Concept of Operations: SeaTA

Enhanced Travel Time Estimates and Traffic Management Practices for the St. Lawrence Seaway

Concept of Operations — October 2017

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16. Abstract

This Concept of Operations (ConOps) is the final installment in a series of three reports focused on identifying opportunities for the application of Intelligent Transportation System (ITS) technology—or equivalent—within the maritime transportation environment of the St. Lawrence Seaway and Great Lakes. The ConOps presented in this paper proposes a computer-based application that will improve the current level of accuracy of estimated times of arrival (ETAs) for vessels operating on the Seaway, and enhance overall system efficiency and situational awareness of Seaway operators and vessels. The proposed application, called SeaTA (for Seaway Time of Arrival) collects real-time operational data (e.g., course, speed, status) from vessels using existing, shipboard Automated Information System (AIS) transceivers, and uses that data to derives ETAs from each vessel's current position to various critical waypoints along their planned routes (e.g., locks, bridges, or navigational hazards). The proposed application is intended to improve overall safety and efficiency of the Seaway, reduce operating costs of vessels and Seaway infrastructure, and yield concurrent efficiencies to the region's heavily-traveled road and rail network.

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The contents of this paper reflect the research findings and recommendations of the Volpe Center authors, and not necessarily the opinions of the other organizations mentioned above.

Table of Contents

Acknowledgements ii
Table of Contents iii
List of Tables v
List of Figures v
Acronyms and Abbreviations vii
Executive Summary ix
1 Scope 1
1.1 Identification 1
1.2 Document Overview 1
1.3 System Overview 1
2 Referenced Documents 3
3 Current System or Situation 4
3.1 Background, Objectives, and Scope 4
3.2 Operational Policies and Constraints 6
3.3 Description of the Current System 7
3.4 Modes of Operation for the Current System or Situation 23
3.5 User Classes and Other Involved Personnel 24
4 Justification For and Nature of Changes 26
4.1 Justification For Changes 26
4.2 Description of Desired Changes 26
4.3 Priorities Among Changes 27
4.4 Changes Considered but Not Included 28
5 Concepts for the Proposed System 29
5.1 Background, Objectives, and Scope 29
5.2 Operational Policies and Constraints 29
5.3 Description of the Proposed System 30
5.4 User Classes and Other Involved Personnel 38
5.5 Support Environment 38

6 Operational Scenarios......39
6.1 Basic SeaTA Application......39
6.2 SeaTA Traffic Management......43
7 Summary of Impacts......47
7.1 Operational Impacts......47
7.2 Organizational Impacts......48
7.3 Financial Impacts......48
7.4 Impacts During Development......50
8 Analysis of the Proposed System......51
8.1 Summary of Improvements......51
8.2 Disadvantages and Limitations......52
8.3 Alternatives and Trade-Offs Considered......53
References......55
Appendix A: Stakeholders......57
Infrastructure Operators......57
Non-port government entities......57
Vessel owners/operators......58
Public and private advocacy groups......59
Port and terminal and shipyard owners and operators......60
Service providers......61
Major shippers of commodities and finished products......63
Recreational users......65

List of Tables

Table 1: List of AIS Message Types (United States Coast Guard). 14

Table 2: List of Regularly Broadcast AIS Reports (United States Coast Guard). 15

Table 3: Summary of options for SeaTA based on data input/ETA calculation methodology and functional extent, mapped to SeaTA versions described in section 4.3 33

Table 4: Proposed Information Display for a Single Vessel in SeaTA.............................35

Table 5: Proposed Information Display for a Single Waypoint in SeaTA.........................37

Table 6: Predicted Arrival Scenario at St. Lambert Locks (Sample Display)...................44

Table 7: Arrival Scenario at St. Lambert Locks Showing SLS Traffic Recommendations and Changes in Lockage Order (Sample Display) 45

Table 8: Color Codes for SLS Traffic Adjusted Lockage Order......................................46

Table 9: Disadvantages and Limitations of SeaTA and Potential Mitigation Strategies...52

List of Figures

Figure 1: Map of the St. Lawrence Seaway and Great Lakes-St. Lawrence Seaway System 5

Figure 2: Excerpt of Seaway Plan No. 115070 Montreal to Lake Ontario Traffic Control Sector No. 1, depicting location of CIP 2...10

Figure 3: Excerpt of Seaway Plan No. 115070 Montreal to Lake Ontario Traffic Control Sector No. 7, depicting locations of CIP 16 and CIP Long Point 10

Figure 4: AIS Data Sharing among the Seaway Agencies and the U.S. and Canadian Coast Guards 12

Figure 5: Graphical Depiction of Tactical Information Transmitted between Vessels and TCCs in the St. Lawrence Seaway 17

Figure 6: Sample of AIS-Based System Overview Information Available through Public Seaway Website..18

Figure 7: Sample of AIS-Based Vessel Information Available through Public Seaway Website 19

Figure 8: Sample of VHF Report-Based Vessel Information Available through Public Seaway Website....19

Figure 9: Sample Lock Order-of-Turn information Available through Seaway Public Website....20

Figure 10: Sample of Water Level Data Available through Seaway Public Website....20

Figure 11: Sample of Bridge Status/Forecasts Available through Seaway Public Website....21

Figure 12: Map of the St. Lawrence Seaway....30

Figure 13: Lock Transit Scenario, Without SeaTA (left) and With SeaTA (right)....40

Figure 14: Lock Transit Scenario, One Vessel Not Compatible with HFM System....41

Acronyms and Abbreviations

Abbreviation	Term
AIS	Automatic Identification System
ARPA	Automatic Radar Plotting Aid
ASM	Application-specific messages
ATON	Aid-to-Navigation
C.I.P.	Call-In Point
CCG	Canadian Coast Guard
ConOps	Concept of Operations
CPA	Closest Point of Approach
DIS	Draft Information System
DGPS	Differential Global Positioning System
DOT	U.S. Department of Transportation
ECDIS	Electronic Chart Display and Information System
ENOAD	Electronic Notice Of Arrival and Departure
ETA	Estimated Time of Arrival
ETD	Estimated Time of Departure
GL-SLS	Great Lakes-St. Lawrence Seaway
GPS	Global Positioning System
ICT	Information and Communications Technology
IEEE	Institute of Electrical and Electronics Engineers
IMO	International Maritime Organization
ITS	Intelligent Transportation Systems
JPO	Joint Program Office
LPA	Laurentian Pilotage Authority (Canada)
MKD	Minimum Keyboard and Display
MMSI	Maritime Mobile Service Identity
MSSIS	Maritime Safety and Security Information System
NOAA	National Oceanographic and Atmospheric Administration
PPU	Portable Pilot Unit
PSC	Port State Control

Abbreviation	Term
RIS	River Information System
SeaTA	Seaway Time of Arrival
SLSDC	Saint Lawrence Seaway Development Corporation (U.S.)
SLSMC	St. Lawrence Seaway Management Corporation (Canada)
STM	Sea Traffic Management
TCC	Traffic Control Center
TMS	Traffic Management System
USCG	U.S. Coast Guard
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
VHF	Very High Frequency (a radio frequency band from 30 MHz to 300 MHz)

Executive Summary

This document provides an overview of a proposed enhanced traffic management system (Seaway Time of Arrival or "SeaTA") to provide travel-time estimates between current locations of vessels transiting the St. Lawrence Seaway and key waypoints along their transit routes. This system would apply to the entirety of the St. Lawrence Seaway, from Montréal to Lake Erie, including sections managed by both the U.S. Saint Lawrence Seaway Development Corporation (SLSDC) and its Canadian counterpart, the St. Lawrence Seaway Management Corporation (SLSMC). This document describes the system's overall functionality and provides operational scenarios summarizing its intended use in practice.

The arrival time estimates generated by SeaTA are intended to initially support the efforts of the Seaway traffic control center personnel and operators of key infrastructure along the Seaway, principally at locks and moveable bridges. If made public, these estimates would find broader use among vessel operators, captains, and pilots as well as intersecting rail and road users (particularly emergency vehicles, and commuter and freight trains) who rely on the moveable bridges that cross the Seaway. The implementation of the SeaTA system could ultimately underpin a broader effort to promote traffic management procedures and navigational tools that would enable coordination of vessel movements system-wide. This document also discusses, in brief, how this system could form the basis for a more comprehensive traffic management system based on some of the concepts embodied by sea traffic management (STM). This extended application could include issuing recommendations for course or speed changes to safely facilitate maximum operational efficiency of the Seaway System while also respecting the interests of individual vessels (e.g., schedule, fuel usage).

The authors believe that reducing delays throughout the system—whether delays of vessels at locks, or trucks queued at an open bridge—will improve the efficiency of the Seaway System and the entire region's intermodal transportation system, however incrementally, and result in inherent cost savings to stakeholders. Although a detailed financial analysis was beyond the scope of this project, the Volpe Center identified potential cost drivers that impact vessel operators, the SLSDC and SLSMC, and other service providers using the Seaway system. There are also potential beneficial impacts to the intermodal transportation system.

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1 Scope

1.1 Identification

This document describes a proposed system called Seaway Time of Arrival, or SeaTA. This system is intended to enhance traffic management activities and operational efficiency of vessel transits through the St. Lawrence Seaway, while also delivering potential efficiencies and enhancement to the overall operation of the Great Lakes-St. Lawrence Seaway transportation system of ports, terminals and intermodal connections.

1.2 Document Overview

This document summarizes a proposed system to provide travel-time estimates between the current location of vessels transiting the St. Lawrence Seaway and key waypoints along their transit routes. This system would apply to the entirety of the St. Lawrence Seaway, from Montréal to Lake Erie, including sections managed by both the U.S. Saint Lawrence Seaway Development Corporation (SLSDC) and its Canadian counterpart, the St. Lawrence Seaway Management Corporation (SLSMC). This document describes the system's overall functionality and provides operational scenarios summarizing its intended use in practice. It also discusses how this system could form the basis for a more comprehensive traffic management system based on some of the concepts embodied by sea traffic management (STM).

The purpose of this document is to communicate the proposed system's core functionality to the SLSDC and SLSMC, as well as to the stakeholders and users of the St. Lawrence Seaway, including ship operators, pilots, ports and terminals, partner government agencies, and others. This document is also meant to provide initial input that will be useful for further development of this system, pending feedback and agreement from these stakeholder groups.

1.3 System Overview

The system summarized in this document is intended to provide travel time estimates to key waypoints for vessels transiting the St. Lawrence Seaway. These estimates are intended to initially support the efforts of traffic control center personnel and operators of key infrastructure along the Seaway, principally at locks and moveable bridges. If made public, these estimates would find broader use among vessel operators, captains, and pilots as well as railroad and road users (particularly commuter trains and emergency vehicle operators) who rely on the moveable bridges that cross the Seaway.

The implementation of this system could ultimately underpin a broader effort to promote Seaway traffic management procedures and use of navigational tools that would enable coordination of vessel movements system-wide among a multitude of agencies responsible for their movements, including Seaway Traffic Control Centers, Canadian Coast Guard (CCG) Traffic Management Montréal, Québec, and Les Escoumins;, pilotage dispatch agencies (Saint Lawrence Seaway

Pilots Association, Lakes Pilots Association and Great Lakes Pilotage Authority), and Rail Traffic Control Montréal and Calgary, among others.

The development of this document and accompanying research was sponsored by the U.S. Department of Transportation's Intelligent Transportation Systems (ITS) Joint Program Office (JPO). It was developed with support from representatives of the SLSDC and SLSMC and incorporates feedback from numerous Seaway users and stakeholders. This concept of operations follows the completion of two foundational research papers: *Overview of Safety, Efficiency, Operational, and Environmental Issues* (Perlman, Stanford, & Wallischeck, St. Lawrence Seaway: Overview of Safety, Efficiency, Operational, and Environmental Issues, 2017) and *Potential Opportunities for the Application of Information and Communication Technologies* (Perlman, Wallischeck, & Stanford, St. Lawrence Seaway: Potential Opportunities for the Application of Information and Communication Technologies, 2017). Preliminary drafts for both reports were completed in June 2016 and distributed to the SLSDC, SLSMC, and their stakeholders for review and feedback. Both are available through the ITS JPO's website at www.its.dot.gov and through the National Transportation Library at https://ntl.bts.gov/.

2 Referenced Documents

As discussed above, the concept for the application described in this document stems from two foundational research papers completed by the Volpe Center in 2016: *Overview of Safety, Efficiency, Operational, and Environmental Issues*; and *Potential Opportunities for the Application of Information and Communication Technologies*. This document also references the *Seaway Handbook*, available at www.greatlakes-seaway.com.

The format and structure of this document is based on the Institute of Electrical and Electronics Engineers (IEEE) Standard 1362—1998 *Guide for Information Technology–System Definition–Concept of Operations (ConOps) Document*.

3 Current System or Situation

3.1 Background, Objectives, and Scope

The geographic area under consideration, the St. Lawrence Seaway (herein referred to as “the Seaway”), is a binational waterway along the border between Canada and the United States, extending from Montréal to Lake Erie and connecting the Atlantic Ocean to the Great Lakes. This section provides context for the discussion of the Concept of Operations (“ConOps”) that is the subject of this paper (and described in detail in sections 4 and 5). It outlines the existing functions for vessel traffic management along the Seaway, and current systems and processes for collecting, communicating, analyzing, and disseminating operational information about the Seaway, adjoining waterways, and related infrastructure, including information about vessels and their movements.

It is worth noting that the Seaway “system,” as defined, does not function as a “formal,” coordinated system. That is, information is often shared on an ad-hoc basis and a large number of the decisions about vessel movements are made by independent agents (i.e., vessel masters, pilots, and pilotage associations) operating with a high degree of autonomy. However, such an arrangement can still be considered a “system”—albeit a largely self-managed system with distributed authority. While vessel traffic in navigational channels, approaching lock structures and bridges, and within confined waters is highly controlled and regulated by U.S. and Canadian Seaway operating corporations, non-regulated elements of the system (e.g., open waters of individual Great Lakes and other bodies, vessel movements within individual ports, and other aspects of individual vessel operation) function with a high degree of autonomy. This document (particularly later sections) considers improvements to the underlying structures and processes that make up this “system.” It is hoped that these improvements may have broad benefits in terms of safety and efficiency.

The safe and efficient operation of vessels on the Seaway is of vital importance, as these waters are a crucial natural resource and transportation network for the region, for the U.S., and for Canada. Over 35 million people rely upon the Great Lakes basin for their drinking water. Shipping via the Great Lakes-Seaway System is one of the key drivers of the U.S. and Canadian economies. The industry creates 227,000 jobs in the two countries, and produces business revenues of $35 billion. Additionally, shipping in the region contributes $4.6 billion in Federal, state/provincial, and local taxes every year. It also supports the economic health of North America’s industrial heartland and a consumer market of more than 100 million people.

Though the Seaway proper extends from Montréal to the middle of Lake Erie, it serves the broader Great Lakes-St. Lawrence Seaway (GL-SLS) system, a 2,034-mile (3,700 km) waterway that spans from the mouth of the St. Lawrence River in the Atlantic Ocean to the farthest reaches of all five Great Lakes. The GL-SLS system covers 95,000 square miles (245,750 square kilometers) of navigable waters bordering eight U.S. states and two Canadian provinces. The Welland Canal (the “upper portion” of the Seaway) opened in 1824 and the current fourth-generation Welland Canal was inaugurated in 1932. The Montréal-Lake Ontario or “lower section” of the Seaway was first opened to deep-draft navigation in 1959. The Seaway carries about 40 million metric tons of cargo annually and generates billions of dollars in employment, purchases, and tax revenue in both the U.S. and Canada (Martin Associates, 2011). For additional background on the overall Seaway system, see Volpe's first white paper produced for this project *St. Lawrence Seaway: Overview of Safety, Efficiency, Operational, and Environmental Issues* (Perlman, Stanford, & Wallischeck, St. Lawrence Seaway: Overview of Safety, Efficiency, Operational, and Environmental Issues, 2017).

