steering commands inputted at the steering wheel. The system makes automatic adjustments to ensure that the rudder corresponds to the requested angle at all times.

11 The *Great Lakes Pilotage Regulations* require applicants to complete a minimum of 15 trips in each compulsory pilotage area in which the applicant intends to perform pilotage duties.

used his personal cellphone to send messages, and the pilot on the *Alanis* used his portable pilotage unit (PPU).[12] The pilot and the master knew each other from working together at a previous company where the master had been the pilot's subordinate.

The initial message, sent by the pilot, indicated that the master had full discretion to select whatever speed and manoeuvres he felt appropriate for the upcoming meeting. The pilot and master then continued to exchange messages about the hydrodynamic forces affecting the *Florence Spirit* in Lock 8. The pilot indicated to the master that wide-beam loaded vessels like the *Florence Spirit* will move sideways in the lock if too much propulsion is applied. The master then indicated that he would increase the *Florence Spirit*'s speed once past Ramey's Bend, and the pilot indicated that the *Alanis* was proceeding slowly.

After exiting Lock 8 at around 1534, the *Florence Spirit* proceeded toward Ramey's Bend at 6 knots. The master was providing helm orders to the wheelsman and was controlling the propeller's pitch. At 1539, the master and the piloting master identified that the ETA they had provided to the Seaway traffic controller would be difficult to meet and discussed whether meeting the ETA would be possible.

At 1543, the *Florence Spirit* passed Ramey's Bend and entered the Welland By-Pass. At 1544, the master increased the propeller's pitch to 57% ahead.[13] At some point around this time,[14] the pilot on the *Alanis* sent a message to the master of the *Florence Spirit* indicating that when the *Alanis* was around 0.8 nautical miles (NM) from the *Florence Spirit*, he would alter course to starboard by 4°. The pilot also indicated that keeping a vessel in the centre for as long as possible reduces bank suction. The master of the *Florence Spirit* acknowledged the pilot's plan and indicated that he would do the same.

The pilot on the *Alanis* also advised the master of the *Florence Spirit* to maintain the separation between the vessels and alter course gradually so that the vessels would be on parallel courses when they met. The pilot indicated that a high-speed pass worked best in this situation. The master of the *Florence Spirit* verbally relayed to the piloting master the contents of the messages that he had exchanged with the pilot on the *Alanis*.

A watch handover was then done on the *Florence Spirit*, with the wheelsman handing over to the incoming wheelsman, and the second officer handing over to the chief officer. By

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12 A PPU is a computer-based portable electronic device that allows pilots to use their own electronic charts and routes to assist them in navigating vessels.

13 On the *Florence Spirit*, a pitch of 55% ahead corresponds to half ahead, a pitch of 65% ahead corresponds to full ahead, and a pitch of 100% ahead corresponds to full ahead sea speed. Between 1543 and 1605, the pitch was moved between 57% ahead and 54% ahead to maintain the vessel at a speed over ground of 9.9 knots.

14 The exact times at which the instant messages were transmitted could not be determined because the instant messaging applications in use did not timestamp individual messages.

1549, the *Florence Spirit* was proceeding at a speed of 9.9 knots.[15] The master and the piloting master again discussed concerns about making the ETA for the next lock. The piloting master told the master to keep the *Florence Spirit*'s speed up.

At 1551, the piloting master asked if the *Florence Spirit* was positioned in the middle of the channel. The *Florence Spirit* was to the starboard side of the centreline at a cross-track distance (XTD) of 13 m[16] at this time. The wheelsman adjusted the heading to 016° gyro (G).[17] Shortly afterwards, the wheelsman informed the piloting master that the *Florence Spirit* was in the centre of the channel.

Around 1556, the piloting master asked for clarification from the master as to whether the pilot on the *Alanis* wanted the *Florence Spirit* to maintain its speed. The master replied that the pilot had no preference about the *Florence Spirit*'s speed.

At 1557, the *Florence Spirit* was to the starboard side of the centreline at an XTD of 12 m. To maintain the ordered course of 016°G, the wheelsman applied the rudder up to 20° to starboard (Appendix B).

1.4.3 Collision sequence

At 1603, the distance between the 2 vessels was approximately 0.8 NM. Shortly after, both the master of the *Florence Spirit* and the pilot on the *Alanis* gave orders to alter course by 4°. The pilot on the *Alanis* ordered course change to 200°G while the *Alanis* was proceeding at 2.9 knots. The master of the *Florence Spirit* ordered a course change to 020°G while the *Florence Spirit* was proceeding at 9.8 knots at an XTD of 8 m (Figure 6).

At 1604:30, the *Florence Spirit* had reached an XTD of 20 m and the wheelsman was applying the rudder up to 35° to starboard to reach the ordered heading of 020°G, but the vessel's heading was at 18.5° and reducing. At 1604:57, the wheelsman increased the rudder to 46° in an attempt to reach 020°G, but the vessel's heading was at 18°G and continuing to reduce. The wheelsman then applied varying degrees of starboard rudder as he continued to attempt to reach the ordered heading (Appendix B). Shortly after, the *Florence Spirit* was at an XTD of 28 m at 9.2 knots. The rudder was positioned at 36° and the vessel's heading was still decreasing.

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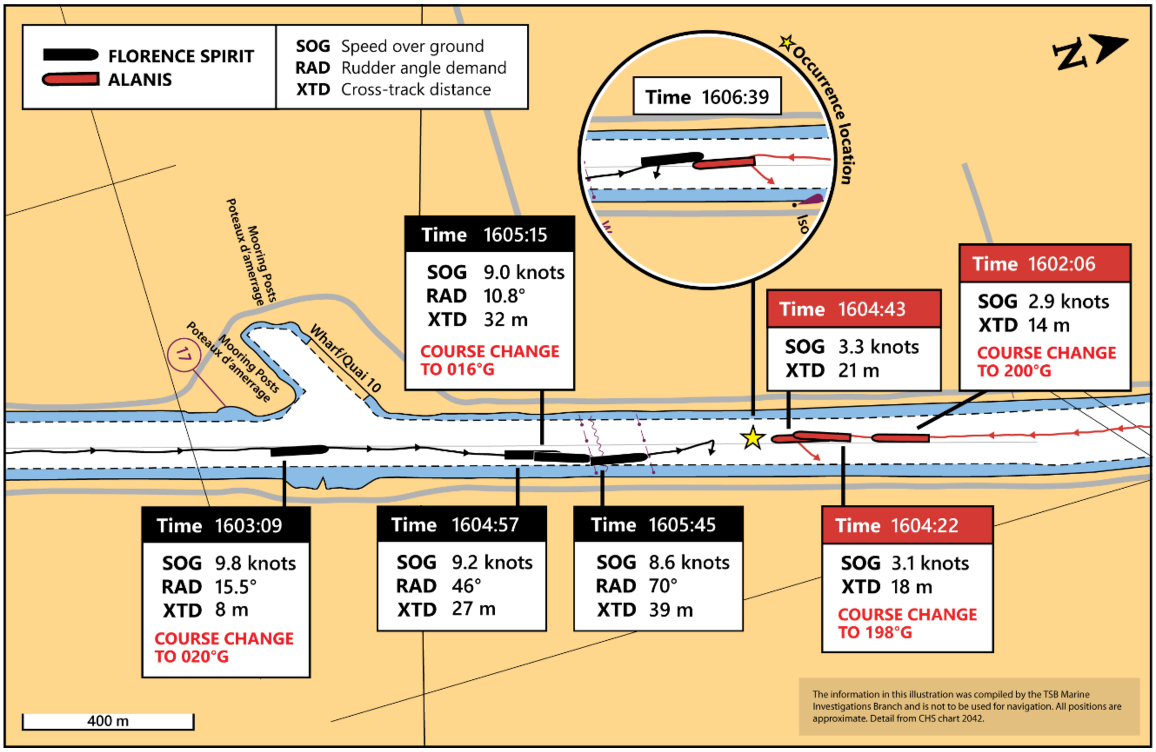
15 All speeds are speed over ground, unless otherwise stated.

16 For the voyage through the Welland Canal, the *Florence Spirit*'s ECS was programmed to measure the vessel's XTD in relation to the centreline of the canal. The ECS XTD function therefore measured the distance between the centreline of the canal and a receiver located on the aft midship section of the vessel.

17 Heading information was obtained from the gyrocompass.

Figure 6. Diagram showing the tracks of the Florence Spirit and the Alanis leading up to the collision (Source: TSB)



By 1605:15, the *Florence Spirit*'s distance off the centreline had increased to an XTD of 32 m,[18] with the speed remaining around 9 knots. The distance between the 2 vessels was 0.38 NM. The master of the *Florence Spirit* ordered the wheelsman to steer to 016°G, with the goal of bringing the vessel parallel to the centre of the channel. The wheelsman reduced the rudder from 30° to 10° starboard.

A few seconds later, the piloting master on the *Florence Spirit* cautioned the wheelsman about the potential for bank suction. Seconds later, the *Florence Spirit* started to sheer to port (Figure 7).

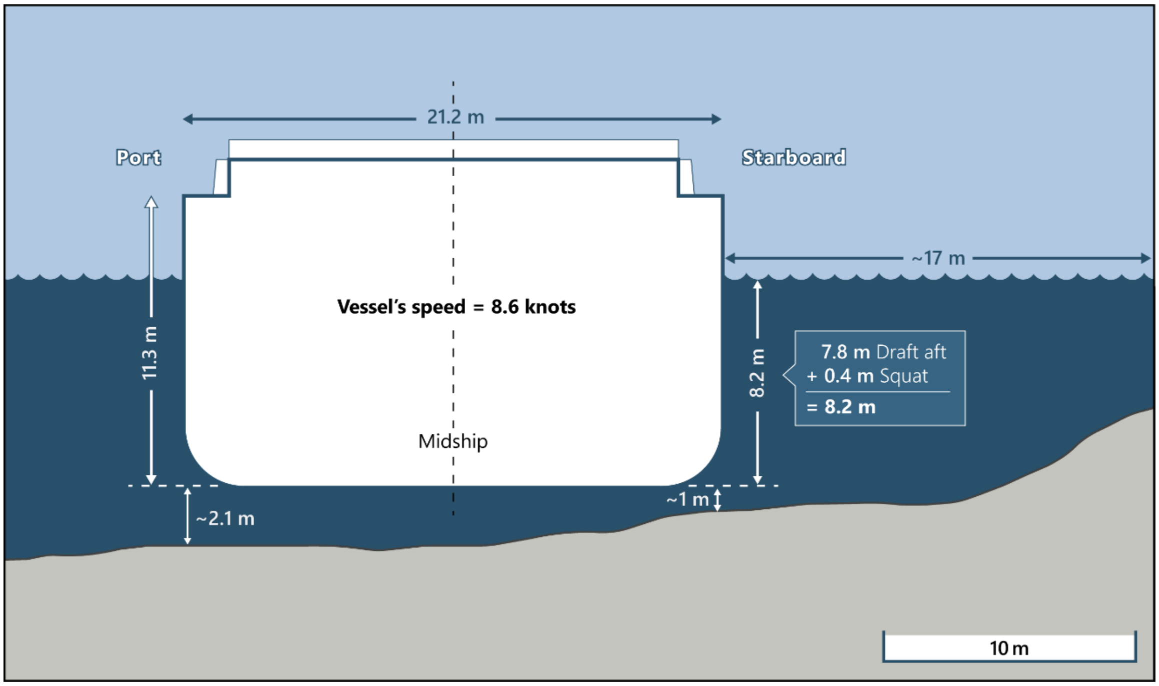
18 The area of the canal where the collision took place has a navigable width of approximately 39 m to each side of the canal centreline.

Figure 7. Four images taken prior to the collision, showing the Florence Spirit sheering to port over a period of 47 seconds, as seen from the Alanis (Source: ALANIS / Rambow Bereederungs GmbH & Co. KG)

At 1605:24, the pilot ordered a course change to 198°G to bring the *Alanis* parallel to the centreline of the canal. Around this time, the pilot also ordered the second officer to set the propeller's pitch to 50% ahead for better steerage during the meeting.

Once the *Florence Spirit* began to sheer, the piloting master ordered the wheelsman to steer hard to starboard. The wheelsman applied the rudder to 70° in response. The master of the *Florence Spirit* then set the propeller's pitch to 91% ahead, increasing the vessel's speed, in an attempt to regain control of the vessel. At 1605:45, the *Florence Spirit* was continuing to sheer to port at a rate of turn of 26° per minute. The distance between the 2 vessels was 0.29 NM. While sheering, the *Florence Spirit* reached a maximum XTD of 39 m at 8.6 knots (Figure 8).

Figure 8. Drawing of the Florence Spirit when it reached the navigable limit of the canal (Source: TSB)



At 1606:12, the pilot on the *Alanis* observed the *Florence Spirit* sheering to port and ordered the second officer to activate the general alarm, which the second officer did. The pilot then requested that the second officer set the propeller's pitch to 0% and ordered the crew to proceed to the bow and stand by to deploy the anchors. The chief officer and crew members proceeded to the bow.

At 1606:30, the master of the *Florence Spirit* ordered the crew to deploy the anchors and asked the piloting master if full astern should be applied. The piloting master responded affirmatively. The master then set the propeller's pitch to full astern. At this time, the 2 vessels' bows were approximately 20 m apart. The *Florence Spirit*'s speed was 6 knots, and the *Alanis*'s speed was 3.5 knots. The *Florence Spirit* continued to sheer to port, crossing over the canal's centreline into the path of the *Alanis*.