Figure 1: Map of the St. Lawrence Seaway and Great Lakes-St. Lawrence Seaway System
(Source: Canadian Geographic)

As with most navigable waterways throughout the world, the Seaway's objectives related to information-exchange and vessel traffic management processes are primarily safety-related. Several port or waterway agencies around the world, responsible for the safe operation of busy, highly-congested waterways, have begun to explore and implement information exchange schemes (commonly called "sea traffic management" (STM) systems) that build upon the core safety objectives to further improve overall operational efficiency and environmental performance. The SLSDC and SLSMC have implemented some systems designed to enhance the operational efficiency of transiting the Seaway, most notably the Draft Information System (DIS) that allows equipped vessels to have greater control of their underkeel clearance (the distance between the lower portion of the ship's hull and the bottom of the waterway). DIS equipped vessels may carry additional cargo and operate at a deeper draft, while maintaining an adequate margin of navigational safety. However, more broad-based efforts to enhance the efficiency of overall Seaway operations have been limited.

While no systemic objectives of this nature are explicitly laid out, it is clear that there is some intent of the Seaway and its stakeholders to leverage system capabilities for efficiency and environmental benefits. Beginning in 2015, the Seaway corporations began installing hands-free systems in their locks that increase the safety of shipboard crews and shoreside line-handlers, and avoid the more time- and labor-intensive process of manual line-handling. Moreover, the Seaway's website lists the following benefits (in addition to improved safety) from its deployment of Automatic Identification System (AIS) technology in 2002:

- Reduced transit times (with accompanying lower fuel consumption) through better traffic management and enhanced scheduling of lockages;
- Enhanced fleet management (more accurate arrival times, leading to more-efficient scheduling of appointments with pilots and ship inspectors); and,
- Improved scheduling of lockages and vessel tie-ups (AIS Project, 2017).

The St. Lawrence Seaway Development Corporation's strategic plan identifies the following goal: "Utilize AIS/GPS/DIS technologies to more efficiently manage vessel traffic control and vessel lockages at the two U.S. Seaway locks" (Saint Lawrence Seaway Development Corporation, 2016). Furthermore, as a general overarching principle for all waterways, vessel operators *will* tend to cooperate as much as possible (and use existing communications systems to do so) in order to enable vessels to complete their voyages safely and efficiently. For example, it is common for a faster vessel to request another to slow down or make room in a channel to enable them to be safely overtaken. Operational characteristics of the existing system are discussed in more detail in Section 3.3.

3.2 Operational Policies and Constraints

In terms of systems for **collecting and handling operational data**, there do not appear to be any significant overarching constraints. The system as it exists today is able to collect a substantial amount of data from all ships through both very high frequency (VHF) radio communications and AIS (discussed in greater detail below). Moreover, since locks and moveable bridges in the Seaway fall under the purview of the SLSDC or SLSMC, system managers should have access to all relevant operational data for these components as well. However, it is unclear how certain data flows occur between the Traffic Control Center (TCCs), pilotage authorities, moveable bridge operators, and other system elements, which impose unforeseen constraints or limits on the dissemination of data. This situation may depend upon whether data is disseminated to system users automatically, or whether it relies upon manual distribution. For example, a critical ship-to-shore VHF radio message received by a Canadian TCC may not be relayed to a U.S. TCC or other concerned party in a timely manner, or vice-versa. There may also be unintended constraints due to technical limits or procedural policy. Similarly, with AIS data, there may be policy constraints limiting the exchange of data between stakeholders. These issues are considered in more detail in the following sections.

In terms of **vessel traffic management**, there are limits to the authority of the TCCs and other agencies responsible for a portion of the Seaway system (e.g., port authorities) that need to be considered. One overarching principle that appears to play a significant constraining role in this area is the principle that a vessel's master has ultimate authority and responsibility for all decisions related to the safety of his/her vessel and crew (United States Coast Guard, 2014) (Quick, n.d.) (Bach, 2009) (International Association of Marine Aids to Navigation and Lighthouse

Authorities, 2008). Depending on how strictly this standard is observed—and considering the availability of pilots—it has the potential to constrain any attempt to manage vessel traffic and consequently to other associated dispatch. There may also be additional limitations related to interjurisdictional issues, when vessel traffic is managed across traffic control sectors, pilotage zones, and across the U.S.-Canada border.

3.3 Description of the Current System

3.3.1 Existing Systems for Gathering and Communicating Operational Data

As a large system spanning numerous large physical components, with a wide range of users, the Seaway encompasses multiple flows of information through several different media. These media range from traditional visual signals (lights, flags, and day-shapes) and sound signals (horns, bells, whistles); to VHF radio communications; to fax, email, and forms submitted via the internet; to AIS. Depending on the medium, information can flow from ship-to-ship, from ship-to-shore, or through any combination of connections among vessels, other users of the system, and system operators. Some data is transmitted automatically (e.g., AIS) while other data is transmitted manually or verbally.

This section outlines all the data that flow throughout the system that may be useful in terms of developing a more complete awareness of present and foreseeable operating conditions. Specifically, this section reviews the availability of data that can help operators and users of the system make informed <u>*tactical*</u> decisions—e.g., decisions made about a vessel that is underway, such as changes in speed and/or course, that will affect the arrival times at various points throughout a voyage. Such tactical data, if utilized to their full potential, may offer substantial improvements in the safety and efficiency of operations. It is important to note that these data *do not* include information flows related to imminent or local conditions and moment-to-moment conduct of a vessel, such as communications related to maneuvering into a lock, to avoid a collision with another vessel, or signaling an approach to a moveable bridge.

Unless otherwise noted, most of the information presented below is maintained in *The Seaway Handbook*, produced by the SLSMC and containing the SLSMC's *Seaway Practices and Procedures* and the SLSDC's *Seaway Regulations* (St. Lawrence Seaway Management Corporation, 2017).

3.3.1.1 Pre-transit Communications

The data collected from vessels in pre-transit communications are generally more relevant for long-term, *strategic* voyage planning (i.e., planning the route and main elements to ensure safety of a vessel's entire, berth-to-berth voyages, and other considerations per IMO Resolution A.893(21): *Guidelines for Voyage Planning*) and less so for tactical decision making. Nevertheless, some information shared in these communications has the potential to continue to be relevant from a tactical perspective throughout a vessel's transit of the Seaway, and this overall category of information may offer opportunities to include information of greater tactical utility in the future, such as more detail regarding voyage plans and vessel operating characteristics. Current required pre-transit communications include the following categories:

- **Advance notice and pre-clearance—**
    - Notice of arrival: All vessels are required to provide at least 96 hours' notice of arrival to the nearest Seaway station prior to all transits or in case re-inspection of the ship is required.
    - Pre-clearance: This information, submitted via online form, includes particulars of ownership, liability insurance, physical characteristics of the ship, and guarantee of payment for any fees incurred.
    - Electronic Notice of Arrival and Departure (ENOAD): All foreign-flagged ships must provide an ENOAD, which includes: vessel details (name, call sign, Maritime Mobile Service Identity (MMSI) number, owner, operator, flag, tonnage); arrival information (points of contact, destination, receiving facility, arrival/departure time); information on the previous and next ports of call (actual/expected arrival and departure times); information on crew, passengers, and cargo; and a vessel security plan.
- **Ballast Water Reporting—**This form is submitted via email or fax to Transport Canada or U.S. Coast Guard.
- **Hazardous Cargo Reporting—**The Hazardous Cargo Load Plan is filed via fax with the nearest Traffic Control Center.

The data in these pre-transit communications are maintained by the Seaway and not shared or distributed with other vessels.

In addition to these formal communications requirements, commercial vessels are required to carry a number of information resources on board, subject to being produced upon inspection—for example: 1) documentary evidence, comprising inspection certificates, load line certificates, crew lists, dangerous cargo manifest and the cargo stowage plan; and 2) evidence of cargo declared, cargo manifest, and dangerous cargo manifest.

3.3.1.2 VHF Radiotelephone Communications While Underway

Vessel-to-vessel communications. Vessels operating in the GL-SLS system must observe the Canadian Modifications to the 72 COLREGS (International Regulations for Preventing Collisions at Sea, 1972) when sailing on the Canadian side of the international demarcation line, and must observe the U.S. Inland Navigation Rules when sailing on the United States side. In terms of communications, these modifications do not vary significantly from the 72 COLREGS and subsequent amendments, so they are essentially the same procedures that all ships observe in international waters around the world.

The rules regarding vessel-to-vessel communications are focused almost entirely on safety, and VHF radio communications have become the de-facto medium, largely replacing prior use of sound and light signals. In other words, rather than making the sound signal to indicate the intent to overtake another vessel, the master or pilot will usually contact his/her counterpart via VHF radio and the two parties come to agreement on when and where the overtaking will occur. Sound and light signals are still occasionally used between vessels, and become mandatory when vessels cannot come to agreement via VHF or when in extremis situations (e.g., sounding the “danger signal”).

In terms of coordinating vessel movements over a longer time span, however, there are few standards and no established rules for vessel-to-vessel communications. This means that it generally falls on the pilots or masters to take the initiative and cooperatively agree on changes in course and/or speed that are mutually beneficial to the two vessels in question. For example, a faster ship may request a slower ship to make way for overtaking (where overtaking is possible and not otherwise prohibited) before heading into a narrow channel where the faster vessel would otherwise be stuck behind the slower vessel and incur avoidable delays. Such efficiency-improving agreements, however, rely on the initiative and situational awareness of the vessel masters, and they generally only consider the benefits that can be attained by one or two vessels at a time. Larger, more systemic benefits—brought about by minor adjustments in course or speed by multiple vessels, often miles apart—would be almost impossible to realize via the current regime of ad-hoc ship-to-ship communications.

Communication between TCCs and individual vessels. As the entire Seaway system falls under the purview of either a U.S. or Canadian TCC, the protocols for ship-to-shore and shore-to-ship communications are fairly extensive and thorough, prescribing a number of procedures that must be followed throughout an entire Seaway transit. In addition to these formal reporting requirements, there are also the usual ad-hoc communications that occur between vessels and shore-side officials as needs arise.

There are a number of formal reporting requirements from ship-to-shore, and assigned VHF channel frequencies for each traffic control sector (including a *call-in* channel, a *work* channel, and a *listening watch* channel). Reporting requirements include:

- **Initial arrival at call-in points and check points—**Vessels are required to provide more extensive information when they make first radio contact with a Seaway TCC. For upbound vessels, these first call-ins would occur when they arrive at call-in point (CIP) 2, if they are transiting from the Lower St. Lawrence River, or before getting underway if they are docked or anchored at Montréal (see figure 2). For downbound vessels, these initial call-ins occur at Long Point approaching the Welland Canal entrance (see figure 3).

  Information to be provided at these initial call-in points includes: (1) name of ship; (2) location; (3) destination; (4) drafts, fore and aft; (5) cargo; (6) manifested dangerous cargo; (7) pilot requirement for Lake Ontario. Vessels entering the Seaway after departing from ports on Lake Ontario or Lake Erie (east of Long Point) will provide the same information when they call in to the appropriate TCC for that sector.

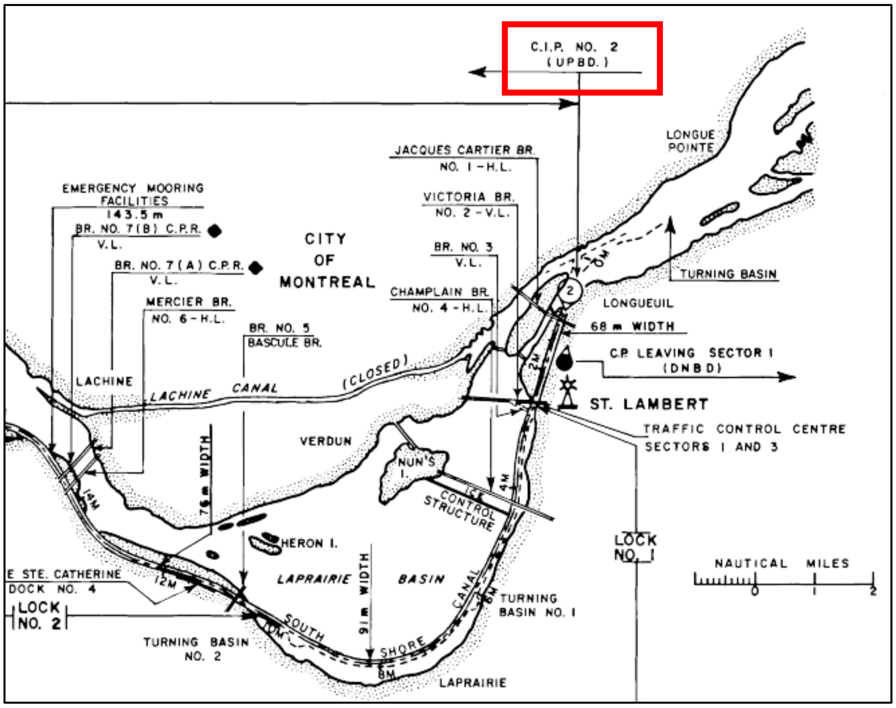


Figure 2: Excerpt of Seaway Plan No. 115070 Montreal to Lake Ontario Traffic Control Sector No. 1, depicting location of CIP 2.

(Source: SLSMC)

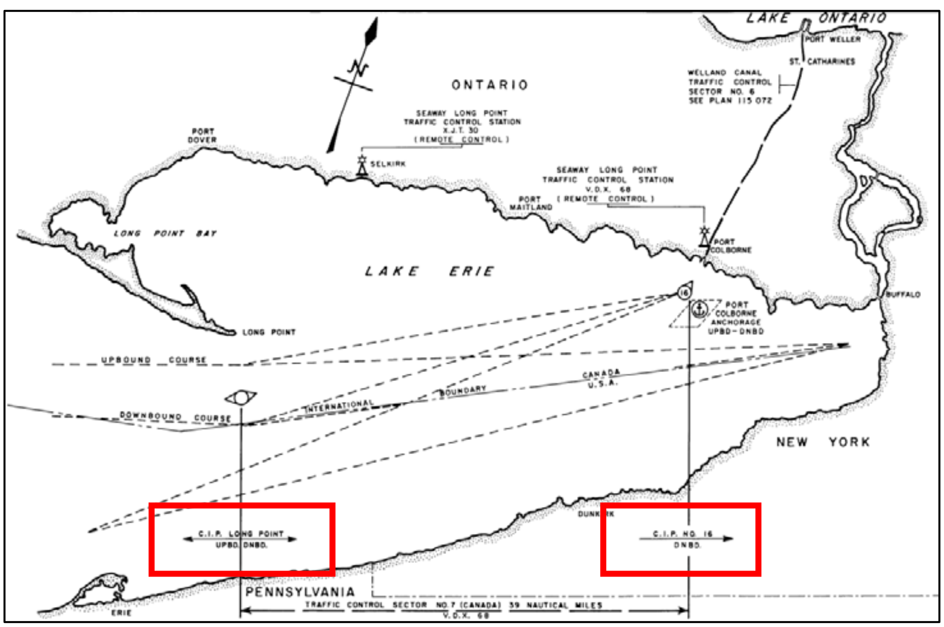


Figure 3: Excerpt of Seaway Plan No. 115070 Montreal to Lake Ontario Traffic Control Sector No. 7, depicting locations of CIP 16 and CIP Long Point

(Source: SLSMC)

- **Other call-in points and check points—**Much less information is required at these locations—this always includes the vessel's name and location, and depending on the location, can include an estimated time of arrival (ETA) at other points farther ahead and/or confirmation of pilot requirements. A few additional procedures are specified for vessels exiting the Seaway into the Lower St. Lawrence River.
- **Other required communications (not location-specific)—**
  - Reporting any changes to previously reported information, including any changes in an ETA of more than 30 minutes.
  - Reporting of accidents, dangerous occurrences, and hazardous conditions on board the ship (such as loss of control of tows, equipment malfunctions, etc.) or in the Seaway (such as low visibility, malfunctioning aids to navigation, etc.).
  - Reporting anchoring, mooring at a dock, or tying up to a canal bank; these circumstances require subsequent permission from the TCC before getting underway again.

Communication between individual vessels and locks/bridges—None of the VHF communications between vessels and shoreside facilities such as locks or bridges fall into the category of "tactical" decision making. This makes sense, because lock order turns are established by the TCCs, and it would not be appropriate for vessels to communicate directly with lock or bridge personnel to make any alternate arrangements. In fact, the *Seaway Handbook* explicitly limits VHF communications between locks and ships to be "solely for transmitting mooring instructions or in an emergency." Similarly, communications by VHF with bridges is "limited to periods of reduced visibility and emergencies only" (all other standard communications with bridges is via light and sound signals).

Marine weather broadcasting and data collection—The CCG, the U.S. Coast Guard (USCG), the National Oceanographic and Atmospheric Administration (NOAA), and Environment Canada regularly broadcast marine weather information and forecasts. Additional data are collected via voluntary reporting, where vessels will report adverse weather or sailing conditions to the nearest TCC.

3.3.1.3 Automatic Identification System (AIS)

AIS is an automated communications-based system that uses VHF-frequency radio broadcasts to allow vessels to send and receive key operational data, such as speed and position, continuously and autonomously (with no need for active operation by crew). These AIS data are also picked up by shoreside transceivers (or "base stations") operated by the SLSDC, SLSMC, and USCG, and integrated directly with the Seaway's Traffic Management System. AIS data are shared directly between vessels (when in VHF radio range of one another), between the SLSDC and the SLSMC, and between the USCG and the SLSDC. In addition, both Seaway agencies and both the USCG and the CCG can access AIS data from one another's systems through the Maritime Safety and Security Information System (MSSIS) (see figure 4 below).

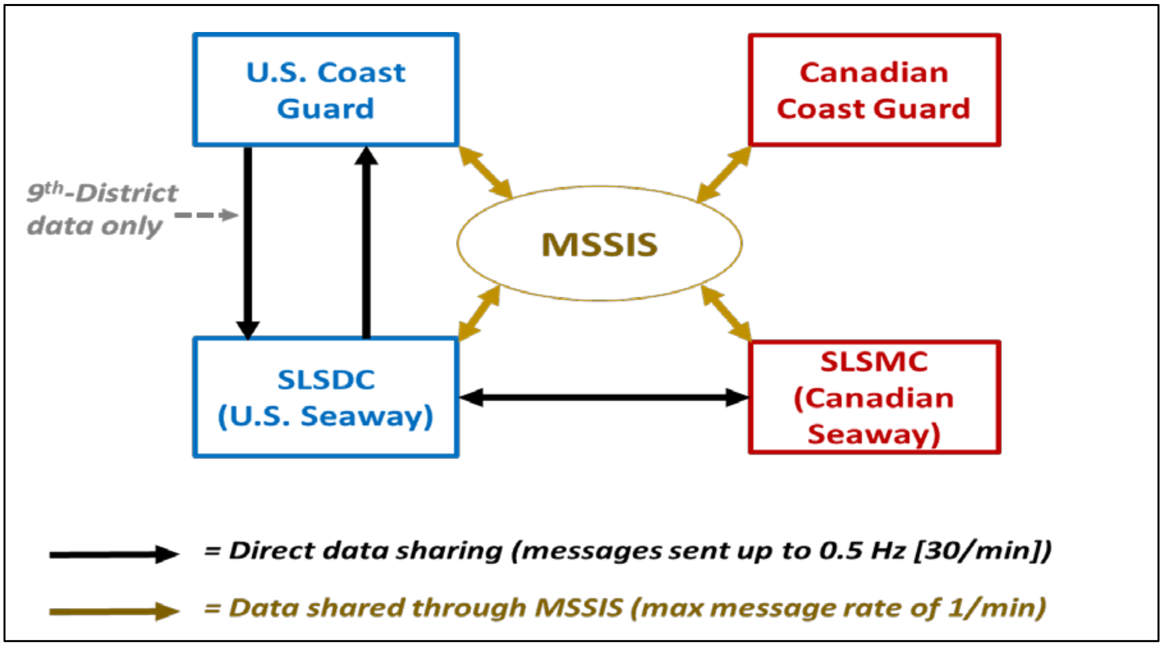


Figure 4: AIS Data Sharing among the Seaway Agencies and the U.S. and Canadian Coast Guards
(Source: Volpe Center)

The Seaway also uses base stations to broadcast operationally relevant data, such as local wind speed and direction, and availability of the next lockage. As VHF signals are generally limited by "line of sight," the range of AIS signals is usually about 30 miles (given the average height of antennae on vessels and base stations). Some waterway AIS networks employ VHF repeaters, which can greatly extend the effective range of a vessel's AIS signal. These VHF repeaters are not currently used on the Seaway. Some real-time information on any vessels operating throughout the Seaway system is available via the internet (on the Seaway's website or through third-party providers), and for vessels without internet access, any relevant operational information they may need about other vessels can be provided by the nearest TCC.

The Seaway was the first waterway in the world to implement mandatory carriage requirements for AIS. All ships with gross tonnage of 300 or greater, length of more than 20 meters, or capacity for more than 50 passengers, are required to be equipped with AIS in order to transit the Seaway between Montréal and Lake Erie. Finally, it should be noted that the monitoring of AIS broadcast messages (i.e., not directed to a specific vessel or shore station) is unrestricted, and information is widely accessible by third parties. Many private vessel owner-operators and third-party providers have deployed AIS receivers in order to track their own vessels or to monitor other vessel movements as a commercial subscription service.

International convention has defined 27 AIS message types for (see table 1). Most of these messages carry prescribed data, but four message types—messages 6, 8, 25, and 26—are "Application Specific Messages" (or ASMs) whose contents can be defined by local authorities. Most of these messages are broadcast-type messages (meaning that they have no specific recipient), but a few of them are "addressed" messages, which are sent to a specific recipient.

AIS technology is widely used in the maritime sector, and already provides much of the functionality that would be associated with emerging surface applications for vehicle-to-infrastructure (V2I) or vehicle-to-vehicle (V2V) communications.[1] Similar to some V2V applications, AIS provides all ships in the system with a wide range of real-time data on other vessels, for example: static data (which are usually entered manually) such as vessel ID, length and beam, and type; dynamic data (which are usually entered automatically from shipboard sensors) such as position, course, speed, heading, rate-of-turn; and voyage-related data (entered manually) such as draft, destination, ETA, and hazardous cargo.

Similar to some V2I applications, shore-based transmitters broadcast to all vessels, providing information such as: weather and waterway conditions, lock-order turns, and other alerts and advisories. There are also efforts underway in the U.S., Canada, and elsewhere around the world to implement virtual and synthetic aids-to-navigation (ATONs) using the AIS system. These ATONs would appear on radar or electronic chart systems that incorporate AIS-based data. (Lane, 2015). AIS systems can also be configured for additional data fields.

[1] In short, V2V and V2I communications would enable motor vehicles to automatically exchange basic safety information and other data between each other and with infrastructure components like traffic signals. These communications capabilities would enable the use of applications to improve safety, mobility, and environmental impacts.

Table 1: List of AIS Message Types (United States Coast Guard).

ID	Name	Description	Source
1	Position Report	Scheduled position report	Vessel
2	Position Report	Assigned scheduled position report	Vessel
3	Position Report	Special position report, response to interrogation	Vessel
4	Base Station Report	Position, UTC, date and current slot number of base station	Base St.
5	Static & voyage- related data	Scheduled static and voyage-related vessel data report	Vessel
6	Binary addressed message	Binary data for addressed communication	Either
7	Binary acknowledgement	Acknowledgement of received addressed binary data	Either
8	Binary broadcast message	Binary data for broadcast communication	Either
9	Standard SAR aircraft position report	Position report for airborne stations involved in SAR operations, only	Other (aircraft)
10	UTC/date inquiry	Request UTC and date	Either
11	UTC/date response	Current UTC and date if available	Vessel
12	Addressed safety related message	Safety related data for addressed communication	Either
13	Safety related acknowledgement	Acknowledgement of received addressed safety related message	Either
14	Safety related broadcast message	Safety related data for broadcast communication	Either
15	Interrogation	Request for a specific message type (can result in multiple responses from one or several stations) (4)	Either
16	Assignment mode command	Assignment of a specific report behavior by competent authority using a Base station	Base Station
17	DGNSS broadcast binary message	DGNSS corrections provided by a base station	Base Station
18	Standard Class B equipment position report	Standard position report for Class B shipborne mobile equipment to be used instead of Messages 1, 2, 3(8)	Vessel
19	Extended Class B equipment position report	No longer required; Extended position report for Class B shipborne mobile equipment; contains additional static information (8)	Vessel
20	Data link management message	Reserve slots for Base station(s)	Base Station
21	Aids-to navigation report	Position and status report for aids-to-navigation	Either
22	Channel management(6)	Management of channels and transceiver modes by a Base station	Base Station
23	Group assignment command	Assignment of a specific report behavior by competent authority using a Base station to a specific group of mobiles	Base Station
24	Static data report	Additional data assigned to an MMSI Part A: Name Part B: Static Data	Either
25	Single slot binary message	Short unscheduled binary data transmission (Broadcast or addressed)	Either
26	Multiple slot binary message with Communications State	Scheduled binary data transmission (Broadcast or addressed)	Either
27	Position report for long-range application	Class A and Class B "SO" shipborne mobile equipment outside base station coverage	Vessel
28–63	Undefined, reserved for future use		

AIS messages are broadcast in a number of different reports that are made at varying frequencies. The first two reports listed in table 2—the regular-frequency reports broadcast from vessels—appear to be the most relevant to Seaway operations.

Table 2: List of Regularly Broadcast AIS Reports (United States Coast Guard).

Report	Messages Used	Frequency	Contents (**Message Parameters**)	Source
Class-A AIS position report	1, 2, 3	Every 2 to 10 seconds when underway, and every 3 minutes at anchor	Message ID User ID (MMSI #) Navigational Status (underway, at anchor, etc.) Rate of Turn Speed over Ground Latitude Longitude Course over Ground True Heading Etc.	Vessel
Class-A Static and Voyage Related Data	5	Every 6 minutes	Message ID User ID (MMSI #) IMO Number Call Sign Vessel Name Type of Ship and Cargo Overall Dimensions Type of Positioning Device ETA at Final Destination Draught Destination Etc.	Vessel
AIS Base Station	4	Every 10 seconds	Position UTC Date Current slot number of base station	Base Station

3.3.1.4 Direct Use of AIS Data on Shipboard Navigation and Shoreside Tracking Equipment

The simplest, most-direct way to view AIS data is through the required Minimum Keyboard and Display (MKD), a stand-alone device mounted near a vessel’s conning station, displaying basic information in text format, including the name, bearing, and range of AIS transmitting stations. However, since AIS stations use standardized interfaces to exchange data with other devices, AIS information can be much more effectively displayed directly on a vessel’s navigational equipment, including the following:

- **Electronic Chart Display & Information Systems (ECDIS)—**Nearly all of the commercial cargo and passenger ships operating on the Seaway are fitted with an ECDIS unit. These devices integrate electronic navigational charts with other navigational data, such as position (derived from a global positioning system (GPS) or differential GPS (DGPS) system), speed, gyrocompass heading, radar, and water depth, in a single display. When integrated with the ship's AIS transceiver, ECDIS units will display key operational information about all vessels within AIS signal range, as well as environmental and other data broadcast from AIS base stations on shore.
- **Portable Pilot Units (PPUs)—**Some of the pilot associations serving in the GL-SLS System utilize PPUs to supplement shipboard navigational devices. These units typically consist of a ruggedized laptop and a dedicated DGPS antenna, and are connected to the ship's AIS station. More sophisticated PPUs can include their own dedicated AIS receivers; highly accurate rate-of-turn generators; sensors that measure vessel roll, pitch and heave; and multiple antennae (necessary for exceptionally long ships). The most precise PPUs can achieve an extremely accurate position to within two centimeters and a heading precision within 0.01 degrees.
- **Automatic Radar Plotting Aids (ARPA)**—Radar units outfitted with ARPA provide more precise tracking of targets, which improves situational awareness and decision making. The units display relative speed and position, true course and speed, and past and predicted tracks of "own-ship" and at least 40 separate target ships. ARPA units can be programmed to create alerts when vessels are on collision courses, or when closest-points-of-approach (CPAs) fall below an acceptable safety buffer. Integrating AIS data in an ARPA unit significantly improves radar target identification and position accuracy, and enables a radar to effectively "see" other vessels that would otherwise be hidden in radar shadows. It also allows operators to identify radar targets as specific vessels, further improving situational awareness and facilitating ensuing radio communications, when required.

AIS data about other vessels or ATONs are usually displayed graphically when integrated with shipboard navigational equipment, but can also be displayed in text, for example, with AIS broadcasts related to weather or other environmental conditions. However it is used, AIS data can increase the situational awareness of the vessel's master and other officers; assist is decision making; and reduce risks when maneuvering in crowded, confined waterways.

AIS data are also used directly in vessel tracking systems. This includes integration of AIS signal data with shoreside tracking equipment similar to the radar and ECDIS units used aboard ship. However, in addition to these direct uses, the Seaway, like many vessel traffic control operations, also aggregates this data to provide system-wide vessel tracking information. This is discussed in more detail in the next section.

3.3.2 Existing Systems for Aggregating and Disseminating System-wide Operational Data

The SLSDC and SLSMC collect a substantial amount of real-time operational data, through VHF communications with ships, from environmental sensors, and through the AIS system. Figure 5 shows the overarching flows of tactically relevant operational information throughout the Seaway system.