At 1606:39, the starboard side of the *Florence Spirit*'s bow collided with the starboard side of the *Alanis*'s bow above the waterline while the vessels were in position 42°58.73' N, 079°13.25' W (Appendix C).

The pilot on the *Alanis* contacted Seaway Traffic Control to inform them of the collision and called the master of the *Florence Spirit* on VHF radiotelephone to inform him that the *Alanis* was going to proceed past the *Florence Spirit's* port side. The master of the *Florence Spirit* acknowledged the pilot's message. The *Alanis* proceeded to Wharf 12 in Port Colborne to carry out repairs. The *Florence Spirit* proceeded stern-first to Wharf 10 in the Welland By-Pass under the conduct of the piloting master. At this time, the *Florence Spirit* had a 7° list to starboard. No pollution or injuries were reported.

1.5 Damage to the vessels

1.5.1 *Florence Spirit*

The *Florence Spirit* sustained damage to the forward starboard section of its hull (Figure 9). The forecastle, starboard shell plating, and associated internal structure were deformed and cracked. The hull was punctured, and a ballast water tank and a cargo hold were breached and partially flooded. The forward bulwarks, railings, vents, and pipework were also damaged.

Figure 9. Damage to the forward starboard section of the Florence Spirit's hull (Source: TSB)

1.5.2 *Alanis*

The *Alanis* sustained damage to the forward starboard section of its hull (Figure 10). There were multiple perforations and deformation of the shell plating. The starboard anchor flukes were also bent.

Figure 10. Damage to the forward starboard section of the Alanis's hull (circled) (Source: TSB)

1.6 Environmental conditions

At the time of the occurrence, the sky was overcast and there were flat light conditions.[19] The visibility was good. The winds were from the west at 10 knots, and the air temperature was 20 °C.

The confined nature of the canal prevents any significant sea state. The water level at Lock 8 was 173.59 m above sea level.

1.7 Vessel certification

1.7.1 *Florence Spirit*

The *Florence Spirit* carried all of the required certificates for a vessel of its class and for the intended voyage. The vessel was certified as a Convention vessel. The *Florence Spirit*'s safe manning document was issued for Near Coastal Class 2 voyages and required 1 master with

[19] In flat light conditions, there is diffused lighting due to cloudy skies, which reduces or eliminates contrast and shadows.

a Master, Near Coastal certificate of competency; 1 chief officer with a Chief Mate, Near Coastal certificate of competency; and 1 watchkeeping mate with a Watchkeeping Mate, Near Coastal certificate of competency.

The vessel operated under a safety management system (SMS) as required by the International Safety Management (ISM) Code.

1.7.2 *Alanis*

The *Alanis* carried all of the required certificates for a vessel of its class and for the intended voyage. The vessel was certified as a Convention vessel. The vessel operated under an SMS as required by the ISM Code.

1.8 Personnel certification and experience

1.8.1 *Florence Spirit*

The master held a Master, Near Coastal certificate of competency issued in 2019. He had joined McKeil Marine in May 2019 as a chief officer and had sailed in this position on several company vessels, including the *Florence Spirit*, in 2019. In May 2020, the master started training as master on board another company vessel, the *Blair McKeil.* On 16 June 2020, he was promoted to the rank of master of the *Florence Spirit*. He had completed 4 trips in the Welland Canal as master of the *Florence Spirit*.

The master also held a pilotage certificate (Piloting Mate level) issued by the GLPA in 2017 and had been in training to obtain his piloting master level since June 2019. At the time of the occurrence, he was completing his 12th of 15 training trips in District 2.[20] He had also completed a St. Lawrence River pilotage course for piloting mates at the Georgian College Centre for Marine Training and Research in 2016. This course included simulator training.

The master had previous navigational experience that included manoeuvring large vessels like the *Florence Spirit* close to the sides of the South Shore Canal in Quebec, while proceeding at speeds of around 6 knots. The master had completed bridge resource management (BRM) training in 2014.

The piloting master held a Master, 500 Gross Tonnage, Near Coastal certificate of competency issued in 2008. He also held a valid Chief Mate, Near Coastal certificate of competency issued in 2016. The piloting master held a pilotage certificate (Piloting Master level) issued by the GLPA in 2013. In 2017, after the piloting master had successfully completed a GLPA-approved Train the Trainer course, the GLPA had approved him to become a trainer and evaluator on all McKeil Marine vessels transiting in all GLPA districts,

[20] District 2 includes the waters of the Welland Canal between Port Weller and Port Colborne, Ontario; the Canadian waters of Lake Erie; and the Canadian portion of the waters connecting Lake Erie and Lake Huron to a latitude of 43°05.5' N.

except for District 3.[21] In April 2020, McKeil Marine promoted the piloting master from chief officer to a supernumerary piloting master trainer[22] on its vessels *Florence Spirit*, *Wicky Spirit*, *Blair McKeil*, and *Hinch Spirit*. In this position, the piloting master moved between vessels in the fleet to train the masters to obtain pilotage certificates.

The piloting master had joined the *Florence Spirit* on 16 June 2020 to train the master to obtain his piloting master level. The piloting master had sailed as a chief officer on board McKeil Marine's bulk carriers *Evans Spirit* and *Florence Spirit* from November 2016 to December 2019. He had joined McKeil Marine in 1990 and began working as a master on company tugs in 1999 in the Great Lakes area, including in the Welland Canal. He had completed BRM training in 2005 and had taken a Simulated Electronic Navigation level 2 course in 1990.

The piloting master's experience included conducting meetings above 9 knots in the Welland Canal.

The chief officer held a Master Mariner certificate of competency issued in 2018. He had joined McKeil Marine in September 2019 and had sailed as second officer and chief officer on company bulk carriers before joining the *Florence Spirit* on 16 April 2020. The same day that he joined the *Florence Spirit*, he started training to obtain a pilotage certificate (piloting mate level). The chief officer had completed BRM training in 2012. He had also completed the Leadership and Managerial Skills course in 2016. The occurrence voyage was his first trip in the Welland Canal.

The wheelsman held a Bridge Watch Rating certificate issued in October 2019. He had joined McKeil Marine in April 2020. Upon joining, he had completed McKeil Marine's crew familiarization on board, as well as skills training modules for company employees. He had completed 1 rotation of 5 weeks as a wheelsman on the *Florence Spirit* before rejoining for another rotation on 02 July 2020. Prior to working on the *Florence Spirit*, he had worked as a wheelsman on the *Saginaw*. He had started his marine career as a deckhand in September 2018.

1.8.2 *Alanis*

The pilot held an unrestricted pilot licence for District 2 issued by the GLPA on 19 August 2017. He also held a valid Master, Near Coastal certificate of competency. In 2018, he had completed a 2-day course on BRM for pilots.

[21] District 3 includes the Canadian waters of Lake Huron north of latitude 43°05.5' N, Georgian Bay, and the Canadian waters of Lake Superior, including the Canadian waters of the St. Mary's River.

[22] The supernumerary piloting master trainer was a new position at McKeil Marine that had been developed to address a shortage of masters with a piloting master level on bulk carriers. McKeil Marine was pairing these trainers with masters who did not have their piloting master level in order to train the masters.

The second officer held an Officer in Charge of a Navigational Watch certificate issued in 2016 and had worked as an officer since 2016. He had joined the *Alanis* as second officer in February 2019.

1.8.3 Human factors

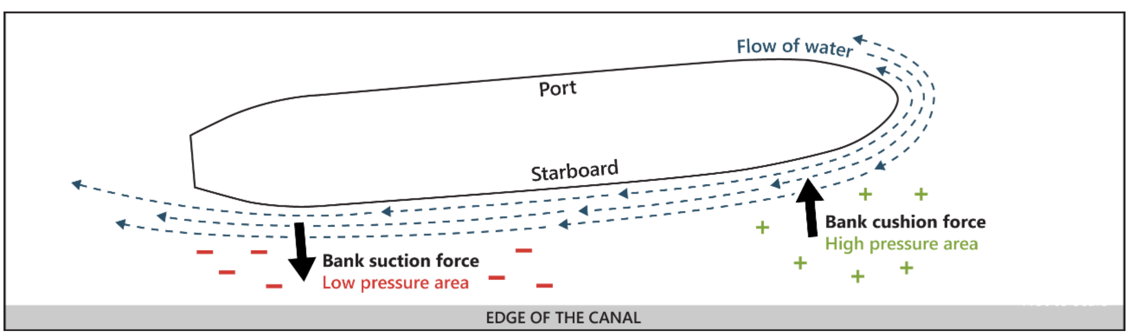
The investigation examined fatigue, medical, and physiological factors, but none were found to have affected the performance of the individuals involved in the occurrence.

1.9 Navigation in confined waters

When navigating in confined waters, a vessel is subject to various hydrodynamic effects that can influence its manoeuverability, one of which is bank effect. Bank effect occurs when a vessel transiting near the bank of a channel is affected by forces caused by the interaction between the side of the vessel and the bank. The closer a vessel gets to the bank, the greater these effects will be.

Bank effect is generated primarily by 2 forces: bank cushion and bank suction (Figure 11). Bank cushion affects the vessel's bow. As the vessel gets closer to the bank of a channel, the bow wave pushes against the bank and creates a cushion that forces the bow away from the bank and produces a yawing movement. The water from the bow wave is then squeezed between the hull and the bank as the vessel proceeds, flowing faster on the side of the vessel that is closer to the bank and making the forces around the vessel asymmetrical. This causes a low pressure area to develop further aft, which results in bank suction at the vessel's stern. This tends to pull the stern toward the bank, which also produces a yawing movement. The combination of the bow pushing away from the bank and the stern pulling toward it creates the potential for the vessel to sheer abruptly toward midchannel.[23,24]

Figure 11. Diagram illustrating bank effect (Source: TSB)



[23] J. F. Kemp and P. Young, *Seamanship Notes*, 5th edition (Butterworth-Heinemann, 1992), p. 35.

[24] Captain D. Parrott, "Bank effect: It can happen when you least expect it," at soundingsonline.com/voices/bank-effect-it-can-happen-when-you-least-expect-it (last accessed on 08 July 2022).

Bank effect is amplified when a vessel is transiting at high speed. A vessel will develop a bigger bow wave when it is moving faster, increasing the bank cushion, compared to a vessel travelling at a slower speed. Bank suction will also amplify because the low pressure forces near the stern increase if the vessel is moving quickly. The minimum safe distance that a vessel must maintain from a bank will change based on the vessel's speed, with a faster vessel requiring more distance.[25]

The influence of bank effect also differs depending on a vessel's type and size. For example, a tug transiting in confined waters may be less susceptible to bank effect than a cargo vessel like the *Florence Spirit* because the tug has a shallower draft, smaller breadth, and lower maximum operating speed. Another factor that can influence bank effect is a vessel's hull shape. A vessel with a box-like hull shape, such as the *Florence Spirit*, will have a higher block coefficient and will displace more water than a vessel with a finer hull of the same length, beam, and draft. A higher block coefficient will increase bank effect because the fuller hull shape constricts the flow of water between the hull and the bank. Other factors that amplify bank effect include the channel profile and the vessel's draft.

1.9.1 Mitigating bank effect during vessel meetings

Bank effect can affect vessels at any time while transiting in confined waters, but the risk increases during meetings because vessels are forced to move off the centre of the channel and proceed closer to the bank in order to pass by one another. For this reason, it is common for navigators to keep their vessels in the centre of a channel for as long as possible before altering course to meet another vessel. According to *The Shiphandler's Guide*, "it is important […] when meeting another ship, not to move over to the starboard side of the canal too early or too far."[26] A course alteration to allow for a meeting between larger vessels usually begins between 0.4 to 0.8 NM before the meeting, depending on the speeds of the vessels.

A safe speed to meet another vessel in confined waters can be determined by assessing the visibility, the manoeuvrability of the vessel, the width of the channel, and the vessel's draft in relation to the water depth. Slower meeting speeds give navigating officers more time to assess and react to any navigational errors, mechanical failures, or other complications. It is important that a vessel's speed is sufficient to maintain control adequately but still allows for extra propulsion power to be available to aid the rudder if necessary.[27]

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25 P. Du, A. Ouahsine and P. Sergent, "Influences of the separation distance, ship speed and channel dimension on ship maneuverability in a confined waterway," *Comptes Rendus Mécanique*, Vol. 346, Issue 5 (2018), pp. 390–401.

26 Captain R. W. Rowe, *The Shiphandler's Guide* (The Nautical Institute, 2000), p. 60.

27 UK Maritime and Coastguard Agency, "Marine Guidance Note – MGN 199 (M): Dangers of interaction," at assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/282279/mgn199.pdf (last accessed on 08 July 2022).

A common strategy during meetings involving larger vessels is for the vessels to mirror each other's speeds and course alterations in order to leverage the repulsive forces generated between them to counteract sheer and compensate for bank effect. Navigators also use the rudder and engine to counteract bank effect.