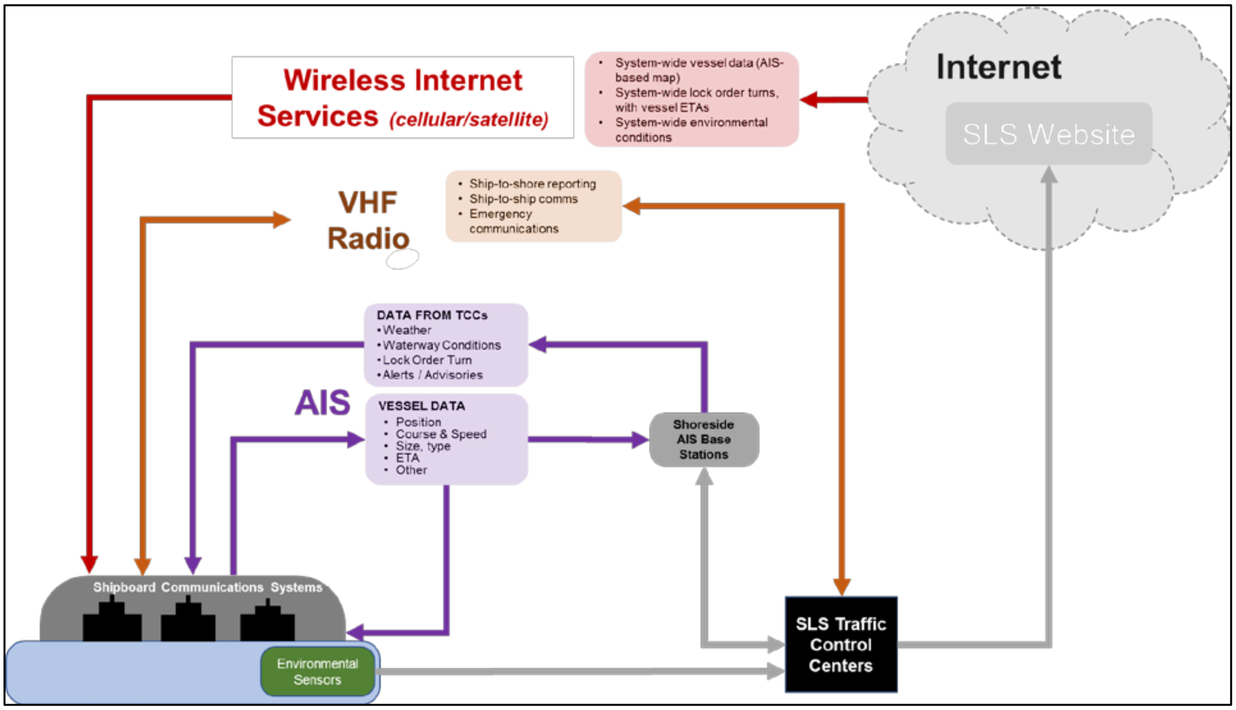
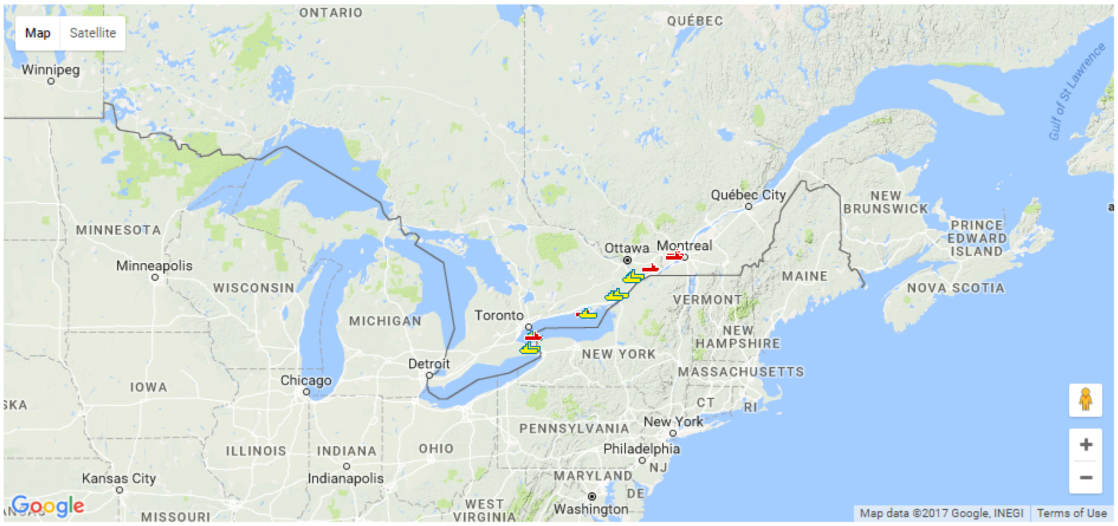


Figure 5: Graphical Depiction of Tactical Information Transmitted between Vessels and TCCs in the St. Lawrence Seaway
(Source: Volpe Center)

While some of this information is made broadly available to system users and the general public via telephone (including "information relative to ship movements" and water-level information at key points throughout the Seaway), the main venue for disseminating broad system-wide information is the Seaway's website (www.greatlakes-seaway.com). Resources on that website include:

- **Vessel tracking via AIS—**The "Seaway Map" uses AIS data to provide real-time vessel tracking information that allows shippers, vessel owners, marine service providers, local businesses, and any member of the general public to monitor vessel traffic on the Seaway. While the USCG does not make its AIS network data available directly to the general public, the Seaway's website does utilize data from Seaway base stations (owned by both the SLSDC and SLSMC), which is usually sufficient to provide complete-system coverage. While the "Seaway Map" also shows locations of locks and port facilities, the information provided about those facilities is only general, static data, with no real-time operational utility. Available views include a system-wide map and overview of all vessels (figure 6), as well as some (but not all) available AIS data on each vessel (figure 7).

GREAT LAKES – ST. LAWRENCE SEAWAY | GREAT LAKES | ST. LAWRENCE SEAWAY | WELLAND CANAL | ST. LAWRENCE – MONTREAL



Last Updated: 2017/04/19, 11:09

The St. Lawrence Seaway's navigation season generally extends from late March to late December.

Show all Vessels

Show/Hide	Last Location	Next Location	Transit Status	
ALGOMA ENTERPRISE	NORTH WALL LOCK 4 EAST	LOCK 4 EAST	In Transit	View Details
CSL ST-LAURENT	C.I.P. LONG POINT - CENTRAL	CALL IN POINT 16	In Transit	View Details
EDZARD SCHULTE	MID LAKE ONTARIO - SOUTH	C.I.P. SODUS POINT - CENTRE	In Transit	View Details
EVANS SPIRIT	SOUTH WALL LOCK 6 WEST	LOCK 6 WEST	In Transit	View Details
FEDERAL BARENTS	SNELL LOCK UPPER WALL	EISENHOWER LOCK	In Transit	View Details
FEDERAL KUSHIRO	CALL IN POINT 3	LOCK 3 BEAUHARNOIS LOWER WALL	In Transit	View Details
GENESIS VICTORY	C.I.P. SODUS POINT - CENTRE	MID LAKE ONTARIO - SOUTH	In Transit	View Details
JOHN D LEITCH	C.I.P. CAPE VINCENT	C.I.P. CROSS OVER ISLAND	In Transit	View Details
ROBERT S PIERSON	CALL IN POINT 14	CALL IN POINT 13	In Transit	View Details
SALVAGE MONARCH	C.I.P. LONG POINT - CENTRAL	CALL IN POINT 16	In Transit	View Details
SEA EAGLE II	NORTHWEST WALL LOCK 7	LOCK 7	In Transit	View Details
SOLINA	C.I.P. CAPE VINCENT	C.I.P. CROSS OVER ISLAND	In Transit	View Details
THUNDER BAY	CALL IN POINT 14	CALL IN POINT 13	In Transit	View Details
WILF SEYMOUR	LOCK 4 BEAUHARNOIS UPPER WALL	ST. LOUIS BRIDGE	In Transit	View Details

Figure 6: Sample of AIS-Based System Overview Information Available through Public Seaway Website

(Source: http://www.greatlakes-seaway.com/en/navigating/map/index.html)

Vessel Name:	ALGOMA ENTERPRISE	Transit Status:	In Transit
Vessel No:	1894	Last Location:	SOUTH WALL LOCK 3
Fleet:	I	ATA:	2017-04-19 10:57
No of Vessel:	1	Country:	CANADA
Width (Meters):	23.17	Next Location:	BRIDGE 5
Length (Meters):	222.49	ETA:	2017-04-19 11:00

Figure 7: Sample of AIS-Based Vessel Information Available through Public Seaway Website

(Source: http://www.greatlakes-seaway.com/en/navigating/map/index.html)

- **Vessel tracking based on VHF radiotelephone reports to TCCs—**Similar to the AIS-based map, this resource displays all the vessels operating throughout the system, but it includes different data, as it is based on manual reports made by vessels via VHF radio at checkpoints throughout the system. TCC personnel manually enter these data into client software, which enables sharing of the information publicly online.

GREAT LAKES ST. LAWRENCE SEAWAY SYSTEM

All Vessels - Alphabetically

As of: 04 19, 11:09

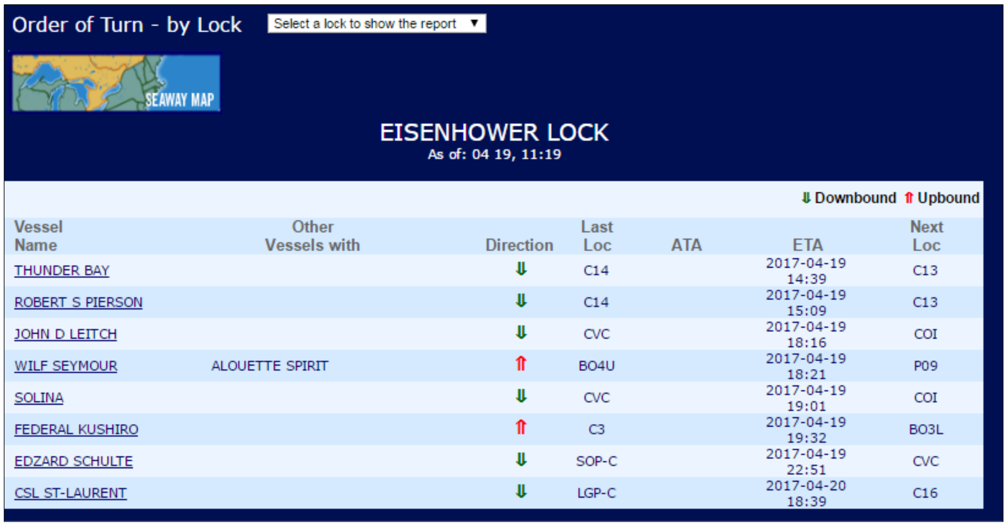
⇓ Downbound ⇑ Upbound

Vessel Name	Fleet	# of Vessels	Direction	Last Loc	ATA	Next Loc	ETA
ALGOMA ENTERPRISE	I	1	⇑	L4NE	2017-04-19 11:07	L4E	2017-04-19 11:09
CSL ST-LAURENT	I	1	⇓	LGP-C	2017-04-19 08:28	C16	2017-04-19 11:30
EDZARD SCHULTE	O	1	⇓	MLO-S	2017-04-19 09:15	SOP-C	2017-04-19 11:15
EVANS SPIRIT	I	1	⇓	L6SW	2017-04-19 11:05	L6W	2017-04-19 11:07
FEDERAL BARENTS	O	1	⇑	SNLU	2017-04-19 09:53	IKE	2017-04-19 10:23
FEDERAL KUSHIRO	O	1	⇑	C3	2017-04-19 10:50	BO3L	2017-04-19 11:21
GENESIS VICTORY	I	2	⇑	SOP-C	2017-04-19 09:55	MLO-S	2017-04-19 15:00
JOHN D LEITCH	I	1	⇓	CVC	2017-04-19 09:25	COI	2017-04-19 12:45
ROBERT S PIERSON	I	1	⇓	C14	2017-04-19 10:44	C13	2017-04-19 12:00
SALVAGE MONARCH	I	2	⇓	LGP-C	2017-04-19 03:02	C16	2017-04-19 10:00
SEA EAGLE II	I	2	⇑	L7NW	2017-04-19 09:34	L07	2017-04-19 11:14
SOLINA	O	1	⇓	CVC	2017-04-19 10:15	COI	2017-04-19 13:30
THUNDER BAY	I	1	⇓	C14	2017-04-19 10:14	C13	2017-04-19 11:30
WILF SEYMOUR	I	2	⇑	BO4U	2017-04-19 10:57	P09	2017-04-19 11:38

Figure 8: Sample of VHF Report-Based Vessel Information Available through Public Seaway Website

(Source: http://www.greatlakes-seaway.com/R2/jsp/R2.jsp?language=E&loc=VT07.jsp)

- **Lock Order of Turn (and Arrivals)—**This resource also uses information manually reported to TCCs via VHF radio. It shows both the ETA provided by each vessel at their last call-in point, as well as the order of proceeding through the lock, as assigned by the TCC. Note that in the example provided in figure 9, based on ETAs provided, it appears that two vessels (the downbound *John D Leitch* and the upbound *Wilf Seymour*) will arrive at the lock within 5 minutes of each other, resulting in a delay as one vessel waits for the other to first pass through the lock.



Order of Turn - by Lock

Select a lock to show the report

SEAWAY MAP

EISENHOWER LOCK

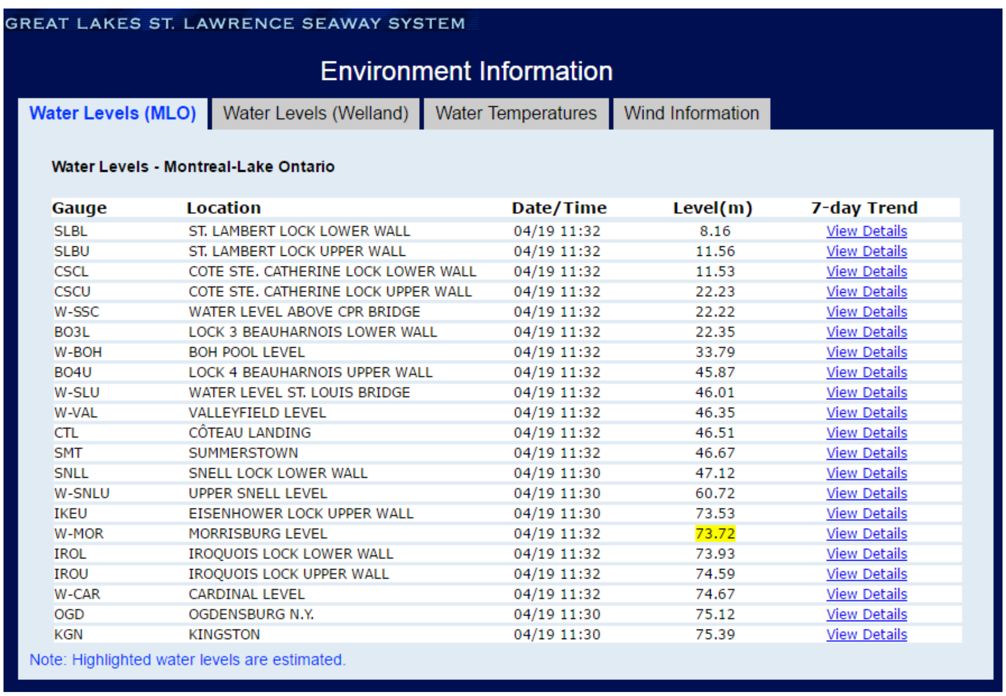
As of: 04 19, 11:19

⇓ Downbound ⇑ Upbound

Vessel Name	Other Vessels with	Direction	Last Loc	ATA	ETA	Next Loc
THUNDER BAY		⇓	C14		2017-04-19 14:39	C13
ROBERT S PIERSON		⇓	C14		2017-04-19 15:09	C13
JOHN D LEITCH		⇓	CVC		2017-04-19 18:16	COI
WILF SEYMOUR	ALOUETTE SPIRIT	⇑	BO4U		2017-04-19 18:21	P09
SOLINA		⇓	CVC		2017-04-19 19:01	COI
FEDERAL KUSHIRO		⇑	C3		2017-04-19 19:32	BO3L
EDZARD SCHULTE		⇓	SOP-C		2017-04-19 22:51	CVC
CSL ST-LAURENT		⇓	LGP-C		2017-04-20 18:39	C16

Figure 9: Sample Lock Order-of-Turn information Available through Seaway Public Website
(Source: http://www.greatlakes-seaway.com/R2/jsp/R2.jsp?language=E&loc=VT00.jsp)

- **Environmental and Water Level Data—**This information is provided by sensors maintained by several agencies throughout the system.



GREAT LAKES ST. LAWRENCE SEAWAY SYSTEM

Environment Information

Water Levels (MLO) | Water Levels (Welland) | Water Temperatures | Wind Information

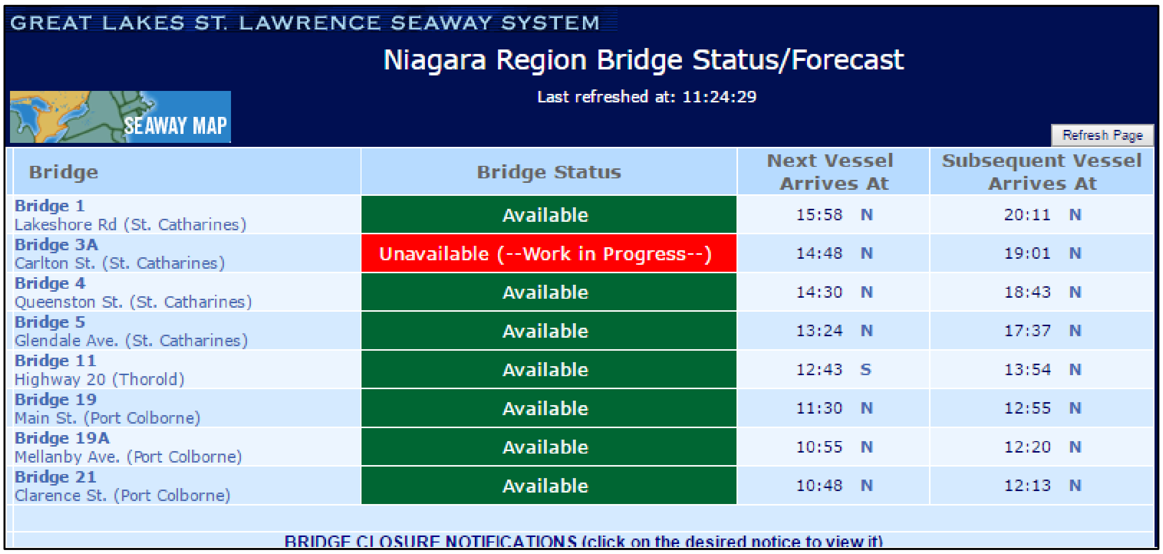
Water Levels - Montreal-Lake Ontario

Gauge	Location	Date/Time	Level(m)	7-day Trend
SLBL	ST. LAMBERT LOCK LOWER WALL	04/19 11:32	8.16	View Details
SLBU	ST. LAMBERT LOCK UPPER WALL	04/19 11:32	11.56	View Details
CSCL	COTE STE. CATHERINE LOCK LOWER WALL	04/19 11:32	11.53	View Details
CSCU	COTE STE. CATHERINE LOCK UPPER WALL	04/19 11:32	22.23	View Details
W-SSC	WATER LEVEL ABOVE CPR BRIDGE	04/19 11:32	22.22	View Details
BO3L	LOCK 3 BEAUHARNOIS LOWER WALL	04/19 11:32	22.35	View Details
W-BOH	BOH POOL LEVEL	04/19 11:32	33.79	View Details
BO4U	LOCK 4 BEAUHARNOIS UPPER WALL	04/19 11:32	45.87	View Details
W-SLU	WATER LEVEL ST. LOUIS BRIDGE	04/19 11:32	46.01	View Details
W-VAL	VALLEYFIELD LEVEL	04/19 11:32	46.35	View Details
CTL	CÔTEAU LANDING	04/19 11:32	46.51	View Details
SMT	SUMMERSTOWN	04/19 11:32	46.67	View Details
SNLL	SNELL LOCK LOWER WALL	04/19 11:30	47.12	View Details
W-SNLU	UPPER SNELL LEVEL	04/19 11:30	60.72	View Details
IKEU	EISENHOWER LOCK UPPER WALL	04/19 11:30	73.53	View Details
W-MOR	MORRISBURG LEVEL	04/19 11:32	73.72	View Details
IROL	IROQUOIS LOCK LOWER WALL	04/19 11:32	73.93	View Details
IROU	IROQUOIS LOCK UPPER WALL	04/19 11:32	74.59	View Details
W-CAR	CARDINAL LEVEL	04/19 11:32	74.67	View Details
OGD	OGDENSBURG N.Y.	04/19 11:30	75.12	View Details
KGN	KINGSTON	04/19 11:30	75.39	View Details

Note: Highlighted water levels are estimated.

Figure 10: Sample of Water Level Data Available through Seaway Public Website
(Source: http://www.greatlakes-seaway.com/R2/jsp/R2.jsp?language=E&loc=EV00.jsp)

- **Bridge Status/Forecast—**This resource is updated using vessel arrival data (manually reported ETAs) and communications from bridge personnel. It appears to be intended primarily for road users, as the “availability” of a bridge refers to whether it can be used by road vehicles, not whether it is open or closed to vessel traffic. Status options include: Available, Available–Opening Soon, Unavailable–Raising, Unavailable–Fully Raised, and Unavailable (- -Work in Progress- -); bridges that are unavailable due to work in progress are typically left in the raised or open position to allow passage of vessel traffic. However, vessel masters or pilots might use the information on estimated arrivals of other vessels, possibly to coordinate arrivals to require only one lift instead of two.[2]


GREAT LAKES ST. LAWRENCE SEAWAY SYSTEM

Niagara Region Bridge Status/Forecast

Last refreshed at: 11:24:29

SEAWAY MAP

Refresh Page

Bridge	Bridge Status	Next Vessel Arrives At	Subsequent Vessel Arrives At
Bridge 1 Lakeshore Rd (St. Catharines)	Available	15:58 N	20:11 N
Bridge 3A Carlton St. (St. Catharines)	Unavailable (--Work in Progress--)	14:48 N	19:01 N
Bridge 4 Queenston St. (St. Catharines)	Available	14:30 N	18:43 N
Bridge 5 Glendale Ave. (St. Catharines)	Available	13:24 N	17:37 N
Bridge 11 Highway 20 (Thorold)	Available	12:43 S	13:54 N
Bridge 19 Main St. (Port Colborne)	Available	11:30 N	12:55 N
Bridge 19A Mellanby Ave. (Port Colborne)	Available	10:55 N	12:20 N
Bridge 21 Clarence St. (Port Colborne)	Available	10:48 N	12:13 N

BRIDGE CLOSURE NOTIFICATIONS (click on the desired notice to view it)

Figure 11: Sample of Bridge Status/Forecasts Available through Seaway Public Website
(Source: http://www.greatlakes-seaway.com/en/communities/bridge/index.html)

3.3.3 Existing Systems for Vessel Traffic Management

As observed in section 3.2 Operational Policies and Constraints, an underlying concern regarding vessel traffic management systems and procedures is the notion that the authority of vessel traffic controllers is constrained by the principle that a master has ultimate responsibility for the safe operation of his/her vessel. This results in a tendency to limit the traffic controller’s influence to a primary focus on safety. Consequently, most efficiency-related decisions are made in a distributed fashion, in a kind of self-organizing system of multiple independent agents (vessel masters and pilots; cargo or passenger terminal operators; service providers such as tugboat operators and fuel bunkering services; and bridge operators, among others) with a high degree of independence. All vessel traffic control systems have to confront issues related to the limits of their authority, and it is certainly a factor in Seaway operations.

[2] The Seaway provides data on bridge availability to third parties, who have developed smartphone-based bridge status applications accessible to the general public.

However, the Seaway operators—particularly the Traffic Control Centers—do have substantial control over the conduct of vessels throughout the Seaway system. There are three TCCs, two in Canada and one in the U.S. In addition to collecting data needed for internal operations of Seaway infrastructure (e.g., locks and bridges) and disseminating information useful to vessels, the Seaway TCCs have been explicitly granted a number of specific authorities related to the conduct of vessels, including the following (St. Lawrence Seaway Management Corporation, 2017):

- **Compliance with Instructions—**"Every ship shall comply promptly with transit instructions given by the traffic controller or any other officer." (*Seaway Handbook*, Rule 27).
- **Order of Passing Through—**"Ships shall advance to a lock in the order instructed by the traffic controller." (*Seaway Handbook*, Rule 36) While this is a clear matter of practical necessity for lock operations (someone has to set the lock order turns), it should be noted that when combined with the restriction on overtaking "once the order of passing through has been established" (listed below), this authority could give traffic controllers a substantial amount of control over the efficiency of traffic flow. In other words, it appears that controllers could choose to establish the "order of passing through" not just on a first come, first served basis, but in such a way (and well in advance of arrivals) as to establish the optimal order for overall system efficiency.
- **Entering, Exiting or Position in Lock—**"Every ship proceeding into a lock shall be positioned and moored as directed by the officer in charge of the lock." (*Seaway Handbook*, Rule 40(3)).
- **Reporting Position at Anchor, Wharf, etc.—**"A ship anchoring in a designated anchorage area, or elsewhere, and a ship mooring at a wharf or dock, tying-up to a canal bank or being held on a canal bank in any manner shall immediately report its position to the traffic controller and it shall not resume its voyage without the traffic controller's permission." (*Seaway Handbook*, Rule 83).
- **Speed limits—**Seaway managers have established speed limits for high- and normal-water conditions. They also have discretion to "…from time to time, designate the set of speed limits that is in effect." (*Seaway Handbook*, Rule 28 and Schedule II).

In addition, there are a number of special rules in place that affect traffic management on the Seaway, including:

- **Meeting and Passing—**
    - "No ship shall meet another ship within the area between the caution signs at bridges or within any area that is designated as a no meeting area by signs erected by the Manager or the Corporation in that area." (*Seaway Handbook*, Rule 31(2).)
    - "Except as instructed by the traffic controller, no ship shall overtake and pass or attempt to overtake and pass another ship (a) in any canal; (b) within 600 m of a canal or lock entrance; or (c) after the order of passing through has been established by the ship traffic controller." (*Seaway Handbook*, Rule 31(3).)

- **Turning Basins—**No ship shall be turned about in any canal, except (a) with permission from the traffic controller; and (b) at the locations set out in the table to this section. (*Seaway Handbook*, Rule 48.)

Though the majority of TCC functions and authorities relate to safety and environmental protection, certain authorities and rules listed above—along with other statements in Seaway documents—suggest that TCCs *do* have explicit authority to manage traffic in order to improve efficiency. For example, the introduction to the section of the *Seaway Handbook* titled, "Information on Ship Transit and Equipment Requirements," explicitly states that "Many of the subjects described in this section are designed to minimize the idle time at locks and to thus achieve the prime aim of minimizing round trip transit times for ships." In some cases, statements and procedures regarding operational efficiency are phrased as *requests* of pilots and masters, suggesting that they are operational goals, if not strict requirements.

3.4 Modes of Operation for the Current System or Situation

The Seaway is a seasonal waterway that typically operates from mid-March to late-December. The procedures and communications discussed above apply to the Seaway's open period. Additionally, the Seaway remains open to navigation during its "closing period," a pre-announced length of time (typically 4-6 weeks) determined by the SLSDC and SLSMC. Special procedures apply during the closing period in order to ensure safe navigation in light of the potential for ice conditions as well as to ensure that vessels not intending to spend the winter in the Great Lakes are able to exit the Seaway before it is closed to all vessel traffic during the winter months.[3] In particular, any vessel transiting the Montréal-Lake Ontario section of the Seaway during the closing period must report its destination to the nearest traffic control station upon entering this section or departing from a port or anchorage in that section. Vessels must also report at a designated calling-in point prior to a clearance date specified by the SLSDC and SLSMC; clearance dates are established to enable final transits of the Seaway prior to its closing date.

The closing period presents special challenges to vessel traffic management, beyond the urgency of ensuring all vessels intending to pass out of the Seaway are through by the closing date. The presence of ice and extreme weather conditions can impose significant constraints on the movement of vessels. For example, ice may narrow the navigable space in a channel, effectively creating more "no-passing" zones. Moreover, requirements for ships to carry two pilots during the beginning and end of each navigation season (when many physical navigational aids are not in place) can also induce transit delays, particularly as these periods coincide with periods when vessel traffic levels are inherently higher than normal and/or when transits can take significantly longer due to ice in the navigation channels. Together, this factors can introduce delays that ripple

[3] In addition to the navigation challenges associated with the onset of winter during the December closing period, there are occasional challenges (e.g., lingering pack ice, or a slow thaw) associated with the springtime opening of the Seaway in March that may impact individual locks or portions of the waterway.

beyond the Seaway and affect the entire intermodal freight supply chain. Such conditions would highlight the utility of potential improvements to the availability of operational data.

3.5 User Classes and Other Involved Personnel

This section summarizes the key organizations and groups that operate and use the Seaway. These groups constitute a subset of all stakeholder groups that otherwise influence the operation of the Seaway. Volpe's first discussion paper developed for this project, *St. Lawrence Seaway: Overview of Safety, Efficiency, Operational, and Environmental Issues*, provides a more comprehensive list of all Seaway stakeholders.

3.5.1 Infrastructure Operators

This group of stakeholders includes the two principal public agencies of the U.S. or Canada that own, operate and maintain the locks, moveable bridges, and fixed spans or tunnels crossing the Seaway, as well as other entities that maintain the fixed and floating navigational aids along the waterway. The two Canadian railroad companies included are responsible for maintaining privately owned moveable railroad bridges spanning the Seaway; operation of these structures is coordinated by the SLSDC and SLSMC.

- Canadian Coast Guard (Ottawa, ON)
- Canadian Pacific Railway (CP) (Calgary, AB)
- Canadian National Railway (CN) (Montréal, QC)
- Saint Lawrence Seaway Development Corporation (Washington, D.C.)
- The St. Lawrence Seaway Management Corporation (Cornwall, ON)

3.5.2 Vessel Owners/Operators

Dozens of U.S., Canadian, and foreign companies own or operate commercial vessels on the Seaway. Appendix A identifies 20 significant users of the Seaway, as well as the major companies that provide scheduled liner service to Montréal and those operating exclusively within the Great Lakes as far east as Lake Erie. In general terms, Canadian- and foreign-flag cargo vessels originating from or destined for Canadian ports are the predominant users of the Seaway. U.S.-flag cargo vessels primarily operate within the confines of the Great Lakes. Although few U.S. flag vessels traverse the Seaway to call on U.S. ports, recent years have seen an increase in U.S. port calls by these vessels, as well as foreign-flag vessels calling on U.S. ports. The Seaway has also seen an increase in the number of cruise ships that call on U.S. and Canadian ports.

Four companies stand out due to the number of vessels they operate on the Seaway: Algoma Central Corporation (operating 31 ships), Canada Steamship Lines (operating 66 ships), Canfornav (operating 41 ships) and Fednav Limited (operating 64 ships). While not all of the vessels owned by these companies operate on the GL-SLS system, many of them do, and represent a significant portion of total traffic.

3.5.3 Port, Terminal, and Shipyard Owners and Operators

Port and terminal owners and operators are the U.S. or Canadian public, quasi-public, public-private and private entities that own, oversee, manage, or operate the commercial ports and cargo terminals in the GL-SLS system. Individual ports may be managed by a single regional, state, provincial, or municipal port authority, or may simply serve as host to an independent terminal operating company. Similarly, a single port may have multiple terminal operators managing various piers and cargo facilities. The list contained in appendix A identifies the principal port and terminal owners in the region.[4]

3.5.4 Service Providers

Thousands of individual businesses support the vessels that operate on the GL-SLS system, or support the maintenance and operation of the physical infrastructure (locks, canals, bridges, tunnels). Among these business are shipyards and other repair facilities; pilotage associations; and a wide range of services including bunkering (fueling), brokerage, freight forwarding, vessel operations, dredging, chandlery, insurance, crewing, towing, and others. The list contained in appendix A is not exhaustive, but includes some of the more prominent service providers in the region.

3.5.5 Major Shippers of Commodities and Finished Products

The list found in appendix A represents many of the primary U.S. or Canadian commercial enterprises that move their bulk commodities or finished products—whether import or export—on the GL-SLS system.

3.5.6 Recreational Users

The GL-SLS system is a major attraction for recreational users. From sailing yachts to motor boats, anglers, kayakers and other outdoorsman, millions of people from the U.S., Canada, and other nations take advantage of this natural resource each year. Hundreds of recreational vessels travel through the canals and locks of the Seaway, traveling between the Lake Erie and Lake Ontario, or between the Atlantic Ocean and the Great Lakes.

[4] Appendix A does not list the hundreds of individual companies that may support cargo operations within individual ports, except in cases where a single entity (typically a private terminal operator) appears to be the sole entity operating within the geographic confines of a port.