1.9.2 St. Lawrence Seaway Handbook guidance

The SLSMC publishes a Seaway Handbook that provides some information about bank suction, ship meetings, and safe speed. With respect to bank suction, the Seaway Handbook that was in force at the time of the occurrence stated:

> a) **BANK SUCTION -** A ship sailing in the proximity of one of the banks of a channel will experience bank suction forces, which are caused by the asymmetrical flow of water around the ship. The closer a ship nears a bank the larger the bank suction forces become. It is therefore important that ships do not get too close to any of the banks.[28]

With respect to ship meetings, the Seaway Handbook provided the following information:

> b) **SHIP MEETING -** Hydrodynamic interaction will take place between two ships meeting or passing each other, either going in the same direction or in opposite directions. The interaction forces and moments on the ships will cause course deviation and yaw to occur. It is important that ships maintain adequate separation when passing or meeting. At present there is insufficient information to determine a "safe" separation distance based on ship size, speed, rudder activity, etc. However, for ships meeting, it is considered that a separation of half the combined beam width of the ships should provide a safe minimum distance. For ships overtaking, the Ministry of Transport recommends a separation of not less than one to two beam widths of the larger ship.[29]

Regarding safe speed, the Seaway Handbook stated that masters and pilots are required to meet other vessels at a safe speed. The handbook also stated that vessels must proceed at a reasonable speed so as not to delay other vessels.

The TSB obtained AIS data for vessels transiting the Welland Canal over the course of 11 days in July 2020, during which time 48 meetings occurred. The majority of the meetings were conducted at speeds of 6 to 7 knots, with vessels typically reducing their transit speeds before meeting. The data also indicated that 7 meetings were conducted with at least 1 vessel proceeding above 8 knots, and 3 of these 7 meetings were conducted with at least 1 vessel proceeding above 9 knots. These meetings at higher speeds involved bulk carriers and general cargo vessels.

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[28] St. Lawrence Seaway Management Corporation, *Seaway Handbook*, "Information on Ship Transit and Equipment Requirements" (March 2020), section 15: Ships Operating in Restricted Channels, p. 10.

[29] Ibid.

1.9.3 Visual perception

Visual navigation is common in confined waters such as the Welland Canal. To visually estimate the position (distance and trajectory) of an oncoming vessel, a navigator will reference multiple cues to gauge its relative motion. These cues are derived from visual input provided by

- landmarks on the banks of the canal and the horizon;
- reference points on the oncoming vessel (e.g., the relative position of the bow and stern);
- reference points on the viewer's vessel (e.g., the relative position of the forward mast to the oncoming vessel); and
- the sensation of motion, which is internal to the viewer.

Accurately perceiving a distant oncoming vessel's movement in the Welland Canal can be complicated by various factors such as sightlines, viewing angle, and flat light conditions. As an object, a distant vessel occupies a very small proportion within the sightline of a viewer, and its movement relative to landmarks within the viewer's sightline may cause illusions. In canals, an oncoming vessel is generally viewed head-on, which creates an unremarkable target compared to vessels in open water that are transiting at greater angles to the viewer.

Another factor that can degrade a viewer's ability to discern a vessel's aspect is flat light conditions (Figure 12). These low-contrast conditions can cause the vessel to blend in with its surroundings, making it harder to see. They can also make it hard to determine how far away a vessel is and how quickly it is coming toward the viewer.

Figure 12. The top image shows the Florence Spirit at 0.8 nautical miles from the Alanis in flat light conditions. The bottom image shows the same view modified by the TSB to demonstrate higher contrast conditions. (Source of both images: ALANIS / Rambow Bereederungs GmbH & Co. KG, with TSB modifications).

Finally, accurately detecting the position of the oncoming vessel is easier when the navigator is centrally located and has a symmetrical field of view. By comparison, off-set viewing of an oncoming vessel makes trajectory estimation challenging, especially when the oncoming vessel is at a distance.

1.10 Safety management system

The main objectives of the ISM Code are to ensure the safe operation of vessels, to prevent injury or loss of life, and to avoid damage to property and the environment. Vessels that are subject to the *International Convention for the Safety of Life at Sea* (SOLAS) are required to comply with the ISM Code and develop an SMS.

The *Florence Spirit* was subject to SOLAS and was therefore required to have an SMS. Although some of McKeil Marine's other vessels were not subject to SOLAS, McKeil Marine still required all of its vessels and the company to comply with the ISM Code and ISO 9001:2015.[30] McKeil Marine had developed and implemented a quality and safety management system (QSMS) in 2015 that included a company manual and vessel-specific procedures. The QSMS had been audited and certified by Lloyd's Register.

[30] ISO 9001:2015 is the latest version of an international standard that specifies requirements for a quality management system. It is published by the International Organization for Standardization (ISO).

The QSMS outlined the responsibilities of the master according to the ISM Code. The QSMS also outlined the responsibilities of all the shipboard crew, with the exception of the piloting master. The manual stated that the master has complete responsibility for the safe operation of the vessel with regard to the safety of personnel, vessel, cargo, and the protection of the environment. Additionally, the QSMS stated that the master must ensure that the vessel complies with speed restrictions, wherever applicable, and have due regard for wake damage.

McKeil Marine had previously specialized in articulated tug-barge operations, but in recent years it had expanded its fleet to include some new larger vessels, such as bulk carriers and tankers. The *Florence Spirit*, which was acquired in June 2016, was the second bulk carrier in McKeil Marine's expanding fleet.

1.11 Organizational drift

Contemporary science on system safety has identified that accidents are usually the result of a confluence of factors, which may include slips and lapses on the part of the individual closest to the technology, but also contributions from organizational behaviour. One of the organizational patterns through which accidents occur in complex systems is a drift into failure. This occurs when components of complex systems interact, evolve, and adapt to new situations in ways that cause operations to drift into the safety margin, often as a result of a scarcity of resources. Because this drift occurs gradually through incremental changes over time, it is not always easily identifiable. As well, there is a tendency for the drift of organizational performance to be judged against the success of the most recent change and not the distance from the original design.[31]

1.12 Bridge resource management

BRM is the management and use of all resources, both human and technical, available to the bridge team to ensure the safe completion of the voyage. A fundamental requirement of effective BRM is strong leadership. Strong leadership supports the development of team situational awareness and facilitates teamwork among the bridge team members. It also helps ensure that the individual roles and duties of bridge team members are coordinated toward a common goal.

1.12.1 Team situational awareness

When people operate in a team environment, team situational awareness is important for safe and effective operations. Team situational awareness involves having a shared perception and comprehension of the current situation in order to be able to project what will happen in the near future. Perception, comprehension, and prediction are driven by the

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[31] S. Dekker, *Drift into Failure: From Hunting Broken Components to Understanding Complex Systems* (CRC Press, 2011), pp. 14–22.

information available to the team, the team's experience and knowledge, and the overriding context. Effective team situational awareness allows team members to develop performance expectations and to understand how their individual roles support the team's goals. As team members develop a shared understanding of a situation, they can communicate to cross-check their perceptions of the situation with each other.

For team situational awareness to develop and be maintained, the right information needs to get to the right person at the right time, which involves coordination among the team.[32] A team's effectiveness is often reflected by the degree to which team members share information (e.g., questioning, cross-checking, coordinating, setting priorities, and contingency planning).[33]

Team situational awareness is crucial for effective decision making. Decision making is a cognitive process used to choose a plan of action from several possibilities. The process involves identifying issues and threats and assessing options, while also taking into account the associated risks. Decision making takes place in a dynamic environment and consists of 4 steps: gathering information, processing information, making decisions, and acting on decisions. Decision making may be biased if the information gathered is ambiguous or inaccurate. It is enhanced by shared team situational awareness among bridge team members.

1.12.2 Leadership

Leadership is a key component in the development of shared team situational awareness and guides the manner in which the bridge team functions. Various aspects of leadership can promote interaction among team members, facilitating a common understanding of individual tasks and the sharing of information that supports those tasks.

Effective communication can help mitigate operational risk by routinely addressing the potential impact of environmental conditions, equipment readiness, and staffing. It can also help establish shared understandings of safety margins that provide bridge team members with a baseline from which to monitor and detect situations that are outside the norm. Open communication can also serve to develop and maintain team situational awareness by encouraging bridge team members to raise any operational concerns with the team at any time. Ensuring that the roles of all team members are made clear allows team members greater comprehension of their responsibilities.

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[32] K. T. Harris, C. M. Treanor and M. L. Salisbury, "Improving patient safety with team coordination: challenges and strategies of implementation," *Journal of Obstetric, Gynecologic, and Neonatal Nursing*, Vol. 35, Issue 4 (2006), pp. 557–566.

[33] C. A. Bowers, F. Jentsch, E. Salas and C. C. Braun, "Analyzing communication sequences for team training needs assessment," *Human Factors*, Vol. 40, Issue 4 (1998), pp. 672–679.

1.12.2.1 Diffused responsibility

In an operational setting, a sense of diffused responsibility can suppress an individual's interaction or intervention by encouraging the perception that someone else is better qualified to act, has more authority to act, or has better proximity to act.[34] Diffused responsibility is more likely to occur in instances when many people are involved or when there is more than one leader or person of authority involved. Diffused responsibility is seen as an indirect outcome of a weak or non-interacting team where members of the group act in loose isolation without a defined common goal. It can result in individuals perceiving that operations are going according to plan because no one is interacting or intervening as a situation gradually becomes increasingly risky.

1.13 Skill-, rule-, and knowledge-based information processing

The degree of conscious control exercised by an individual over their activities can be assessed based on the individual's manner of information processing. Broadly speaking, the interactions of skill-, rule-, and knowledge-based information processing reflect how the individual is interacting in the operational environment and performing tasks at hand.

Knowledge-based information processing is largely conscious, occurring as an individual experiences novel situations. As training progresses, rules will be learned that will produce methodical responses in familiar situations.[35] Practising tasks that are performed less frequently or are less familiar enables a person to develop, to some degree, the skills required to perform the actions. The goal of regular interaction with procedures and practices is to make performance more automatic, where the individual responds appropriately upon perceiving relevant cues.

When a scenario requires the performance of less familiar tasks, individuals rely on memory prompts (e.g., a checklist or operational briefing) to help initiate the appropriate sequence of actions. Training helps the individual anticipate the workload and potential consequences of the tasks ahead.[36] Recurrent training can also be useful in ensuring that training remains relevant to actual work being performed and helps reinforce knowledge and rules related to operational contexts.

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[34] S. Snook, *Friendly Fire: The Accidental Shootdown of U.S. Black Hawks Over Northern Iraq* (Princeton University Press, 2000), pp. 119–135.

[35] J. Reason, *The Human Contribution: Unsafe Acts, Accidents and Heroic Recoveries* (CRC Press, 2008), p. 14.

[36] Ibid., pp. 13–14.

1.14 Communication between vessels

There is no requirement for vessels to communicate to coordinate a meeting. However, if they choose to do so, the Seaway handbook specifies that "ship-to-ship communications must be carried out on designated VHF channels."[37]

VHF communication employs closed-loop communication and standardized phraseology to clarify intentions and develop a mutual understanding of the meeting. VHF communication between 2 vessels can aid in the development of team situational awareness because the audio is broadcast on the bridge, allowing bridge team members in proximity to hear the closed-loop communication between sender and receiver.

VHF communication between 2 vessels can also allow for greater awareness between vessels operating in the general vicinity, as well as traffic monitoring authorities. Finally, VHF communication is recorded by the vessel's voyage data recorder to support data collection for investigations.

1.15 Personal electronic devices

In recent years, the use of personal electronic devices (PEDs), such as cellphones, has been linked to numerous accidents across transportation modes worldwide. The TSB has previously identified risks associated with the use of cellphones in accidents in all transportation modes.[38] As well, over the years, the U.S. National Transportation Safety Board,[39] the UK Marine Accident Investigation Branch, and the UK Maritime and Coastguard Agency[40] have raised concerns about the use of PEDs in transportation.

The risks of using PEDs highlighted in past investigation reports or studies are as follows:

- PEDs, as a form of private communication, may interfere with the development of shared mental models in operational teams.
- Interacting with PEDs requires the use of cognitive resources that can distract from teamwork during the conduct of a vessel.
- The use of PEDs incurs head-down time that risks interrupting instrument and outside scans during normal and emergency operations.

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37 St. Lawrence Seaway Management Corporation, Seaway Handbook, "Information on Ship Transit and Equipment Requirements" (March 2020), Part 1: General Transit Information, section 8: Use of VHF radio, p. 7.

38 TSB Air Transportation Safety Investigation Report A18A0088, TSB Marine Investigation Report M12L0147, and TSB Railway Investigation Report R10V0038.

39 U.S. National Transportation Safety Board reports AAR-13/02 and MAR-11/02. The NTSB also has "Eliminate Distracted Driving" on their 2021–2022 Most Wanted List of Transportation Safety Improvements, at ntsb.gov/Advocacy/mwl/Pages/mwl-21-22/mwl-hs-05.aspx (last accessed on 08 July 2022).

40 UK Maritime and Coastguard Agency, "Marine Guidance Note – MGN 299 (M+F): Interference with safe navigation through inappropriate use of mobile phones," at gov.uk/government/publications/mgn-299-interference-with-safe-navigation-from-inappropriate-use-of-mobile-phones (last accessed on 08 July 2022).

- The use of PEDs may reduce cognitive resources required to detect critical cues related to system behaviour and to process relevant information or trends.
- Texts or instant messages sent via PEDs are often brief and informal, containing abbreviations, symbols, or various idioms, which poses a risk of critical content being omitted or misinterpreted in operational settings.

The use of PEDs when driving a vehicle represents a critical source of distraction for drivers; as a result, legislation that prohibits PED use by drivers has been enacted in numerous jurisdictions across North America. Major rail companies have followed suit by prohibiting the use of PEDs in almost every operational context.[41] In aviation, there are regulations restricting the use of PEDs.[42] Additionally, air operators are required to establish procedures for the use of PEDs on board aircraft.[43]

There are presently no Canadian regulations with respect to the use of PEDs in the marine mode. During the investigation, it was also noted that individuals are not always aware of the risk of using PEDs or of policies prohibiting their use in operational settings.

McKeil Marine had a policy prohibiting the use of PEDs during work hours. The McKeil Marine QSMS provided additional information on the use of PEDs as follows:

> The use of personal digital devices (cell phones, tablets etc) or use of the vessel computer for personal reasons while on watch is not permitted.
>
> Use of communications equipment for vessel's business in situations where a distraction could jeopardise the safe navigation of a vessel is up to the discretion of the Officer of the Watch. Officer's of the Watch [*sic*] should not hesitate to not answer the phone, or end communications in any situation they feel necessary.[44]

The *Florence Spirit* had a placard on the bridge to remind the bridge crew of the prohibition of cellphones; however, McKeil Marine's policy on PEDs was not actively enforced.

The GLPA also had a directive on the use of cellphones and other similar devices in the workplace. The directive stated that

> when a pilot has the conduct of a vessel when manoeuvring, the use of a cell phone to perform activities as part of his official duties is allowed but should be limited to necessity. […] the use of a cell phone for personal reasons is strictly prohibited.[45]

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41 An example of where PEDs are tolerated is in some yard switching operations.

42 Subsections 602.08(1) and 602.08(2) of the *Canadian Aviation Regulations* (as amended 25 November 2021) state that no air operator shall permit the use of a PED on board an aircraft, where the device may impair the functioning of the aircraft's systems or equipment, and that no person shall use a PED on board an aircraft except with the permission of the operator of the aircraft.

43 The procedure must meet the *Commercial Air Service Standards* and must be specified in the air operator's company operations manual.

44 McKeil Marine Limited, *Quality Safety Management System* (2018), section 7.2.6.5: Digital Device Policy.

45 Great Lakes Pilotage Authority, Directive AD-002: Cellular Phone and Other Similar Devices Usage at the Workplace (May 2014), section 6.1(a).

The GLPA directive was also not actively enforced, and the pilot on the *Alanis* was not aware of the directive.

From 1527 to 1555, the master of the *Florence Spirit* and the pilot on the *Alanis* exchanged 22 messages using an instant messaging program. The master used his cellphone to do so, and the pilot used his PPU. Although the GLPA directive did not define a PPU as a type of PED, in this occurrence, the PPU was being used for instant messaging in a manner similar to a PED. No messages were exchanged in the 11 minutes leading up to the collision.

1.16 Marine pilotage in Canada

Marine pilotage is provided by licensed pilots or pilotage certificate holders. These individuals are navigators with expert local knowledge of geography, weather, currents, and sailing conditions. They take the conduct of a vessel and navigate it in areas where pilotage knowledge is required, such as in ports, rivers, canals, etc. All vessels that are subject to compulsory pilotage are required to be under the conduct of a licensed pilot or pilotage certificate holder.[46]

Pilotage services in Canada are governed by the *Pilotage Act,* which states that "[a] licensed pilot or pilotage certificate holder who has the conduct of a ship is responsible to the master for the safe navigation of the ship."[47] Licensed pilots work for or are contracted by a pilotage authority. Pilotage certificate holders are masters or officers employed on Canadian vessels. The *Pilotage Act* states that in order to have the conduct of a vessel in a compulsory pilotage area, a pilotage certificate holder must be a regular member of that vessel's complement.[48]

Pilotage services in Canada are provided by 4 pilotage authorities: the GLPA, the Pacific Pilotage Authority (PPA), the Laurentian Pilotage Authority (LPA), and the Atlantic Pilotage Authority (APA). Each pilotage authority is a Crown Corporation with the regulatory authority to establish compulsory pilotage areas and administer pilotage services within them.

At the time of the occurrence, the pilotage authorities were responsible for issuing pilot licences and pilotage certificates. All 4 of the pilotage authorities were issuing pilot licences, and the GLPA, the APA, and the LPA were also issuing pilotage certificates. Table 2 shows the number of individuals holding either a pilot licence or a pilotage certificate in 2020, by pilotage authority.

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46 Transport Canada, *Pilotage Act* (as amended 09 June 2021), subsection 38.01(1).

47 Ibid., subsection 38.01(3).

48 Ibid., subsection 38.01(1).

Table 2. Number of licensed pilots and holders of pilotage certificates in 2020, by pilotage authority

Pilotage authority	Licensed pilots	Pilotage certificate holders
GLPA	60.1*	257
APA	49	52
LPA	195	2
PPA	132	0

* The number of licenced pilots for the GLPA is a decimal because the GLPA calculates this number as as full-time equivalents rather than as headcount.

The *General Pilotage Regulations* specify the minimum qualifications that must be met in order to be granted a pilot licence or pilotage certificate, as well as national requirements for training and revalidation. For pilotage certificates, the *Pilotage Act* stipulates that a certificate will not be issued "unless the Authority is satisfied that the applicant has a degree of skill and local knowledge of the waters of the compulsory pilotage area equivalent to that required of an applicant for a licence for that compulsory pilotage area."[49]

At the time of the occurrence, any restrictions on pilotage certificates were issued at the discretion of the individual pilotage authorities. Restrictions could limit licence or certificate holders to operating on particular types of vessels (e.g., vessels of a certain type or size) or in particular geographic areas. Restrictions could also limit pilot licence or pilotage certificate holders to operating only on vessels for which they hold a valid certificate of competency. Both the APA and LPA were restricting pilotage certificates based on vessel size and geographic area of operation. The GLPA was restricting pilotage certificates based on geographic area of operation only. The *Pilotage Act* and its associated regulations do not provide guidance about issuing restrictions.

Internationally, the practice is to issue restrictions on pilotage certificates that limit masters and officers to working on specific vessels and routes on which they have demonstrated their proficiency.[50] Restrictions can be placed on pilotage certificates in Canada to help mitigate the risk of certificate holders operating particular types of vessels or in particular areas where they have not demonstrated their proficiency.

The *Pilotage Act* has been reviewed a number of times over the years, with the most recent review occurring in 2018. One of the findings of the 2018 review was that standards and requirements for obtaining pilot licences, pilotage certificates, and waivers are inconsistent between the 4 pilotage authorities. It was recommended that TC implement and administer

49 Ibid., section 22.

50 International Maritime Organization, Resolution A.960(23), *Recommendations on Training and Certification and on Operational Procedures for Maritime Pilots other than Deep-Sea Pilots* (adopted 05 December 2003) Annex 1, section 3.

a standardized pilotage exemption scheme and stipulate the requirements in a new national regulation. It was also noted that TC should facilitate and promote a national pilotage certification program for the training and evaluation of ship masters and navigational officers and that, where appropriate, the pilotage certification should extend to cover a class of ship in the same company.[51]

As a result of the 2018 review, the responsibility for oversight and enforcement of the *Pilotage Act* was transferred from the 4 pilotage authorities to TC in March 2020. In June 2021, the responsibility for issuing pilot licences and pilotage certificates was also transferred to TC.

Since June 2021, the process for issuing pilot licences and pilotage certificates has involved each pilotage authority ensuring that an applicant meets all the requirements set out by the pilotage authority's regulations. When all requirements are met, the pilotage authority sends an application and accompanying documentation to TC, who then issues the certificate or licence. Any restrictions applied to a pilotage certificate are based on information provided by the pilotage authority.

1.16.1 Great Lakes Pilotage Authority

At the time of the occurrence, the majority of GLPA pilotage certificate holders held pilotage certificates that were restricted only by geographic area of operation. This was because before 2011, the GLPA had a system in place that exempted some Canadian vessels from requiring a licensed GLPA pilot on board in compulsory pilotage areas, based on an annual declaration by companies confirming that certain officers met the conditions set out in the *Great Lakes Pilotage Regulations*.

In 2011, the exemption system was replaced with a pilotage certificate system, the same one that was in effect at the time of the occurrence. Existing masters and chief officers who had served on vessels that had held exemptions were given the option to apply for pilotage certificates under the pilotage certificate system. These certificates were restricted only to particular GLPA districts. Of the 257 GLPA pilotage certificate holders in 2020, 237 held a pilotage certificate restricted only by geographic area of operation.

In September 2020, the GLPA implemented a process whereby restrictions are placed on newly issued pilotage certificates when a candidate

- has a certificate of competency with a capacity limitation,
- is on a vessel that does not transit in the whole district (such as a vessel that remains in a particular port), or
- has a medical condition.

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51 Transport Canada, *2018 Pilotage Act Review*, Recommendation 23, at tc.canada.ca/sites/default/files/migrated/17308_tc_pilotage_act_review_v8_final.pdf (last accessed on 08 July 2022).

When the pilotage certificate system was introduced, new candidates wishing to obtain a pilotage certificate were required to either pass an examination held by a board of examiners or complete an approved Great Lakes Marine Pilotage Certificate Training Program. These training programs were offered by individual companies that had taken the initiative to develop and implement a program based on GLPA standards. When a company developed a training program, the GLPA reviewed, analyzed, and approved it. Companies were also audited to ensure that the standards of their training program were in accordance with the GLPA's quality management system. The GLPA was responsible for ensuring that successfully completing one of these training programs was equivalent to passing an examination for a pilotage certificate.[52] The GLPA's training structure was unique for the issue of pilotage certificates in Canada; none of the other pilotage authorities had similar programs.

Most masters and officers opted to go through a training program instead of taking the examination. The training program typically took 2 years to complete and included 2 certification levels: piloting mate and piloting master. The GLPA defined a piloting master as a navigating officer or a master who

> […] has been deemed solely by the company to possess the required skills and abilities to assume command of a vessel.
>
> [The] Piloting Master is trained, assessed and capable of piloting in all waters and through canals and locks of the Great Lakes region.[53]

The GLPA defined a piloting mate as a navigation officer who is

> […] trained, assessed and capable of piloting in open, restricted and canal waters.[54]

The GLPA relied on the companies' training programs to ensure that candidates at the piloting master level had the skills and abilities to assume the conduct of a vessel. In 2013, the GLPA made an agreement with industry that if the pilotage certificate holder changed companies, the certificate holder was to complete a certain number of trips with the new company and familiarize themselves with the new company's training program. The GLPA also communicated to industry that a minimum of 1 piloting master had to be on board in the position of either master or chief officer while a vessel was in a compulsory pilotage area.

Up until 2018, it was typical for vessel masters with pilotage certificates to train subordinate officers for navigation in pilotage areas. In 2018, after consultation with industry, the GLPA authorized companies to create supernumerary piloting master trainer positions. Individuals in this position were permitted to rotate between different vessels within a company in order to train masters to become piloting masters. This change was

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52 Transport Canada, C.R.C., c. 1266, *Great Lakes Pilotage Regulations* (as amended 01 July 2011), section 12.5.

53 Great Lakes Pilotage Authority, *Great Lakes Marine Pilotage Certificate Training Program*, Introduction, p. 1-2.

54 Ibid.

made to help companies address a shortage of masters on bulk carriers with pilotage certificates.

1.16.1.1 Great Lakes Pilotage Authority trainers and evaluators program

At the time of the occurrence, companies that had a Great Lakes Marine Pilotage Certificate Training Program were required to have their own GLPA-approved trainers and evaluators. Trainers provided candidates with required training and sign-off once specific skills were acquired. Evaluators conducted a final evaluation of a candidate on board before a certificate was issued.

To become a trainer or evaluator for piloting mates, a piloting master or piloting mate was required to make 10 trips in 3 years as a piloting master or piloting mate in each district. These trips could be completed on any type of vessel. To become a trainer for piloting masters, a piloting master was required to additionally provide proof of 2 trips that each involved locks, canals, docking, and undocking.

Piloting mates and piloting masters seeking to become trainers were also required to successfully complete the GLPA-approved in-class Train the Trainer course and hold certain certifications.[55] After a piloting mate or piloting master had completed the required trips and training, the company recommended the candidate to the GLPA as a trainer or evaluator. The GLPA verified the candidate's training record to ensure the requirements had been met and then informed the company as to whether or not the candidate had been approved as a trainer or evaluator.

The responsibilities of a master and supernumerary piloting master trainer in a training environment were not specifically defined by the GLPA, although the GLPA had an undocumented expectation that the supernumerary piloting master trainer was responsible for the master in training.

1.16.1.2 Continuous proficiency assessments and recurrent training

At the time of the occurrence, the GLPA had a pilot quality assurance program that assessed the competencies of licensed pilots through an evaluation every 5 years. The program was developed to meet IMO Resolution A.960(23), which set out recommendations on training, certification, and operational procedures for pilots.[56] Under the quality assurance program,

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55 These include a valid certificate of competency, an Industry Canada radio certificate, and a medical certificate.