4 Justification For and Nature of Changes

4.1 Justification For Changes

In its discussion paper *St. Lawrence Seaway: Overview of Safety, Efficiency, Operational, and Environmental Issues,* Volpe found that the most of the more significant operational challenges facing the Seaway are largely physical, such as size constraints imposed by current lock dimensions and the lack of redundancy (Perlman, Stanford, & Wallischeck, *St. Lawrence Seaway: Overview of Safety, Efficiency, Operational, and Environmental Issues*, 2017). For example, all but three of the Seaway's 15 locks are "single locks" that can accommodate the ascent or descent of only one vessel at a time, and vessels can only pass in one direction of travel (i.e., upbound or downbound) at a time.[5]

However, the pervasive availability and coverage of ship position, speed, heading, and other information provided through AIS suggests that some operational challenges can be met with the use of information and communication technology (ICT), to improve the coordination of vessel transits and, thereby, incrementally improve operational efficiency and safety. To date, however, AIS data have not been used explicitly to improve system-wide operational efficiency on the Seaway. This Concept of Operations proposes to use these data in a way that will allow traffic management personnel to make better-informed decisions about lock order turns and relay other navigational instructions or recommendations to vessels, with the specific intent of improving collective, system-wide operational efficiency and reducing overall delays. It will also allow individual vessel operators to make tactical navigational decisions based on a broader array of information about other vessels transiting the Seaway.

4.2 Description of Desired Changes

The desired changes—as proposed by this document—will entail the introduction of a new system: Seaway Tim of Arrival (or SeaTA). The SeaTA application will add automated, real-time travel estimates to the information available to vessel masters, pilots, Seaway traffic management personnel, and others. It will enable personnel to view estimates of an individual vessel's expected arrival times at key points throughout the Seaway. ETAs used in current Seaway traffic management are based on estimates made manually by vessel masters (with no standard process for generating them) and provided to the TCCs orally via VHF radio at call-in points. These ETAs are then entered manually by TCC personnel into desktop client software in order to

[5] There are instances where two or more small commercial vessels (e.g., three, 100-foot long tugboats), may be able to share a lock transit; however, all vessels must be travelling in the same direction for multiple-vessel lockages.

make them available online. The new estimates will substantially improve on this by using current information provided through AIS (position, speed, and heading) as well as system information on posted speed limits and current lock transit times. Automated calculation and display of ETA data will also avoid the risks associated with manual data entry.

These estimates may be *further* improved by drawing upon historic AIS and environmental condition data (weather, ice, traffic, etc.). This would allow current estimates to be calibrated to actual historic travel times along system segments. *Even higher precision* will be possible when adjustments are made for current weather and waterway conditions, which can be accomplished by calibrating travel time estimates with historical travel times and their correlated historical weather and waterway conditions. In other words, if it is known that a number of vessels of a given type and load have transited a specific section of the Seaway in a given time, at a given time of day, under a specific set of weather conditions, that information can be used to more-precisely derive current estimates of travel times for similar vessels, loads, and weather conditions.

4.3 Priorities Among Changes

SeaTA could be implemented at various levels of sophistication, depending on resource and data availability and desired level of accuracy. The SLSDC and SLSMC could either select a desired level of sophistication at the outset, or consider a phased approach, whereby the initial implementation of SeaTA is relatively simple and successive updates introduce additional levels of sophistication. As a rough outline, Volpe has identified the following potential stages of implementation for SeaTA (or “versions”), based on increasing levels of complexity:

1. **Next Waypoint Ahead—**SeaTA provides ETA for only the next waypoint in a vessel’s voyage. Travel times would be derived based on a vessel’s current speed and posted speed maximums for upcoming segments. This iteration may have limited utility, but would largely avoid sources of variability in travel time estimates and would allow for automatic, real-time updates to ETAs (e.g., as a vessel reduces speed due to weather conditions).
2. **Limited Future Waypoints—**SeaTA provides ETAs for all waypoints between a vessel’s current location and the next lock (including ETA at the lock entrance). Similar to version 1, this version would calculate travel times based on posted speed maximums for each segment and the vessel’s current speed.
3. **All Future Waypoints and Final Destination—**SeaTA provides ETAs for all waypoints between a vessel’s current location and its final destination (including ETA at its final destination). Similar to versions 1 and 2, this version would calculate travel times based on posted speed maximums for each segment and the vessel’s current speed. Lockage times would need to be assumed based on observed averages. The full transit profile offered by this version could provide substantial value for Seaway users and ports, but the addition of lockage times also introduces a potentially significant source of uncertainty.
4. **All Future Waypoints and Final Destination, Plus Vessel History Data—**End-user functionality is identical to version 3 but travel time estimates take into account historical

vessel transit profiles in order to improve accuracy over version 3. Since vessels may not always travel at maximum posted speeds, travel time estimates can be weighted by the speeds observed during previous seasons. Historic transit data could be integrated generally, or according to vessel class. This version could also account for historic lockage times.

5. **All Future Waypoints and Final Destination, Plus Vessel History and Environmental Data—**End-user functionality is identical to versions 3 and 4, but travel time estimates also factor in existing and prior weather conditions, time-of-day, currents, or other environmental factors, to generate very accurate, precise and reliable ETAs.

4.4 Changes Considered but Not Included

A second phase of development for SeaTA would seek to leverage the travel time estimates as a means to implement enhanced STM strategies. Such practices would follow examples currently being evaluated and implemented in Europe, including MonaLisa and River Information Systems (RIS), by allowing traffic management personnel to provide vessels with enhanced information about prevailing traffic conditions and the intended paths of nearby ships. This enhanced version of the SeaTA concept would allow a broader, systemic management of traffic, optimizing across the entire Seaway system and enabling more efficient overall use of the Seaway (and potentially the entire GL-SLS system). For example, efficiency could be improved by adjusting speeds well in advance to facilitate passing lock entries and by using system-wide travel time estimates to coordinate arrival times to coincide with available berths. The Volpe Center's second paper, titled *St. Lawrence Seaway: Potential Opportunities for the Application of Information and Communication Technologies*, provides an overview of STM systems in development and related technologies (Perlman, Wallischeck, & Stanford, *St. Lawrence Seaway: Potential Opportunities for the Application of Information and Communication Technologies*, 2017).

These more elaborate versions of SeaTA were not considered at this stage because they will first require, as a foundation, the basic functionality envisioned for the core SeaTA application. Moreover, discussions with representatives from the SLSDC and SLSMC suggested that additional coordination would be needed with the Seaway's key user groups to reach an agreement on how to implement such a system while also respecting and maintaining existing protocols and balancing competing interests.

5 Concepts for the Proposed System

5.1 Background, Objectives, and Scope

As noted above, in the course of its background research Volpe found that the majority of the operational challenges facing the Seaway are due to sheer physical limitations of the system, and therefore, are unlikely to be completely resolved by new technology applications alone. However, the SLSDC and SLSMC have been quite progressive in adopting new technologies into their operations, which presents potential opportunities. Most significant was the 2002 integration of AIS data into the Seaway traffic management system, with the mandatory carriage of AIS transponders implemented in 2003 for commercial vessels exceeding 300 gross tons, 20 meters, or 50 passengers. It is through that requirement that a comprehensive set of data is now available, at no cost to the Seaway or its largest commercial users. That AIS information, combined with some of the operational constraints of the Seaway, form an opportunity to enhance operational safety and efficiency.

The proposed system would leverage the comprehensive availability of AIS speed, position, course, and vessel data to enhance the management of Seaway traffic and core system components and resources. SeaTA will use real-time position, speed, and course data, combined with system constraints—and possibly even historical data—to generate travel time estimates for each vessel from its present position to key waypoints along its route. These waypoints will include locks, moveable bridges, traffic control sector boundaries, check points and call-in points, and navigation hazards, as well as other locations that would be of interest to the system's users. Traffic management, lock operations, and bridge operations personnel would be SeaTA's initial users, but the user base could be expanded to meet interest and need.

SeaTA may also form the foundation for a more comprehensive STM system that could enable enhanced voyage planning and traffic management through the Seaway. Though the majority of this ConOps focuses on the core functionality of the basic SeaTA application, it also identifies opportunities for future development of a more robust, capable SeaTA-based traffic management system.

5.2 Operational Policies and Constraints

At the outset, SeaTA will be used solely by SLSDC and SLSMC traffic management personnel and personnel responsible for operation of locks and moveable bridges. SeaTA will be used as a decision support tool, to be used within the context of existing operational policies of the SLSDC and SLSMC. Further development and implementation of SeaTA may expand its user base to Seaway users and stakeholders. Its underlying functionality may also be used as the basis for a more proactive traffic management tool, approximating the concepts of STM being explored in Europe and elsewhere.

5.3 Description of the Proposed System

5.3.1 Operational Environment and Characteristics

The SeaTA application will provide travel time estimates for key waypoints in the Seaway proper, extending from Montréal along the St. Lawrence River to Lake Ontario and Lake Erie, encompassing the 15 locks and 18 moveable bridges in this span. Key waypoints such as locks, road and railroad crossings, and population centers are shown in figure 12 and described below.

Figure 12: Map of the St. Lawrence Seaway
(Source: Canadian Geographic)

- **Locks—**Precise arrival time information at locks will allow for coordinated movements of vessels through the Seaway's lock systems. In terms of traffic-flow management, these are the most critical waypoints, as vessels take an average of 45 minutes to transit a lock, meaning that multiple vessels arriving at a lock within a narrow window of time, in an uncoordinated manner, will incur substantial delays.[6]

  Using SeaTA, vessels approaching a lock from opposite directions may be coordinated to facilitate passing entries for both. Similarly, more precise arrival estimates may allow lock operations personnel to avoid empty lock transits (for a detailed example, see figure 13). Finally, these precise estimates will allow the SLSDC and SLSMC to coordinate the assignment of personnel to locks while minimizing unnecessary on-duty time. This latter information will be particularly useful as locks throughout the system are equipped with

[6] This is particularly true when two successive vessels are heading in the same direction (i.e., both upbound or both downbound), since the lock must be cycled "empty" between each vessel's lockage. In that case, a second vessel arriving less than approximately 75 minutes after the first would need to slow down significantly, tie up or anchor until the lock has moved the first ship, then emptied (or filled) itself to be ready to move the second ship. By contrast, the ideal scenarios are "passing entries," whereby a lock alternates between moving upbound and downbound vessels, without having to cycle empty. (For example, an upbound vessel exits the upper end of the lock chamber, then passes a downbound vessel that immediately enters the lock; when that vessel then exits the lock's lower end, it passes the next upbound vessel that enters the lock, which is already in the right position to accommodate the vessel. The opposite scenario is also true, i.e., downbound-upbound-downbound.)

hands free mooring hardware. With fewer ships transiting locks requiring assistance tying up from shoreside personnel, knowing exact arrival times of ships that will require line-handling personnel could reduce costs and improve personnel scheduling.

- **Moveable bridges—**The SLSMC and SLSDC joint website (http://www.greatlakes-seaway.com/en/communities/bridge/) currently posts ETAs for each of the next two ships expected at 18 moveable bridges on the Seaway. These ETAs are determined by each vessel and communicated verbally via VHF radio to a Seaway TCC. The availability of more precise, AIS-based arrival time predictions at these bridges could enhance this public information function.

  Not only does this service provide valuable information to truckers and automobile drivers, but also to emergency vehicle operators. Having more precise arrival time estimates can facilitate more effective emergency vehicle operations, allowing emergency vehicle drivers to gain more precise situational awareness regarding current or upcoming vessel transits where bridge closures future might disrupt their planned routes. In addition, some bridges accommodate rail traffic, including scheduled, fast-moving passenger service (which pass over a bridge rapidly) and long, slow moving daily freight trains (which can take several minutes to cross a bridge). Additional information to coordinate vessel arrivals with train schedules—particularly freight trains—would likely provide a benefit and avoid potential schedule conflicts or delays.

- **High-risk meeting areas—**Precise travel time estimates might facilitate safer navigation of certain sections of the Seaway, particularly restricted and no-meeting areas (identified in *The Seaway Handbook*) and sections of the St. Lawrence River and canals, where passing maneuvers might be permitted but are not ideal (e.g., bends, narrow sections). The application could also be extended to temporary hazards; for example, if a ship becomes grounded or disabled, the TCC could create a temporary waypoint to allow SeaTA to determine when the next vessel will arrive at the hazard's location.

- **Pilot District Boundaries—**All foreign-registered (i.e., not U.S. or Canadian flagged) vessels exceeding 1,500 gross tons are subject to compulsory pilotage requirements when transiting the Seaway. Though individual vessel operators arrange for pilot transfers directly with the appropriate pilotage authority, SeaTA could also allow for more general awareness of when vessels requiring pilotage are likely to reach pilot transfer points and pilot district boundaries.

- **Ports—**SeaTA could provide port operators with advance estimates of inbound vessels' arrival times as vessels transit the Seaway. Similar to the proposed use of SeaTA to provide estimates to pilotage authorities, vessel operators would continue to follow existing procedures to coordinate their arrival with their destination port, but port operators could use SeaTA to view a comprehensive picture of multiple inbound vessels arriving simultaneously or in sequence. This functionality would incorporate destination information furnished through AIS so that arrival times are only provided for a vessel's intended port, rather than all ports in the Seaway.

- **Populated Areas—**SeaTA could offer enhanced situational awareness to the SLSDC, SLSMC, USCG, CCG, and others agencies regarding the proximity of hazardous or dangerous cargo to populated or other sensitive areas. Such enhanced awareness could enable these entities to anticipate when a heightened state of alertness might be warranted.

As described in section 4.3, travel time estimates can be based on a range of inputs, depending on the level of accuracy desired and resources available. In general, the range of potential implementation paths vary along two dimensions: Data Inputs/ETA Calculation Methodology and Functional Extent. Table 3 summarizes the full range of proposed implementation options for SeaTA along these two dimensions.

SeaTA will rely upon the Seaway's pervasive AIS coverage as its primary data source. As described in section 3, AIS provides key operational data from most vessels operating in the system—particularly position, speed, and heading—and these data could be used to derive travel time estimates. The most basic estimates would utilize a combination of a vessel's current speed and speed limits for each segment it will transit. Though this calculation would be relatively simple, it is also likely to provide the least certainty, as it relies on fairly significant assumptions that vessels will maintain their current speed or travel at the speed limit for the remainder of their transit. This method could be enhanced by taking into account an individual vessel's maximum speed, which will vary significantly depending on vessel type and loading characteristics. For example, a tugboat with a heavy barge in tow may be physically limited to traveling slower than most of the speed limits in the Seaway, while other vessels such as larger ocean freighters traveling "light" or "in ballast" (without cargo), are likely to be able to exceed all Seaway speed limits.

A more elaborate method of calculating travel time estimates could enable more accurate estimates by introducing historical transit data. AIS data from the Seaway has been collected and archived over the 15 years since the system was installed. This enormous database should be able to provide relevant information for every class of vessel that regularly uses the Seaway, in all potential loading and weather conditions. And, given that many vessels use the Seaway year after year, there should be substantial amounts of useful data that are vessel-specific. Ultimately, this database should be able to provide adjustments and refinements based on virtually any conditions that would affect transit times.

In its simplest form, SeaTA would only provide travel time estimates extending as far as the next lock, bridge or other waypoint established by the Seaway. However, data could also be mined to assess typical lock transit times, which would enable end-to-end estimates for a vessel's voyage through the Seaway. This capability would ultimately be necessary if SeaTA were expanded to serve as the foundation for an STM (or similar) system.

If SeaTA provides transit information beyond the next lock, it will also need to account for a vessel's intended destination so as not to provide estimates beyond that point—e.g., for downbound vessels only transiting the Welland Canal from Lake Erie to a final destination in Lake Ontario. The application can draw upon destination information provided as part of AIS voyage-related data.