56 International Maritime Organization, Resolution A.960(23), *Recommendations on Training and Certification and on Operational Procedures for Maritime Pilots Other than Deep-Sea Pilots* (adopted 05 December 2003), states that each applicant for a pilot licence should demonstrate the necessary knowledge of various factors for the waters in which they are to be certified or licensed. These factors include, but are not limited to, the following: names and characteristics of the channels, shoals, headlands and points in the area; depths of water throughout the area, including tidal effects and similar factors; proper courses and distances in the area and anchorages in the area (section 7.1, p. 6). Resolution A.960(23) also specifies that competent

pilots underwent continuous proficiency assessments at the pilotage simulator. The assessments involved simulating a variety of scenarios, including emergency situations. The pilot was evaluated by peers and the directors of operations. The GLPA also had a pilot quality assurance committee that reviewed incidents and pilotage issues. The pilot quality assurance program did not apply to pilotage certificate holders.

The GLPA also required pilots to undergo a variety of recurrent training, including BRM training and emergency ship-handling training in the simulator. BRM training was required to be renewed once every 5 years and emergency ship-handling training was required to be carried out in the simulator once every 10 years to ensure pilots could carry out appropriate manoeuvres in emergency situations and manage the consequences. There were no recurrent training requirements for pilotage certificate holders.

1.16.2 McKeil Marine pilotage certificate training program

McKeil Marine had developed and implemented a Great Lakes Pilotage Certificate Training Program that was audited and approved by the GLPA in 2016. McKeil Marine relied on the training program to ensure the proficiency of pilotage certificate holders and did not have a requirement for continued proficiency assessments after certificates were issued or a requirement for recurrent training, nor were these required by the GLPA.

In April 2020, McKeil Marine introduced supernumerary piloting master trainer positions due to a lack of certified masters with pilotage certificates. McKeil Marine promoted 3 of its piloting masters to these positions. Two of the supernumerary piloting master trainers held Master, 500 Gross Tonnage certificates of competency.

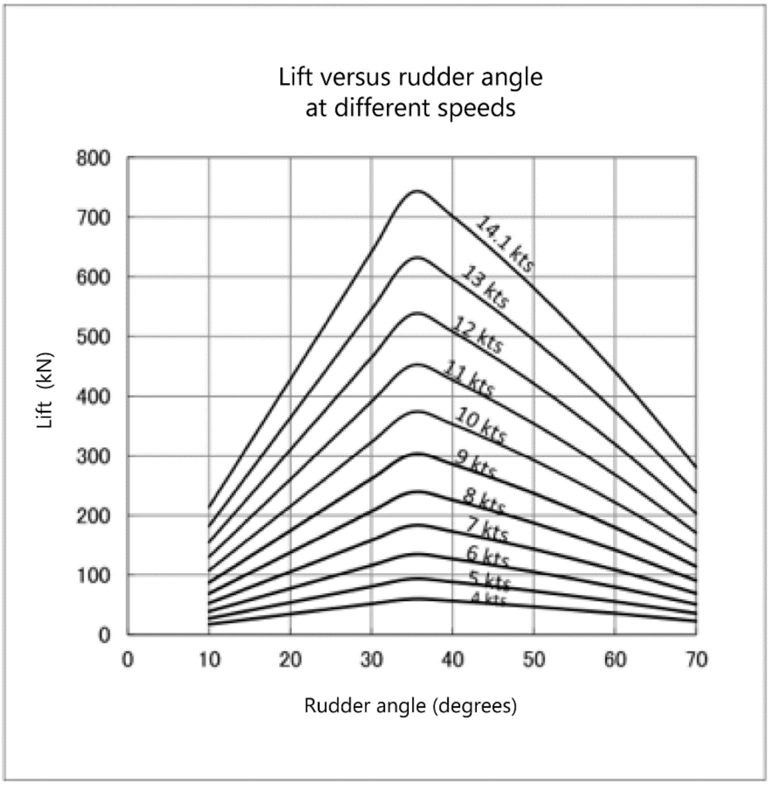
1.17 Rudder lift force

The *Florence Spirit* was fitted with a fishtail rudder that was capable of turning 70° to both port and starboard to allow for increased manoeuvrability at very reduced speeds (below 4 knots).[57] Above 4 knots, the rudder was still capable of turning 70° to both port and starboard, but the lift force generated by the rudder reached its maximum at 35° and then began to decline for rudder angles applied in excess of 35° (Figure 13).

pilotage authorities should ensure, at intervals not exceeding 5 years, that pilots continue to possess recent navigational knowledge of the area to which the certificate or licence applies (section 6.1, p. 5).

57 Under SOLAS Chapter II-1, Part C, vessels are required to have a main steering gear that is capable of turning the rudder from 35° on one side to 35° on the other side at its deepest seagoing draft and running ahead at maximum ahead service speed. Most vessels therefore have rudders that turn from 35° on one side to 35° on the other side.

Figure 13. Lift force in relation to rudder angle at different speeds (Source: Japan Hamworthy & Co. Ltd.)



The *Florence Spirit* was constructed to Bureau Veritas's rules, which recommended that steering systems such as the one on the *Florence Spirit* include a limit system to prevent the use of the rudder at angles above 35° when the vessel is at full speed. Bureau Veritas's rules also required a notice to be posted at all steering wheel stations indicating that rudder angles of more than 35° are to be used only at very reduced speed.[58] The investigation determined that the steering stand on the *Florence Spirit* did not contain such a notice, and the steering gear had no limit system. At the time of the occurrence, the *Florence Spirit* was classified under Lloyd's Register, which does not have rules about operational limits or notices for steering systems of this type.

The fact that the lift force generated by the rudder at full speed reached its maximum at 35° and declined at greater angles was not indicated in the steering gear manual, the rudder arrangement plan, or the manoeuvring characteristics of the *Florence Spirit,* and both McKeil Marine and the bridge team were unaware of this information. It was common practice for the bridge team to apply rudder angles above 35° while the vessel was proceeding at speeds above 4 knots, and rudder angles of up to 70° were applied just prior to the occurrence when the *Florence Spirit* was proceeding at speeds in the range of 8 to 9 knots.

58 Bureau Veritas, *Rules for the Classification of Steel Ships* (2020), Part C, Chapter 1, section 11, article 5.3.2(b). This article was in force at the time the *Florence Spirit*'s keel was laid in 2003.

The *Florence Spirit*'s sister vessel *Longwave* was fitted with the same type of rudder and similarly had no information indicating the rudder limitations, with the exception of the pilot card, which noted a maximum rudder angle of 70° at a maximum speed of 2.5 knots and a pitch of 25%. The other sister vessel, the *NACC Argonaut,* was fitted with a different type of rudder.

1.18 Reproduction of events with navigation simulator

The TSB worked with the Maritime Simulation and Resource Centre[59] to simulate the sequence of events leading up to the collision and to explore alternative scenarios. The centre produced a virtual model of the *Florence Spirit* using all of the vessel's actual manoeuvring characteristics at the time of the occurrence. The loading conditions and the rudder performance were taken into account in the model. The meteorological and environmental conditions were also reproduced using water level and bathymetric data for the Welland Canal provided by the SLSMC. A vessel model similar to the *Alanis* was used to represent the *Alanis*. The simulator was able to simulate bank effect, squat effect, and other hydrodynamic forces generated between the vessels during the meeting in confined waters.

Multiple runs of the simulator were conducted with the vessels at different speeds and positions in the canal. The course alterations and rudder angle were also varied, and different crash stops were attempted. Based on the simulator runs, the following observations were made:

- When the *Florence Spirit* made a 4° course alteration at 0.8 NM while proceeding at a speed of 9.9 knots, the angle of approach to the bank made it impossible to bring the vessel back parallel to the centreline without it sheering across the centreline.
- When the *Florence Spirit* reached an XTD of 31 m at 9.9 knots, it experienced an uncontrollable sheer to port due to bank effect that could not be stopped by applying the maximum propeller pitch and 35° rudder angle.
- The maximum propeller pitch and 35° rudder angle were effective at regaining control of the *Florence Spirit* when it was proceeding at 6 knots at an XTD of 37 m.
- When the *Florence Spirit* moved off the centre of the channel at a speed of 9.9 knots, a greater rudder angle was required to compensate for bank effect.
- It was harder for the individual at the helm to identify trends in the *Florence Spirit*'s movement when steering on a course than when steering on a landmark.
- When the *Alanis* performed a crash stop as the *Florence Spirit* started the sheer to port, the *Florence Spirit* collided with the port midsection of the *Alanis*.

59 The Maritime Simulation and Resource Centre, located in Québec, Quebec, is a division of the Corporation des pilotes du Bas Saint-Laurent (CPBSL). The centre's mission is to ensure training and development for pilots belonging to the CPBSL and to share its expertise in simulation with other pilots and maritime professionals.

1.19 Similar occurrences

Since 1995, the TSB has investigated 17 occurrences where vessels were influenced by hydrodynamic effects. Seven of these occurrences involved collisions in confined waters,[60] and 10 involved groundings, strikings, or bottom contact.[61]

In one of these occurrences, the container vessel *Cast Prosperity* and the tanker *Hyde Park* collided while under the conduct of pilots during an overtaking manoeuvre in a dredged channel in Lac Saint-Pierre, Quebec. The investigation found that the strength of the hydrodynamic forces at work was not appreciated early enough, nor was the need for early and decisive action to prevent the vessels from drawing together. The investigation also found that neither the LPA nor the Corporation des pilotes du Saint-Laurent central had guidelines to help pilots reduce the risk of severe hydrodynamic interactions between vessels in meeting and overtaking situations. As a result, the Board issued a safety concern indicating that

> […] without adequate guidance, pilots and crews may not be able to mitigate risks associated with hydrodynamic interaction and to avoid collisions during meeting and overtaking situations in the future.[62]

Since 1995, the TSB has also received reports of 13 other occurrences where vessels were influenced by hydrodynamic effects.[63] Nine of these occurrences involved a vessel sheering due to hydrodynamic effects.[64]

The U.S. National Transportation Safety Board has also investigated several collisions involving a loss of steering control due to hydrodynamic effects.[65]

Finally, the TSB has investigated occurrences where BRM[66] and communication between vessels prior to a meeting[67] have been factors.

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60 TSB marine investigation reports M05C0033, M05L0205, M02C0064, M98F0039, M97C0057, M96C0088, and M95L0070.

61 TSB marine investigation reports M19C0387, M16C0036, M11C0001, M02C0064, M00C0019, M99C008, M99C0005, M96C0222, M96L0142, and M94L0031.

62 TSB Marine Investigation Report M05L0205.

63 TSB marine occurrences M21C0215, M13C0051, M07C0036, M06C0038, M05C0074, M01L0086, M98C0098, M96C0088, M96F0026, M96C0069, M96C0022, M95C0026, and M95C0008.

64 TSB marine occurrences M97C0087, M97F0029, M97C0083, M97C0089, M95C0009, M95C0053, M95C0061, M95C0055, and M95M0010.

65 U.S. National Transportation Safety Board reports MAR-21/01, MAR-16/01, MAR-12/02, and MAR-11/04.

66 TSB marine investigation reports M19P0057, M17A0390, M14P0014, M14C0193, M14C0219, M12L0147, and M04L0092.

67 TSB marine investigation reports M12L0098, M08C0081, M05C0033, M05L0205, M04L0099, and M01C0059.

1.20 TSB Watchlist

The TSB Watchlist identifies the key safety issues that need to be addressed to make Canada's transportation system even safer.

Safety management **is a Watchlist 2020 issue**. As this occurrence demonstrates, even when formal safety management processes are present, they are often not effective at identifying hazards or reducing the risks. In this occurrence, the *Florence Spirit* had an SMS that was certified and audited by an approved authority; however, there were gaps when it came to guidance on safe speed for meeting and passing in confined waters and crew familiarization with the rudder characteristics. There were also gaps in the enforcement of PED policies and an absence of guidance to clarify the responsibilities of piloting masters when on board in the role of a supernumerary trainer.

ACTIONS REQUIRED

Safety management will remain on the Watchlist for the **marine** transportation sector until:

- TC implements regulations requiring all commercial operators to have formal safety management processes; and
- Transportation operators that do have an SMS demonstrate to TC that it is working—that hazards are being identified and effective risk-mitigation measures are being implemented.

2.0 ANALYSIS

The *Florence Spirit* developed an uncontrollable sheer to port and collided with the *Alanis* as a result of hydrodynamic forces generated by the *Florence Spirit*'s high speed and proximity to the bank of the canal. The investigation looked at the planning and approach for the meeting and factors that influenced bridge resource management (BRM). The investigation also examined the use of personal electronic devices (PEDs), guidance on safe speed for meetings in confined waters, and rudder effectiveness. Finally, the investigation looked at the process for issuing pilotage certificates within the Great Lakes Pilotage Authority (GLPA) and the GLPA's requirements for recurrent training and proficiency assessments for pilotage certificate holders.

Given that this occurrence had similarities with other occurrences involving an uncontrollable sheer, the scope of the investigation included an evaluation of the *Florence Spirit*'s mechanical systems. They were found to be serviceable and to not be a factor in the occurrence.

2.1 Planning and approach for the meeting

A meeting of vessels like the *Florence Spirit* and the *Alanis* in the Welland Canal is a challenging manoeuvre with little tolerance for error due to the complex and varying hydrodynamic forces generated around the vessels. Once a vessel comes under the influence of hydrodynamic effects, it can sheer uncontrollably, making it important that a bridge team anticipates these effects and plans ahead to mitigate them. This involves planning the speed and course alterations for the vessel's approach and monitoring for any signs that the vessel is being influenced by hydrodynamic forces. It also requires coordination of the speed and manoeuvres between the 2 meeting vessels in order to leverage ship-to-ship interaction and mitigate hydrodynamic forces.

2.1.1 Communication between vessels

In this occurrence, before the vessels met, the pilot on the *Alanis* and the master of the *Florence Spirit* exchanged a series of brief and informal instant messages about the speed and course alterations of the vessels, as well as good practices to avoid bank suction in meetings. The pilot and the master had sailed together as former bridge team members, and this familiarity prompted the non-standard exchange about the meeting.

The initial message, sent by the pilot, indicated to the master that the master had full discretion to select whatever speed and manoeuvres he felt appropriate for the meeting with the *Alanis*. Based on experience and training, the pilot had an understanding that typically vessels approach meetings at speeds of 6 to 7 knots. This understanding matches the TSB's observations of average vessel meeting speeds in the Welland Canal over the 11 days leading up to the occurrence. From this message, the master inferred that the discretion provided by the pilot literally meant that any speed up to and including the maximum permissible speed of 9.9 knots was appropriate. This supported the master's goal of transiting as quickly as possible, which was influenced by the earlier traffic backlog in the canal and the fact that the time required to arrive at the basin south of Lock 7 had been underestimated.

A subsequent message from the pilot, sent with the aim of stating his intentions, informed the master of the course alterations and timing that the pilot planned to use to position the *Alanis* for the meeting. The pilot had planned to alter course by 4° at 0.8 NM from the *Florence Spirit* to give the *Alanis* time to reach the minimum separation distance of 21.1 m, given its speed of around 3 knots.

For the master, who was relatively new to his role and whose former supervisor was the pilot , the message from the pilot likely appeared to be a compelling source of technical advice about how to conduct the manoeuvre. As a result, the master opted to make the same course alteration the pilot intended to make: namely, 4° at 0.8 NM from the *Alanis*. However, the *Florence Spirit* was already at a cross-track distance (XTD) of 8 m, was proceeding faster than the *Alanis,* and was already affected by bank suction, which increased the complexity of coordinating the *Florence Spirit*'s manoeuvres with the *Alanis*.

Finding as to causes and contributing factors

The exchange of brief and informal instant messages between the master of the *Florence Spirit* and the pilot on the *Alanis* influenced decisions regarding the *Florence Spirit*'s speed and course alterations, increasing the complexity of coordinating the *Florence Spirit*'s manoeuvres with the *Alanis*.

2.1.2 Meeting speed

As the *Florence Spirit* proceeded at 9.9 knots into the meeting, the piloting master asked the master if the pilot on the *Alanis* wanted the *Florence Spirit* to slow down. The master, who had interpreted the pilot's non-prescriptive message about the meeting speed as conveying indifference, indicated that the pilot had no preference about the meeting speed. This interpretation of the pilot's message gave the piloting master the impression that the meeting could be conducted successfully at this speed, and the fact that the message was coming from a licensed pilot added credibility to it.

The piloting master had also experienced successful meetings at similar speeds in the Seaway, which reinforced the plausibility that conducting the meeting at this speed was feasible. As a result, the piloting master was not compelled to intervene. The request by Seaway Traffic Control for the *Florence Spirit* to proceed at maximum permissible speed due to the earlier traffic backlog in the canal, coupled with the fact that the time required to arrive at the basin south of Lock 7 had been underestimated, contributed to self-induced pressure on the bridge team to proceed as fast as possible.

Combined, these factors resulted in the *Florence Spirit* proceeding into the meeting at 9.9 knots while the *Alanis* was proceeding at around 3 knots. The *Florence Spirit*'s high speed consequently reduced the wheelsman's ability to maintain the vessel's heading leading up to the meeting and increased the vessel's susceptibility to hydrodynamic forces. It also meant that the vessel had less reserve power to regain steering control in the event of a sudden sheer.

Finding as to causes and contributing factors

The *Florence Spirit* proceeded into the meeting at the maximum permissible speed of 9.9 knots, which increased the hydrodynamic forces acting on the vessel and reduced the ability to maintain steering control.

2.1.3 Vessel positioning in the canal

When both vessels made the 4° course alteration at 0.8 NM, the master began visually monitoring the *Alanis* so that he could order the next course alteration to bring the *Florence Spirit* parallel in the canal at the same time as the *Alanis*. Although the *Alanis* was moving off the centreline of the canal, the master visually misperceived its position as still being in the centre. A number of factors contributed to this misperception. The *Alanis*'s aspect was difficult to discern visually because it was moving much more slowly than the *Florence Spirit*; there were minimal navigational reference points in the landscape; flat light conditions prevailed; and the *Florence Spirit* was already off the centreline of the canal, so the master was observing the *Alanis* from an off-set viewing position. As a result, while the master waited for visual cues that the *Alanis* had moved off the centreline, the *Florence Spirit* continued on a course toward the bank, reaching an XTD of 32 m. According to the Seaway Handbook, the safe minimum distance between the 2 vessels was 21.1 m, which meant that the XTD of each vessel had to be a minimum of 21 m as well.

The master had successfully manoeuvred large vessels like the *Florence Spirit* close to the bank in the past; however, in those prior instances, the master had been proceeding at speeds of around 6 knots, which meant the hydrodynamic effects acting on the vessel were not as strong as those acting on the vessel during the occurrence voyage. Because the *Florence Spirit* was proceeding faster in proximity to the bank, the hydrodynamic effects acting on the vessel were stronger than those the master had previously experienced.

Finding as to causes and contributing factors

After the *Florence Spirit* altered course by 4° to mirror the *Alanis*'s course alterations, the *Florence Spirit* maintained a course that brought it close to the bank at a high speed, which increased the hydrodynamic effects acting on the vessel.

2.1.4 Influence of bank effect

As the *Florence Spirit* was proceeding to an XTD of 32 m, the wheelsman was applying greater rudder angles to try to maintain the vessel on course. The vessel's responsiveness to rudder orders decreased as it got closer to the edge of the canal until the vessel's heading began to reduce as bank cushion took effect and began to push the bow to port. When the master gave the order to bring the vessel parallel to the centreline, he and the piloting master were unaware that greater rudder angles were compensating for the hydrodynamic forces.

In response to the master's order, the wheelsman reduced the starboard rudder angle being applied. However, the reduced rudder force was no longer sufficient to counteract the hydrodynamic forces that were acting on the vessel. Given that the vessels were approximately 300 m (less than 2 ship lengths) away from one another when the *Florence Spirit* began to sheer, there were no repulsive forces between the vessels to help the *Florence Spirit* counteract the hydrodynamic effects. As well, attempted corrective action to increase wash over the rudder had no effect on controlling the sheer.

Finding as to causes and contributing factors

The hydrodynamic forces generated by the combination of the *Florence Spirit*'s speed and proximity to the bank produced a yawing moment on the vessel that caused it to sheer uncontrollably to port into the path of the *Alanis* and collide with it.

2.2 Factors affecting bridge resource management

BRM is about making effective use of the resources available—human, hardware, and information—to manage the threats and challenges that can arise during navigation. Leadership is a key component underpinning effective BRM. Leadership facilitates the development of a cohesive bridge team and guides the manner in which the team functions. Clearly defined roles allow bridge team members to work together while pursuing a common goal for which they are mutually accountable. The continuous exchange of information and team situational awareness also contribute to BRM and the vessel's safe navigation.

In this occurrence, leadership and team situational awareness on the *Florence Spirit* were hindered by different factors. One factor was the instant messaging communication between the master and pilot, which contributed to the master's attention being diverted from coordinating the meeting with his own bridge team and excluded other bridge team members from having safety-critical information. Given that the master was relatively new in his position as master, he likely considered his communication with the pilot an operational advantage. The master may have perceived that he and the pilot were working together toward a shared goal (coordinating a successful meeting) when in fact, they each had separate considerations related to their own individual vessels that needed to be factored into their meeting approaches, such as those related to speed, ship-handling characteristics, and vessel position in the canal.

Another factor that influenced leadership and team situational awareness on the *Florence Spirit* was the training arrangement between the master and the piloting master, which involved the piloting master being on board as a supernumerary for training purposes. The supernumerary master trainer position was new and unusual because, in the past at McKeil Marine, a trainer was a senior crew member who held a pilotage certificate. Neither the

GLPA nor McKeil Marine provided prescriptive guidance about the responsibilities of masters and piloting masters when the piloting master was a supernumerary, nor was the new position of supernumerary master trainer defined in McKeil Marine's safety management system (SMS). Without prescriptive guidance on the level of oversight that the piloting master was expected to provide, the piloting master understood his role to be an overseer who was primarily shadowing the master's pilotage techniques with a responsibility to intervene only if required. This meant that the piloting master largely had bystander status while the master coordinated the meeting based on information derived from the instant messages sent by the pilot on the *Alanis*.

The training arrangement was also complicated by the differing certification levels of the master and piloting master. The piloting master's certificate of competency as master was limited to vessels under 500 gross tonnage, which did not allow him to be master on a vessel of the *Florence Spirit*'s tonnage. This may have contributed to the piloting master providing the master with added discretion in planning the meeting. As well, the piloting master was confident in the master's skillset when it came to vessel handling in confined waters.

Combined, these factors led to diffused responsibility for the vessel's navigation between the master and piloting master that reduced cohesion among the bridge team and impacted the team situational awareness and communication needed to monitor the vessel's progress and identify the risks associated with hydrodynamic forces. Although a risky situation was unfolding, there was the appearance, on the bridge, that the meeting was proceeding according to plan. The perception persisted as a result of diffused responsibility that allowed signs indicating the severity of bank effect to go unaddressed. While the master focused on the goal of successfully conducting the meeting, the others on the bridge of the *Florence Spirit,* including the piloting master, were largely peripheral to the plan as it unfolded. Consequently, the bridge team members, who were relatively new to the *Florence Spirit*, resorted to performing their perceived roles to the best of their ability.

The wheelsman understood that his role was to steer on the ordered courses. After the *Florence Spirit*'s speed was increased to 9.9 knots, the wheelsman was consistently applying rudder to starboard, which was compensating for bank effect. Because he was focused on the goal of maintaining the ordered courses and was ultimately able to come close to doing so, it likely seemed unnecessary to report the ongoing need for starboard rudder to the master. Meanwhile, the chief officer, who had never sailed in the Welland Canal before, was focused on observing the manoeuvre in order to learn it. These individual areas of focus precluded the bridge team members from actively assisting the master during the approach.

Finding as to causes and contributing factors

Diffused responsibility between the master and piloting master on the *Florence Spirit* precluded coordination and communication among bridge team members, hindering their ability to monitor the vessel's progress and detect the influence of hydrodynamic forces acting on the vessel.

2.3 Methods of communication between vessels

Given the availability and familiarity of electronic devices that allow communication via texting or instant messaging, bridge team members may find these methods more compelling to use than the standard means of communication between vessels. However, the private nature of texts and instant messages can impede the exchange of vital operational information, interfere with team situational awareness among the bridge teams on both vessels, and exclude other vessels and traffic management authorities from safety-critical information. As well, given that texts and instant messages are typically brief, informal, and not closed-loop, they can increase the risk of omissions or misinterpretations.

Although the air and rail transportation sectors have regulations regarding the use of PEDs that help reduce texting and instant messaging in operational settings, there are currently no Canadian regulations regarding the use of PEDs in the marine transportation sector. In the absence of a regulatory framework, some organizations, such as McKeil Marine and the GLPA, have created policies around the use of PEDs. However, these policies are not always actively enforced, and individuals in safety-related positions do not always comprehend the risks of using texting or instant messaging programs for critical navigation tasks, whether via PEDs or company-issued electronic devices such as PPUs.

As this occurrence demonstrates, the use of instant messages as a primary communication channel can result in misinterpretations and can exclude bridge team members from critical content, resulting in reduced team situational awareness. It can also minimalize interactions between bridge team members.

Finding as to risk

If company policies regarding the hazards of using personal electronic devices in operational settings are not actively enforced, there is a risk that the use of personal electronic devices will jeopardize navigational safety.

2.4 Speed management for meetings in confined waters

Hydrodynamic interaction continues to be a contributing factor in marine occurrences. For this reason, meetings in confined waters must be carried out at speeds that are sufficient to maintain control while also mitigating the risks of hydrodynamic effects and ensuring enough reserve propulsion power is available to regain control of the vessel in the event of a sheer.

At the time of the occurrence, the Seaway had set a speed restriction in the Welland By-Pass of 8 knots, but allowed a tolerance of an additional 1.9 knots. Although the speed tolerance was originally intended for short-term use or for use in exceptional circumstances, in the 11 days prior to the occurrence, there were a number of meetings in the Welland By-Pass conducted at speeds above 8 knots involving vessels of similar size to the *Florence Spirit*. Vessels of similar size to the *Florence Spirit* are at a greater risk of sheering when proceeding at high speeds in confined waters due to the complex and varying hydrodynamic forces generated around the vessel. As well, when proceeding at high speeds in confined waters, there is less time for masters and pilots to react to any navigational errors, mechanical failures, or other complications. Despite this, at the time of the occurrence, vessels could select a meeting speed of up to 9.9 knots in the Welland By-Pass without any guidance or cautions about the risks of doing so.