Table 3: Summary of options for SeaTA based on data input/ETA calculation methodology and functional extent, mapped to SeaTA versions described in section 4.3

		Functional Extent		
		Next Waypoint SeaTA provides ETA to next waypoint vessel will encounter	**Next Lock** SeaTA provides ETA to all waypoints between vessel's current location and next lock (inclusive of entrance to next lock)	**Entire Remaining Voyage** SeaTA provides ETA to all waypoints between vessel's current location and its final destination (if provided via AIS) or to Seaway boundary
Data Source/ETA Calculation Methodology	**Current/Static Data** Simple estimates based on a vessel's current speed and posted speed maximums for upcoming	Version 1	Version 2	Version 3
	Current/Static + Historic Transit Data Estimates based on vessel's current speed and posted speed maximums, but weighted based on speed profile data from previous seasons	NA	NA	Version 4
	Current/Static + Historic Transit + Environmental Data Estimates based on vessel's current speed and posted speed maximums, but weighted based on speed profile data from previous seasons and prevailing environmental conditions (e.g., wind, current, visibility)	NA	NA	Version 5

5.3.2 Interfaces to External Systems or Procedures

The SeaTA application will be integrated with the Seaway's existing procedures and practices for vessel traffic management and operation of physical assets (i.e., locks, moveable bridges). Currently, TCC personnel issue lock order turn assignments on a first come, first served basis. That is, as vessels reach a designated point approaching each lock, they are assigned the next turn for that lock. This practice is not expected to change. SeaTA will simply allow TCC personnel to identify with more advance notice when each vessel will reach the lock approach.

With its initial implementation, SeaTA would not be used to issue recommendations or requests for speed or course changes unless they are safety-critical, continuing the current practice. However, a future expansion of the application and its use could support implementation of STM practices that coordinate the long-term transit of vessels through the Seaway, and perhaps throughout the GL-SLS System, for maximum safety and efficiency. An example of one of the simplest improvements in efficiency that could be achieved would be to notify masters and pilots when they are on track to arrive at a lock at a time when they will have to wait for other vessels to pass. Those masters/pilots could then decide whether to slow down in order to arrive at a time that would not require any waiting, potentially saving fuel and avoiding the potential costs of tying up outside a lock.

5.3.3 Capabilities or Functions of the Proposed System

In all but the most rudimentary implementation scenarios, the SeaTA application will provide real-time travel time estimates for individual vessels, from their current position to key waypoints in the Seaway. (In its most basic forms, SeaTA would only provide ETAs to the next waypoint or a series of waypoints leading to the next lock entrance.) Users will select specific vessels through the application interface and be presented with a list of upcoming waypoints for that vessel and the estimated time of arrival at each waypoint. Using comparable data from other vessels, the application interface may also be able to determine potential conflicts. For example, it may indicate when the selected vessel will arrive at a lock entrance within a set time of another vessel (e.g., 15 minutes), when the selected vessel may encounter an oncoming vessel around a critical bend, or when the selected vessel may pass other vessels in a narrow channel.

Table 4 provides an example of the proposed interface that would appear when a user selects a specific vessel. In practice, the user would see a graphic representation of the Seaway, with icons representing vessels and waypoints (e.g., locks, bridges, and other geographic points). The user would move the display's cursor over a selected icon (in this case a hypothetical vessel, the *Algoperlman*) and click on it; a "pop-up" window would then open on the map display providing detailed ETA information. (Other pop-up windows may also be available to the user that provide other pertinent details regarding the vessel and its status, such as navigational data (current course, speed), vessel particulars (dimensions, cargo), local weather, pilotage status, etc.)

Table 4: Proposed Information Display for a Single Vessel in SeaTA

Upbound ETAs
Vessel: *Algoperlman*
Current date and time: *10/14/16 at 11:25*
Dest: *Thunder Bay*

Segment	From	To (Leg Destination Point)	Leg Distance	Speed	Leg Time (HH: MM)*	ETA at Next Demarcation Point*
0	Present position	Lower mouth of South Shore Canal	6.50	10.0	00:39	10/14/16 at 12:04
1	Lower mouth of South Shore Canal	Lower Entrance, St. Lambert Locks	2.22	6.0	00:22	10/14/16 at 12:26
2	Lower Entrance, St. Lambert Locks	Upper Entrance, St. Lambert Locks	0.36	6.0	00:03	10/14/16 at 12:29
3	Upper Entrance, St. Lambert Locks	Lower Entrance, St. Catherines Locks	6.95	6.0	01:09	10/14/16 at 13:39
4	Lower Entrance, St. Catherines Locks	Upper Entrance, St. Catherines Locks	0.37	6.0	00:03	10/14/16 at 13:43
5	Upper Entrance, St. Catherines Locks	Upper Entrance South Shore Canal	6.69	6.0	01:06	10/14/16 at 14:49
6	Upper Entrance South Shore Canal	Lake St. Louis Buoy A13 (Can.)	2.32	10.5	00:13	10/14/16 at 15:03
7	Lake St. Louis Buoy A13 (Can.)	Lower Entrance Lower Beauharnois Lock	7.73	12.0	00:38	10/14/16 at 15:41
8	Lower Entrance Lower Beauharnois Lock	Upper Entrance Upper Beauharnois Lock	1.91	6.0	00:19	10/14/16 at 16:01
9	Upper Entrance Upper Beauharnois Lock	Lake St. Francis Buoy D3 (Can.)	12.97	9.0	01:26	10/14/16 at 17:27
10	Lake St. Francis Buoy D3 (Can.)	Lake St. Francis Buoy D49 (Can.)	14.97	12.0	01:14	10/14/16 at 18:42
11	Lake St. Francis Buoy D49 (Can.)	Snell Lock (Lower Entrance)	14.64	8.5	01:43	10/14/16 at 20:25

Segment	From	To (Leg Destination Point)	Leg Distance	Speed	Leg Time (HH: MM)*	ETA at Next Demarcation Point*
12	Snell Lock (Lower Entrance)	Upper Entrance Snell Lock	0.86	6.0	00:08	10/14/16 at 20:34
13	Upper Entrance Snell Lock	Lower Entrance, Eisenhower Lock	2.37	6.0	00:23	10/14/16 at 20:58
14	Lower Entrance, Eisenhower Lock	Upper Entrance, Eisenhower Lock	0.80	6.0	00:07	10/14/16 at 21:06
15	Eisenhower Lock	Iroquois Lock	22.16	11.5	01:55	10/14/16 at 23:01
16	Lower Entrance, Iroqois Lock	Upper Entrance, Iroqois Lock	0.98	6.0	00:09	10/14/16 at 23:11
17	Iroquois Lock	McNair Island Light Buoy 137A (Can.)	20.42	13.0	01:34	10/15/16 at 00:45
18	McNair Island Light Buoy 137A (Can.)	Deer Island Lt. 186 (U.S.)	18.03	11.5	01:34	10/15/16 at 02:19
19	Deer Island Lt. 186 (U.S.)	Bartlett Point Lt. 227 (U.S.)	11.73	8.5	01:22	10/15/16 at 03:42
20	Bartlett Point Lt. 227 (U.S.)	Tibbetts Point (Cape Vincent, NY)	15.21	13.0	01:10	10/15/16 at 04:52

*Indicates Nominal Transit Time and Estimated Time of Arrival (ETA)

SeaTA will also be capable of presenting customized information for a specific waypoint or set of waypoints to support personnel operating locks and moveable bridges, who may not need to know the full projected transit profile for a single vessel, but for whom the projected arrival time of all vessels at their location could be useful. In the example presented in table 5, SeaTA would provide advance notice that several ships are likely to arrive at the designated lock shortly after 19:00. This information could also help vessel masters and pilots make decisions about altering speed, to avoid arriving at a lock only to have to tie up and wait for another vessel to complete its transit. The display in table 5 is similar to displays currently on the Seaway website for lock arrivals, with the key difference being that the proposed display in table 5 would be based on real-time and historical AIS data, and would be available for many additional waypoints (not just locks), while the displays currently available are only based on a limited number of ETAs called in by vessel masters at checkpoints.[7]

Table 5: Proposed Information Display for a Single Waypoint in SeaTA

Updbound ETAs
Selected Waypoint: *Eisenhower Lock*
Current date and time: *10/14/17 at 11:25*

Vessel Name	Current Speed (knots)	Distance to Waypoint (nm)	Travel Direction	Travel Time (HH:MM)*	ETA at Next Demarcation Point*
Vessel 1	14.3	37.0	Up	2:35	10/14/17 at 14:00
Vessel 2	16.4	47.0	Down	2:51	10/14/17 at 14:16
Vessel 3	11.4	62.1	Down	5:26	10/14/17 at 16:51
Vessel 4	9.7	56.0	Up	5:46	10/14/17 at 17:11
Vessel 5	13.2	72.2	Down	5:28	10/14/17 at 16:53
Vessel 6	11.9	80.7	Down	6:46	10/14/17 at 18:11

*Indicates Nominal Transit Time and Estimated Time of Arrival (ETA)

(Window would open after user clicks on waypoint icon in map display.)

5.3.4 Operational Risk Factors

Section 5.3.1 describes several potential approaches for deriving travel time estimates, ranging from simple to complex. It is worth noting that the simpler methods described may vary in accuracy, particularly since they would not take into account specific vessel characteristics or prevailing weather, water, or traffic conditions. Even the more sophisticated methods could vary in the accuracy of the estimates they produce, and this inherent risk of variability would need to be communicated to users.

[7] For example, the current *Seaway Handbook* (Schedule III–Calling-In Table) requires the vessel to report ETAs for only 12 points along the entire 370-mile length of the Seaway proper. By comparison, Volpe has identified at least 13 potential SeaTA waypoints (locks, bridges and existing Check-In-Points) in the 51.5 mile section of Traffic Control Sector 1 alone.

5.4 User Classes and Other Involved Personnel

Volpe has identified the following user classes for SeaTA:

- **Traffic management personnel**—SeaTA will provide Seaway TCC traffic management personnel with a comprehensive view of ETAs for all vessels and waypoints throughout the Seaway.
- **Physical asset operations personnel—**Personnel responsible for operating specific assets (e.g., locks, moveable bridges) will use SeaTA in a similar manner to the traffic management user class, but with a view restricted to the specific asset they operate.
- **Vessel masters and pilots—**Vessel masters and pilots will use SeaTA to enhance their situational awareness regarding other Seaway traffic that may affect their voyage. This user class can use information provided by SeaTA to make tactical voyage decisions to ensure a safe and efficient voyage.
- **Pilotage authorities and port operators—**This user class may use SeaTA as an informational tool, though they will continue to communicate directly with vessels to coordinate the timing of pilot and berth availability, respectively.
- **Traveling public—**SeaTA may find a use among members of the public as part of existing services. Though a SeaTA interface will not necessarily be made available publicly, data supporting SeaTA could be integrated into existing information portals, including those pertaining to bridge status (http://www.grandslacs-voiemaritime.com/en/communities/bridge/index.html) and current vessel positions (http://www.greatlakes-seaway.com/en/navigating/map/index.html).

5.5 Support Environment

The SLSDC and SLSMC would be responsible for implementing and maintaining SeaTA, potentially with support from a contractor.

6 Operational Scenarios

This section summarizes several operational scenarios, exploring in more detail how SeaTA might be used by the key user classes described in the previous section. It begins with examples of how the basic SeaTA application, which provides travel time estimates, could be used as a decision support tool. It also presents an illustrative example of how the basic SeaTA application could be a foundation for more significant enhancements to traffic management and coordination in the Seaway.

6.1 Basic SeaTA Application

6.1.1 Coordination of Vessel Lock Transits

The SLSDC and SLSMC can use the SeaTA application to coordinate vessel transits through the locks they operate. As described earlier, lock-order turns are currently assigned on a first come, first served basis. Depending on the order and timing of arrivals, this can result in various inefficiencies, such as cycling (filling or draining) an empty lock, vessels burning excess fuel as they travel at full speed only to have to stop and wait, and overall delays due to missed opportunities for passing transits.

Simply knowing with greater precision when vessels are due to arrive would enable traffic managers to assign lock order turns that optimize the flow of vessels through the lock (minimizing empty lock cycling and overall wait times), with minimal changes to vessels' course and speed. Whereas AIS currently allows traffic management personnel to view real-time (or near-real-time) speed, position, and heading information about vessels transiting the system, SeaTA will provide them with a complete rundown of arrival times for *all* vessels at *all* key waypoints. This will allow them to determine whether arrivals at locks are likely to conflict (particularly for vessels approaching the same lock from opposite directions) and adjust lock order turns accordingly. This should facilitate the maximization of passing lock entries and minimization of empty lock transits. For an illustrative example, see figure 13 and figure 14, which compare lockage delays with and without the use of SeaTA.

In the examples provided in figure 13, it is assumed that all of the vessels are compatible with the hands-free mooring system. On the left-hand side of the graphic, SeaTA is not used, so lock orders are assigned in the order vessels are expected to arrive (V1, V2, V3). As a result, V2 is delayed for a total of 10 minutes and V3 is delayed for 46 minutes. Both vessels have burned more fuel than necessary, since they could have traveled much slower and avoided the need to tie up, and resources were wasted in cycling an empty lock. Total delays = 56 minutes.

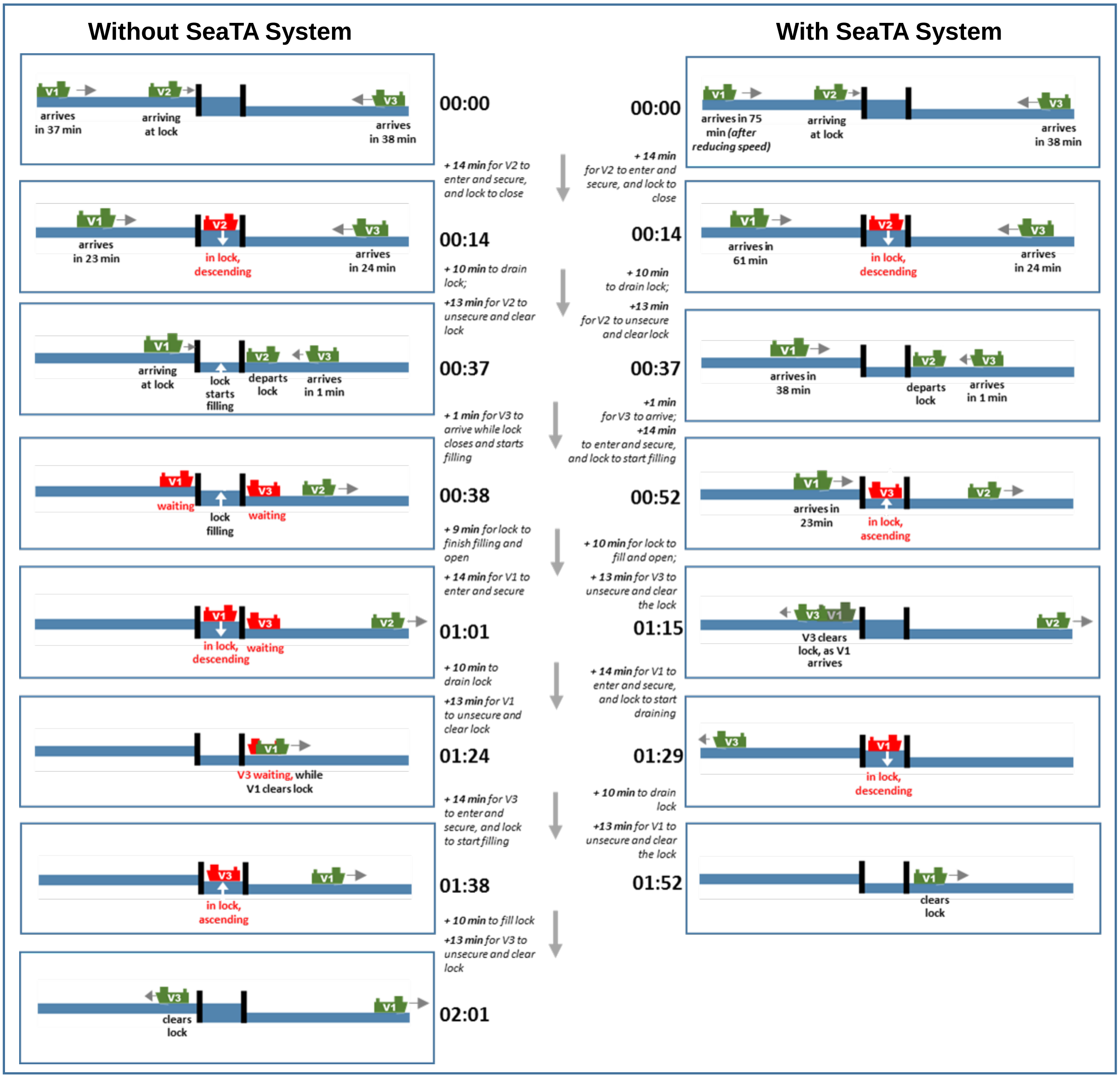


Figure 13: Lock Transit Scenario, Without SeaTA (left) and With SeaTA (right)
Vessels not underway (either waiting at a lock or in a lock transit) are shown in red;
vessels underway are shown in green.
(Source: Volpe Center)

In the right-hand side of figure 14, SeaTA information allows traffic managers to assign the lock order as: V2, V3, and then V1. Based on this, V1 is told the lock won't be available for 75 minutes from the start of the scenario, so it slows down to save fuel. V1 is delayed for a total of 38 minutes, and neither V2 nor V3 experience a delay. Total delays = 38 minutes. In this scenario, one simple change in lock order saves 18 minutes overall, avoids wasted fuel, and avoids two tie-ups and one empty lock cycle.