The investigation determined that McKeil Marine, the Seaway, nor the GLPA had guidance to support navigating officers in determining safe vessel speeds for meeting or passing and the associated hazards of hydrodynamic effects in confined waters. Ensuring that vessels proceed safely in the Welland Canal is a shared responsibility between the Seaway, the GLPA, and the companies whose vessels transit in this area. Consequently, each has a responsibility to provide the necessary guidance to support navigating officers in mitigating the risk of hydrodynamic effects.

Finding as to risk

In the absence of guidance for bridge teams on safe vessel speeds for meeting or passing and the associated hazards of hydrodynamic effects in confined waters, there is a risk that vessel meetings will be conducted outside safe limits.

2.5 Rudder effectiveness

Manoeuvring is a key aspect of safe navigation, especially in confined waters. It is therefore important that bridge team members have information about any factors that affect a vessel's steering system. This information can be provided in a variety of ways, including through placards, the vessel's manoeuvring characteristics, and the vessel's pilot card.

The *Florence Spirit* was fitted with a fishtail rudder, which is an uncommon type of rudder, making it important that information on the rudder's characteristics be available to the bridge team members. While the *Florence Spirit*'s fishtail rudder was capable of turning 70° to both port and starboard, at speeds above 4 knots the lift force generated by the rudder reached its maximum at 35° and then began to decline for rudder angles applied in excess of 35°.

The *Florence Spirit* was constructed to Bureau Veritas' rules, which recommended installing a limit system to prevent the use of the rudder at angles above 35° when the vessel was at full speed, as well as posting a notice at all steering wheel stations indicating that rudder angles of more than 35° were to be used only at very reduced speed. However, the *Florence Spirit*'s steering gear had no limit system installed, nor did the steering stand have a notice posted. At the time of the occurrence, the *Florence Spirit* was classified under Lloyd's Register, which does not have rules about operational limits or notices for steering systems of this type.

Information about the decline in lift force at rudder angles greater than 35° was unavailable on the *Florence Spirit*, and both McKeil Marine and the bridge team were unaware of this phenomenon. It was common practice for the bridge team to apply rudder angles greater than 35° while the vessel was proceeding above 4 knots, and rudder angles of up to 70° were applied just prior to the occurrence while the *Florence Spirit* was proceeding at speeds in the range of 9 knots as part of evasive action to try to avoid the collision.

During simulator runs, it was demonstrated that the hydrodynamic effects acting on the *Florence Spirit* at the time of the occurrence were strong enough to overwhelm the rudder's lift force regardless of the rudder angle being applied, and so the lift force generated by the rudder was not considered causal. Nevertheless, it remains important that navigators have access to key information about factors that have the potential to impact the success of manoeuvres and therefore navigational safety.

Finding as to risk

If bridge teams do not have information about factors that can influence the effectiveness of steering systems, there is a risk that these factors will unknowingly compromise the safety of manoeuvres.

2.6 Process for issuing pilotage certificates

Licensed pilots and pilotage certificate holders must have expertise in ship-handling and specialized knowledge of pilotage areas in order to safely navigate vessels through confined waters. Because vessel speeds and manoeuvres for meetings in confined waters are largely left to the discretion of licensed pilots or pilotage certificate holders, it is important that these individuals have the skills and knowledge for the safe conduct of their operations.

After the GLPA regulations were introduced in 2011, the GLPA issued new pilotage certificates to individuals who had previously held exemptions under the old GLPA system. While the GLPA restricted these certificates to specific districts, they otherwise placed no restrictions to limit candidates to certain types of vessels, companies, or certificate of competency levels. This meant that, as long as candidates remained within their assigned district(s), they were permitted to pilot any type of vessel for any company. Candidates who subsequently passed through the GLPA training program were also issued pilotage certificates restricted only by district.

The pilotage certificate system was designed around an assumption that pilotage certificate holders would remain working on the same vessel, for the same company, in the same districts, over time. However, in 2018, the GLPA and industry made an agreement that allowed for the creation of supernumerary piloting master trainer positions, which enabled trainers to rotate between different company vessels. The fact that GLPA pilotage certificates did not limit pilotage certificate holders to certain types of vessels, companies, or certificate of competency levels meant that supernumerary piloting master trainers were permitted to work as trainers on any type of vessel, regardless of whether they had the skills and knowledge to do so. This represented a drift away from the original design of the pilotage certificate holder program, whereby the piloting master was intended to be a member of the vessel's complement, to new arrangements that had not been risk-assessed by either companies or the GLPA.

In 2020, due to a lack of certified masters with pilotage certificates, the piloting master was promoted to the position of a supernumerary trainer for the master of the *Florence Spirit.* In the absence of any limitations on his pilotage certificate aside from geographic area of operation, the piloting master was permitted to work as trainer on any type of vessel. The *Florence Spirit* was a different type of vessel from the tugs on which he had acquired the majority of his piloting experience and he did not hold the required certificate of competency to be master on this class of vessel. This led to a mismatch of the piloting master's skills and knowledge with the operational context in which he was working.

Internationally, the practice is to issue restrictions on pilotage certificates to limit masters and officers to working on specific vessels and routes on which they have demonstrated their skills and knowledge. Restrictions can be placed on pilotage certificates in Canada to help mitigate the risk of certificate holders operating particular types of vessels or in particular areas where they do not have the requisite skills and knowledge. The practice of issuing pilotage certificates without limitations on vessel type or certificate of competency can result in pilotage certificate holders being in novel operating contexts with skills and knowledge that do not readily transfer to the new context.

While the responsibility for issuing pilotage certificates was transferred to TC in June 2021, any restrictions are based on information provided by the individual pilotage authorities. In September 2020, the GLPA implemented a process whereby restrictions are recommended to TC for newly issued pilotage certificates when a candidate has a certificate of competency with a capacity limitation, is on a vessel that does not transit in the whole district, or has a medical condition. However, there have been no retroactive changes to restrictions on pilotage certificates that were issued before September 2020, and the majority of GLPA certificate holders continue to operate with certificates restricted by geographic area of operation only.

Finding as to risk

Restrictions on pilotage certificates introduced by the GLPA in September 2020 apply only to newly issued certificates. Pilotage certificates issued to individuals before this date were issued without consideration of limitations on vessel types or certificate of competency, which poses a risk that individuals holding these certificates will be permitted to perform pilotage duties for which they are inadequately prepared.

2.7 Recurrent training and proficiency assessments

A common practice in the workplace is for employees to undergo recurrent training and regular proficiency assessments. Proficiency assessments provide an opportunity to identify and mitigate potential gaps in skills and knowledge. Recurrent training ensures individuals continue to possess the skills and knowledge required to effectively perform their duties.

Although the regulations require pilotage certificate holders to have a degree of skills and knowledge that is similar to that of licensed pilots, there are discrepancies between the GLPA requirements for licensed pilots and pilotage certificate holders when it comes to recurrent training and proficiency assessments. While licensed pilots are required to undergo both recurrent training and regular proficiency assessments, there is no such GLPA requirement for pilotage certificate holders. The GLPA relies on individual companies to set criteria for proficiency assessments and recurrent training for pilotage certificate holders and to carry out both, but this is not always done, as was the case at McKeil Marine.

This situation can leave pilotage certificate holders without recurrent training on key topics such as BRM, which is an invaluable tool for managing and coordinating crew tasks, handling issues and threats, and making decisions. It can also leave them without simulator refresher training, which provides an opportunity to practise canal navigation and emergency ship-handling. Finally, it can also mean that pilotage certificate holders do not undergo proficiency assessments that can help identify and mitigate potential gaps in their skills and knowledge.

Finding as to risk

If requirements for pilotage certificate holders to maintain and develop their skills and knowledge after certification are not in place, there is a risk that gaps in proficiency may develop and persist over time.

3.0 FINDINGS

3.1 Findings as to causes and contributing factors

These are conditions, acts or safety deficiencies that were found to have caused or contributed to this occurrence.

1. The exchange of brief and informal instant messages between the master of the *Florence Spirit* and the pilot on the *Alanis* influenced decisions regarding the *Florence Spirit*'s speed and course alterations, increasing the complexity of coordinating the *Florence Spirit*'s manoeuvres with the *Alanis*.

2. The *Florence Spirit* proceeded into the meeting at the maximum permissible speed of 9.9 knots, which increased the hydrodynamic forces acting on the vessel and reduced the ability to maintain steering control.

3. After the *Florence Spirit* altered course by 4° to mirror the *Alanis*'s course alterations, the *Florence Spirit* maintained a course that brought it close to the bank at a high speed, which increased the hydrodynamic effects acting on the vessel.

4. The hydrodynamic forces generated by the combination of the *Florence Spirit*'s speed and proximity to the bank produced a yawing moment on the vessel that caused it to sheer uncontrollably to port into the path of the *Alanis* and collide with it.

5. Diffused responsibility between the master and piloting master on the *Florence Spirit* precluded coordination and communication among bridge team members, hindering their ability to monitor the vessel's progress and detect the influence of hydrodynamic forces acting on the vessel.

3.2 Findings as to risk

These are conditions, unsafe acts or safety deficiencies that were found not to be a factor in this occurrence but could have adverse consequences in future occurrences.

1. If company policies regarding the hazards of using personal electronic devices in operational settings are not actively enforced, there is a risk that the use of personal electronic devices will jeopardize navigational safety.

2. In the absence of guidance for bridge teams around safe vessel speeds for meeting or passing and the associated hazards of hydrodynamic effects in confined waters, there is a risk that vessel meetings will be conducted outside safe limits.

3. If bridge teams do not have information about factors that can influence the effectiveness of steering systems, there is a risk that these factors will unknowingly compromise the safety of manoeuvres.

4. Restrictions on pilotage certificates introduced by the Great Lakes Pilotage Authority in September 2020 apply only to newly issued certificates. Pilotage certificates issued to individuals before this date were issued without consideration of limitations on vessel types or certificate of competency, which poses a risk that individuals holding these certificates will be permitted to perform pilotage duties for which they are inadequately prepared.

5. If requirements for pilotage certificate holders to maintain and develop their skills and knowledge after certification are not in place, there is a risk that gaps in proficiency may develop and persist over time.

4.0 SAFETY ACTION

4.1 Safety action taken

4.1.1 Transportation Safety Board of Canada

On 01 February 2021, the TSB sent a marine safety advisory letter (MSA 01/21) to McKeil Marine regarding the effectiveness of the *Florence Spirit*'s rudder angle in relation to the vessel's speed.

4.1.2 Transport Canada

On 15 July 2021, Transport Canada conducted a flag state inspection and identified deficiencies related to McKeil Marine's quality safety management system. The deficiencies included:

- ineffective company procedures for safe navigation in confined waters;
- an absence of protocols and procedures for when the vessel's master or mate is undergoing pilotage training with a piloting master trainer on board; and
- inadequate coverage in the safety management system of communications protocols regarding the use of authorized communication devices for the safe navigation of the vessel.

Additionally, Transport Canada identified 2 deficiencies to McKeil Marine for violating its own company policies. The vessel's speed in the Welland Canal violated McKeil Marine's under-keel clearance policy. There was no record of this breach, although it was required by company policy to be reported.

As a result of the inspection, Transport Canada issued administrative monetary penalties to McKeil Marine.

4.1.3 McKeil Marine

Following the occurrence, McKeil Marine reviewed the incident and produced an internal investigation report that was shared with all masters. It also took the following actions:

- Issued a fleet advisory on bank effect and bridge conduct
- Held a pilotage trainer meeting to review bridge conduct, communication, and bank effect
- Added a training module on bank effect to its Great Lakes Marine Pilotage Certificate Training Program and modified other modules to include more guidance on the dynamics between the trainer and trainee
- Conducted rudder timing and efficiency tests on company vessels and updated the vessels' manoeuvring characteristics posted on the bridge
- Ensured that new and upcoming masters took ship-handling simulator training
- Required piloting mates to complete additional training in the Seaway simulator

- Required the occurrence master to complete 2 sessions of simulator training and extended the number of training trips that he was required to complete in the Welland Canal to 25

4.1.4 Great Lakes Pilotage Authority

Following the occurrence, the Great Lakes Pilotage Authority (GLPA) reviewed the incident with a focus on compliance with the *Pilotage Act* and its regulations.

On 08 September 2020, the GLPA implemented a process requiring restrictions to be placed on newly issued pilotage certificates when a candidate

- has a certificate of competency with a capacity limitation;
- is on a vessel that does not transit in the whole district (such as a vessel that remains in a particular port); or
- has a medical condition.

As of 12 April 2021, the GLPA had issued 3 pilotage certificates with restrictions. The restrictions related to vessel size, vessel type, company of operation, geographic area (such as a port), and capacity limitations on the candidate's certificate of competency.

On 08 March 2022, the GLPA emphasized to companies with Great Lakes Marine Pilotage Certificate Training Programs that their programs need to clearly define the roles and responsibilities of all bridge team members.

On 21 March 2022, the GLPA amended its policy concerning the use of electronic devices to emphasize prohibiting the use of electronic devices while employees are engaged in pilotage duties on the bridge of a vessel.

4.1.5 St. Lawrence Seaway Management Corporation

Following the occurrence, the St. Lawrence Seaway Management Corporation conducted a review of speed management. The following actions were taken:

- Seaway Notice No. 10 was issued in March 2021, indicating that although speed limits listed in the Seaway Handbook would remain unchanged, tighter tolerances would be applied for the majority of locations throughout the Seaway to ensure the speed limits listed in the Seaway Handbook are followed more closely.
- Seaway Notice No. 16 was issued in May 2021, indicating that the speed limits specified in the Seaway Handbook are to be followed and deviations are to be short and strictly for navigational safety.

This report concludes the Transportation Safety Board of Canada's investigation into this occurrence. The Board authorized the release of this report on 20 July 2022. It was officially released on 29 August 2022.

Visit the Transportation Safety Board of Canada's website (www.tsb.gc.ca) for information about the TSB and its products and services. You will also find the Watchlist, which identifies the key safety issues that need to be addressed to make Canada's transportation system even safer. In each case, the TSB has found that actions taken to date are inadequate, and that industry and regulators need to take additional concrete measures to eliminate the risks.

APPENDICES

Appendix A – Manoeuvring characteristics for the *Florence Spirit*

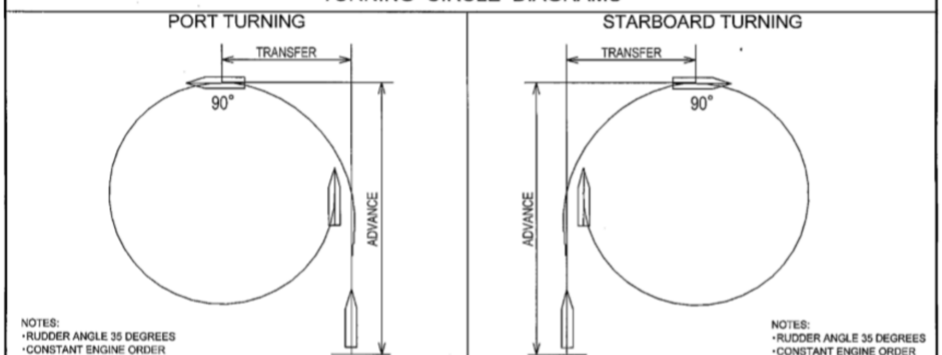
MANEUVERING CHARACTERISTICS
M.V. "ARKLOW WILLOW"

TIME AND DISTANCE TO STOP

NOTE : USING PROPELLER PITCH FULL ASTERN AND WITH MINIMUM APPLICATION OF RUDDER

		NORMAL LOADED CONDITION		NORMAL BALLAST CONDITION	
		TIME	DISTANCE	TIME	DISTANCE
	FULL SEA SPEED	6 ' - 00 "	1,326 m	3 ' - 52 "	967 m
MANEUVERING SPEEDS	FULL SPEED	6 ' - 17 "	1,100 m	3 ' - 51 "	725 m
MANEUVERING SPEEDS	HALF SPEED	6 ' - 23 "	982 m	3 ' - 50 "	621 m
MANEUVERING SPEEDS	SLOW SPEED	5 ' - 24 "	795 m	3 ' - 09 "	472 m

TURNING CIRCLE DIAGRAMS



SPEED	CONDITION	NORMAL LOADED CONDITION			NORMAL BALLAST CONDITION		
		TIME	ADVANCE	TRANSFER	TIME	ADVANCE	TRANSFER
FULL SEA SPEED	PORT	1 ' - 31 "	465 m	211 m	1 ' - 14 "	437 m	185 m
	STARBOARD	1 ' - 31 "	465 m	211 m	1 ' - 14 "	437 m	185 m
FULL SPEED	PORT	1 ' - 55 "	382 m	155 m	1 ' - 32 "	361 m	136 m
	STARBOARD	1 ' - 55 "	382 m	155 m	1 ' - 32 "	361 m	136 m
HALF SPEED	PORT	1 ' - 52 "	367 m	184 m	1 ' - 47 "	336 m	158 m
	STARBOARD	1 ' - 52 "	367 m	184 m	1 ' - 47 "	336 m	158 m

MAXIMUM AVAILABLE RUDDER ANGLE

HARD STARBOARD	70 DEGREES
HARD PORT	70 DEGREES

ENGINE ORDER / RPM / PROP. PITCH - SPEED TABLE

	ENGINE ORDER	RPM	PITCH (deg.)	SPEED (KNOTS) LOADED CONDITION WITHOUT SEA MARGINE	SPEED (KNOTS) BALLAST CONDITION WITHOUT SEA MARGINE
	FULL SEA SPEED	600/139	20.2	14.2	16.1
MANEUVERING SPEEDS	FULL AHEAD	600/139	13.6	12.5	12.7
MANEUVERING SPEEDS	HALF AHEAD	600/139	11.0	11.0	11.2
MANEUVERING SPEEDS	SLOW AHEAD	600/139	8.0	9.0	9.3
	DEAD SLOW AHEAD	600/139	5.0	6.5	6.7
	DEAD SLOW ASTERN	600/139	-5.0		
	SLOW ASTERN	600/139	-8.0		
	HALF ASTERN	600/139	-11.0		
	FULL ASTERN	600/139	-18.0		

WARNING

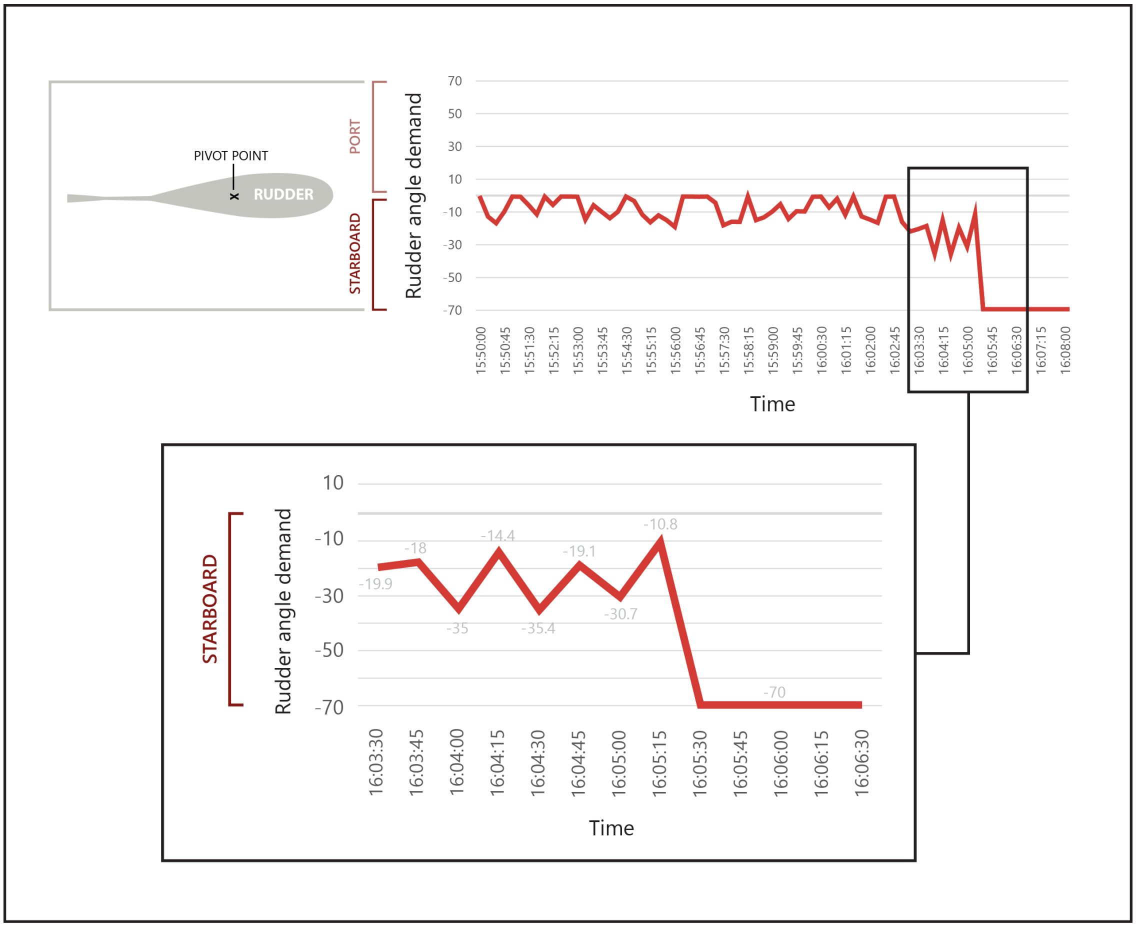
THE RESPONSE OF THE M.V. "ARKLOW WILLOW" MAY BE DIFFERENT FROM THAT USED ABOVE IF ANY OF THE FOLLOWING CONDITIONS. UPON WHICH THE MANEUVERING INFORMATION IS BASED ARE VARIED:

1. CALM WEATHER WIND 10 KNOTS OR LESS. CALM SEA.
2. NO CURRENT.
3. WATER DEPTH TWICE THE VESSELS DRAFT. OR GREATER.
4. CLEAN HULL.
5. INTERMEDIATE DRAFTS OR UNUSUAL TRIM.

KYOKUYO SHIPYARD CORPORATION

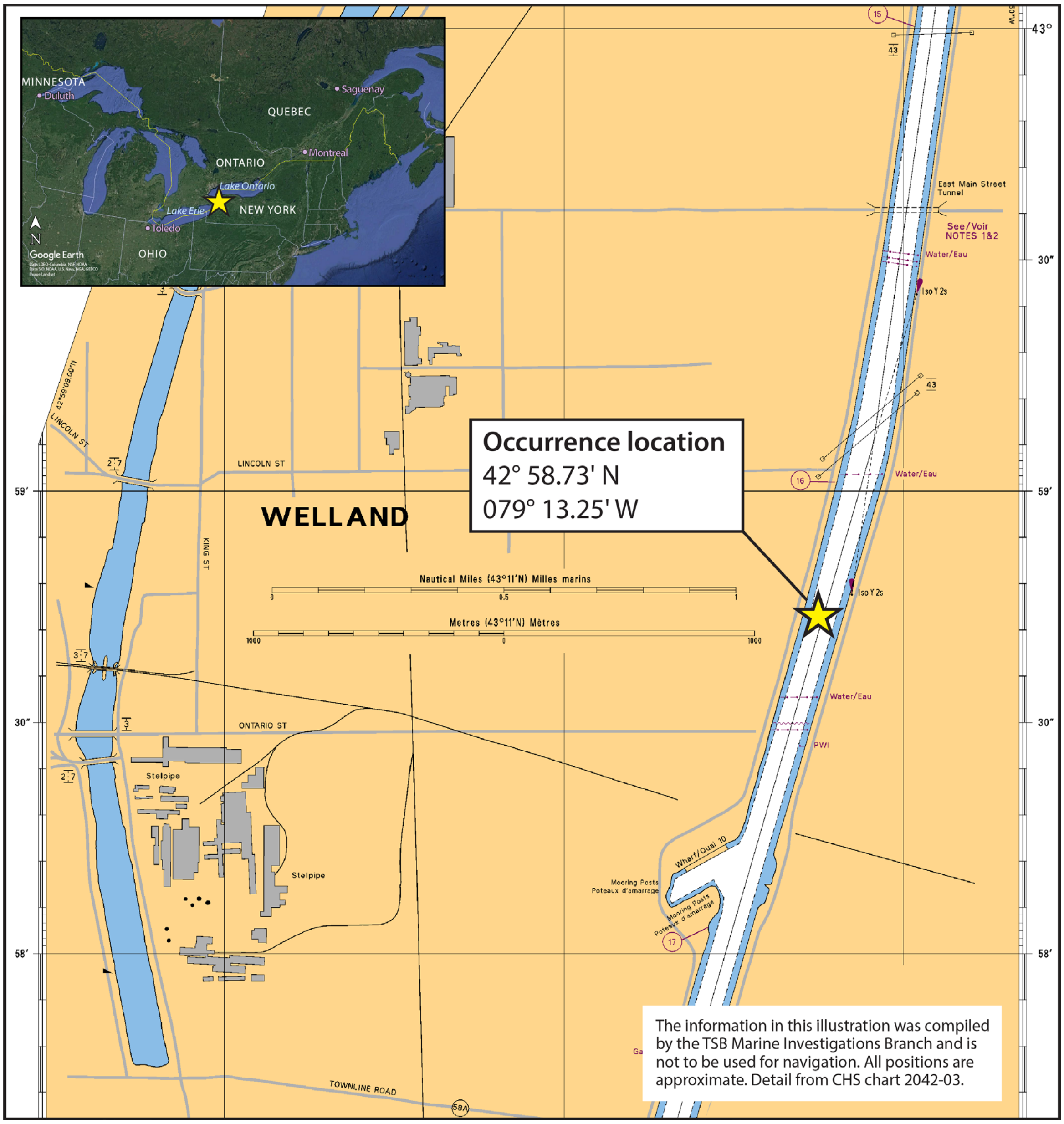
Source: McKeil Marine

Appendix B – Schematic showing rudder angle demands on the *Florence Spirit* in the 13 minutes before the collision



Source: TSB

Appendix C – Area of the occurrence



Source of main image: Canadian Hydrographic Service chart 2042-03, with TSB annotations.
Source of inset image: Google Earth, with TSB annotations.