In figure 14, it is assumed one of the vessels (V1) is *not* compatible with the hands-free mooring system. This case illustrates the even greater impact that SeaTA can have when different lockage times are factored in. In this case, without SeaTA, V2 is delayed for a total of 10 minutes and V3 is delayed for 53 minutes. Total delays = 63 minutes. With SeaTA, only V2 is delayed, for 38 minutes—resulting in an overall savings of 25 minutes.

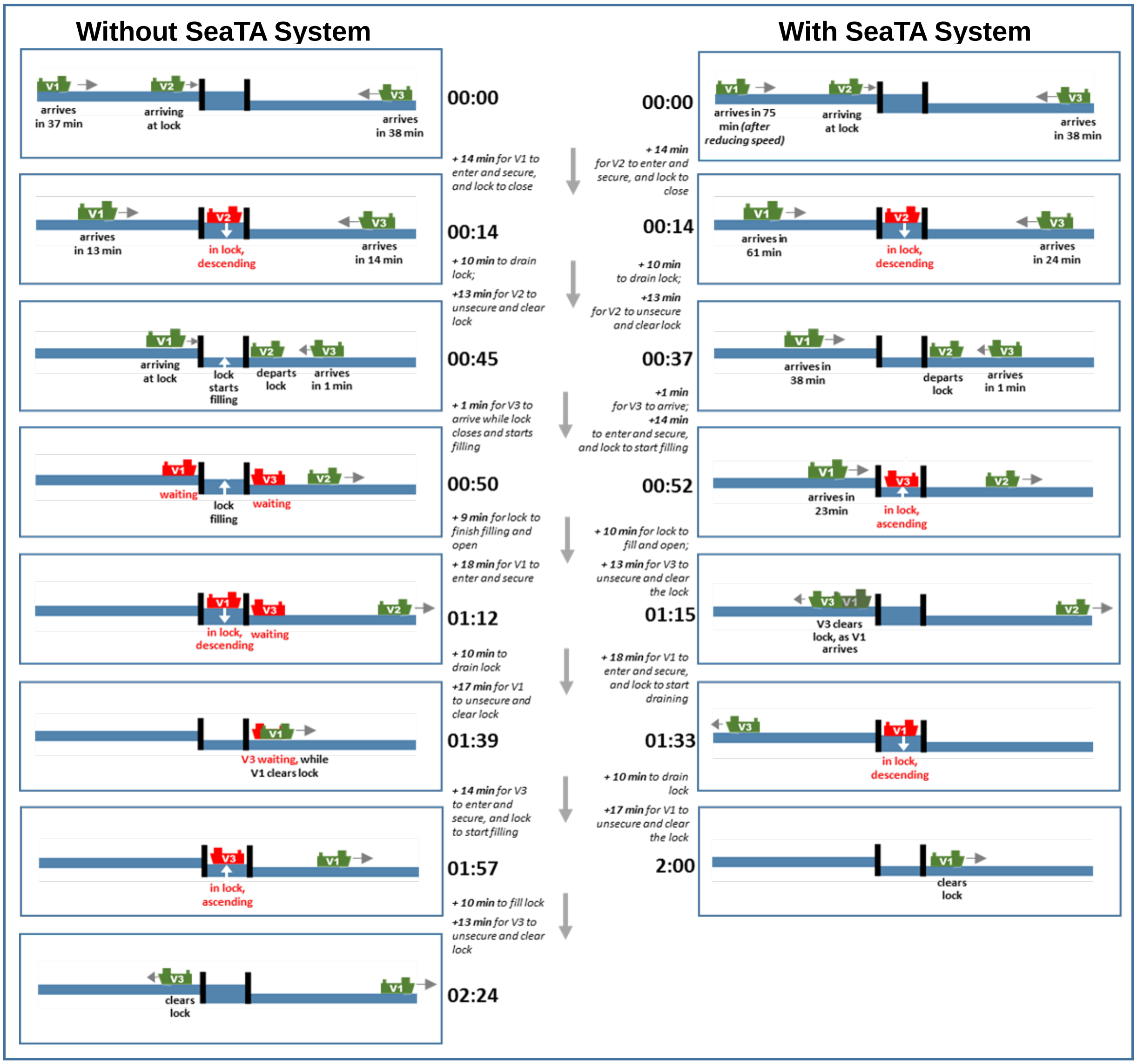


Figure 14: Lock Transit Scenario, One Vessel Not Compatible with HFM System

Assumes one of the vessels (V1) is not compatible with the hands-free mooring system and therefore takes longer to secure in the lock.

(Source: Volpe Center)

Though not depicted in these scenarios, SeaTA could provide an additional benefit to the SLSDC and SLSMC by enabling more efficient scheduling of line-handling personnel. As hands free mooring systems are installed at locks across the Seaway, shoreside line-handling personnel will be needed less frequently, but will still be required to assist vessels that are not compatible with the hands-free mooring system. As demand for line-handlers declines, SeaTA may facilitate more efficient scheduling of their time and availability to assist vessels that cannot use the hands free mooring system.

6.1.2 Advance Identification of High-Risk Vessel Meetings

The Seaway managers have identified a number of “no passing” zones, based upon channel width, configuration, and other factors. In addition, there are likely to be number of other points along the Seaway where there may be a higher risk for vessels to pass one another, particularly in high wind or poor visibility conditions. In situations where a number of vessels may be travelling in opposite directions at different speeds, and with varying distances between them, it could take substantial effort to identify all the various likely meeting points.

SeaTA could be employed to help vessel traffic management personnel identify when two vessels are likely to reach a high-risk passing or meeting zone in a similar time window. If a meeting is identified well in advance and conditions warrant taking action, Seaway traffic control might act on the information provided by SeaTA and instruct one or both vessels to make course or speed adjustments so they pass at a safer point. With such information provided well in advance, vessel masters could adjust their speed in the most efficient manner, slowing down to maintain a constant speed up to the no-passing zone, instead of proceeding at full speed only to realize at the last minute that they have to slow down dramatically. Vessel masters and pilots could also act on this information independently and coordinate among each other to avoid overtaking or meeting in hazardous areas.

6.1.3 Traffic Management in Poor Weather Conditions and During Closing Period

Accurate SeaTA estimates may be particularly valuable during periods with poor weather conditions, as enhanced situational awareness of vessel locations and status can help to ensure that all vessels are proceeding safely. Moreover, during early and late season operations when ice clearing procedures may be necessary, additional information about expected vessel arrivals may help in coordinating their transits with ice-clearing. Finally, during the Seaway’s closing period, the SLSDC and SLSMC require specific calling-in procedures to ensure that vessels not wintering in the Great Lakes are able to exit the Seaway prior to its closing date. ETAs for non-wintering vessels’ downbound transits through the Seaway could supplement these radio communications to help ensure that all vessels have sufficient time to exist the system prior to its close.

6.1.4 Coordination of Moveable Bridge Operations

Eighteen moveable bridges, serving both rail and road traffic, pass over the St. Lawrence Seaway. SeaTA may facilitate both the operation and use of these bridges. Bridge operators may find SeaTA a useful tool to anticipate potential schedule conflicts between trains and approaching vessels well in advance of vessels reaching the whistle sign to request a bridge opening. Bridge operators could assess the movement of approaching vessels and determine whether any of their ETAs will coincide with a scheduled train crossing.

In such situations, this information can help give precise advance notice to approaching train operators and/or vessels. Though vessels are explicitly given priority over trains, if a situation demands that a vessel delay its passage beneath a moveable bridge, information provided through SeaTA could allow the vessel to make a small adjustment in speed, well before its arrival at the bridge, to adjust its arrival time until after the train traffic has passed. Small adjustments to speed are always preferable alternatives to instances when vessels must slow abruptly, potentially to the point where their maneuverability is reduced. Furthermore, overall efficiency and environmental performance will be improved when ships are able to travel at constant speeds. Information provided through SeaTA may be particularly useful in coordinating vessel transits with the schedules of passing freight trains, which may be more difficult to stop for a passing vessel and whose passage over a bridge could take a significant amount of time.

6.2 SeaTA Traffic Management

Though the majority of this document has described the basic SeaTA application for providing travel time estimates to key waypoints for vessels transiting the Seaway, this section will provide operational scenarios for potential enhanced uses of SeaTA to underpin a more comprehensive, Seaway traffic management system based on the concepts underlying STM. In particular, with reasonably accurate travel time estimates available, the Seaway management agencies and their stakeholders may begin to move beyond distributed independent voyage planning and system management to a coordinated approach that seeks to optimize transits of all vessels throughout the system, with cascading efficiencies for port and terminal operators, pilots, and other service providers. SeaTA could give the SLSDC and SLSMC, and potentially individual vessel operators, a view of end-to-end travel time in the absence of interactions with other vessels and other potential sources of delay. This information could serve as a starting point for coordinating vessel transits through the Seaway to account for prevailing traffic conditions as well as berth availability at ports and terminals.

An illustrative example of such a system is presented in table 6[8], which envisions ten vessels traveling up the St. Lawrence River towards the St. Lambert Locks (Lock 1), at distances ranging from 37 to 198 miles from the lock entrance. In this example, vessel speeds range from 10.3 to 21.0 miles per hour. Based upon their current speeds and distances, the vessels would arrive at the times and in the order shown. Note that the arrival order may involve some slower vessels being overtaken by faster vessels, subject to Seaway regulations for safe navigation.

[8] For the sake of simplicity, the transit times and ETAs provided in this example assume that the vessels will continue at a constant speed for the remainder of their approach to the next waypoint. This example also assumes – again, for the sake of simplicity – that all vessels are travelling in the same direction.

Table 6: Predicted Arrival Scenario at St. Lambert Locks (Sample Display)

Upbound ETAs
Selected Waypoint: *St. Lambert Locks*
Current date and time: *10/14/17 at 12:45 PM EDT*

Vessel	Current Speed (Knots)	Distance to Lock 1 (nm)	Transit time (HH:MM)	ETA at Lock 1	Est. Arrival Order
OOCL Eric	18.3	37	2:01	10/14/17 at 14:46	1
Overseas Craig	15.4	47	3:03	10/14/17 at 15:48	2
Hansa York	14.9	62.1	4:10	10/14/17 at 16:55	3
Algomiddlebrook	13.1	56	4:16	10/14/17 at 17:01	4
CSL Stanford	15.7	72.2	4:35	10/14/17 at 17:21	5
CSL Stephen	16	80.7	5:02	10/14/17 at 17:47	6
Algolavigne	14.2	88.5	6:13	10/14/17 at 18:59	7
Algoperlman	12.5	114.3	9:08	10/14/17 at 21:53	8
MSC Joe	21	198.1	9:26	10/14/17 at 22:11	9
Tom McKeil	10.3	128.2	12:26	10/15/17 at 01:11	10

(Window would open after user clicks on waypoint icon in map display.)

Based upon this data, four vessels (*Hansa York, Algomiddlebrook, CSL Stanford* and *CSL Stephen*) would all arrive at Lock 1 within the space of one hour (from 16:55 to 17:47). Similarly, the *Algoperlman* and the *MSC Joe* would arrive at the lock entrance within 18 minutes of one another (21:53 and 22:11). Using an arbitrary lockage time of 60 minutes per vessel (without a “passing entry” of a downbound vessel), the arrival times of these vessels will need to be adjusted.

In addition, the SLS Traffic Control Center is monitoring the entire SLS system, including the final destination for each vessel. If they learn that the berth assigned to the *CSL Stanford* will not be cleared until several hours later than anticipated, it would then be clear that the vessel should not arrive for at least eight hours. Therefore, the current lockage order (#5) for that vessel could be adjusted downward, resulting in a fuel savings and without otherwise “penalizing” the vessel (there would be no additional overall delay).

Merging this information, the SLS Traffic Control Center would issue speed recommendations (speed reductions) to five vessels, and adjust the lockage order (four vessels advanced one place each, and one vessel “bumped” four places in the order). The recommendations are shown in table 7. These data could be displayed within the SLS Traffic Control Center, and shared with vessels through a secure portal (potentially through AIS), to improve situational awareness.

Table 7: Arrival Scenario at St. Lambert Locks Showing SLS Traffic Recommendations and Changes in Lockage Order (Sample Display)

Upbound ETAs
Selected Waypoint: *St. Lambert Locks*
Current date and time: *10/14/17 at 12:45 PM EDT*

Vessel	Unadjusted Arrival Order	Adjusted Lockage Time	SLS Traffic Adjusted Lockage Order	SLS Traffic Recommendation	Action Code Color (see Table 8)
OOCL Eric	1	14:50	**1**	Maintain current speed	
Overseas Craig	2	15:50	**2**	Maintain current speed	
Hansa York	3	17:00	**3**	Maintain current speed	
Algomiddlebrook	4	18:00	**4**	Recommend reduce speed to achieve arrival at 18:00 due to other lock traffic	
CSL Stephen	6	20:00	**5**	Recommend reduce speed to achieve arrival at 20:00 due to other lock traffic	
Algolavigne	7	21:00	**6**	Recommend reduce speed to achieve arrival at 21:00 due to other lock traffic	
Algoperlman	8	22:00	**7**	Maintain current speed	
MSC Joe	9	23:00	**8**	Recommend reduce speed to achieve arrival at 23:00 due to other lock traffic	
CSL Stanford	5	0:00	**9**	Recommend reduce speed to achieve arrival at 00:00 to accommodate delay in berth availability at destination	
Tom McKeil	10	1:15	**10**	Maintain current speed	

(Window would open after user clicks on waypoint icon in map display.)

Table 8 explains the color codes used in the SLS Traffic Adjusted Lockage Order.

Table 8: Color Codes for SLS Traffic Adjusted Lockage Order

Green: No Change in Speed or Lockage Order	SLS Traffic Recommendation does not change lockage order from that based on vessel's current position, speed and ETA at Lock 1.
Yellow: No Change or Improvement in Lockage Order, Change in Speed	SLS Traffic Recommendation maintains or improves vessel's lockage order, but includes a recommendation for a speed adjustment (typically a reduction) due to other vessel traffic or other system conditions.
Red: Change in Speed and Lockage Order	SLS Traffic Recommendation bumps vessel down in lockage order (from its pure speed-based lockage order), due to other vessel traffic or other system conditions (e.g., lack of berth at final destination).

7 Summary of Impacts

7.1 Operational Impacts

7.1.1 Interfaces with Primary or Alternate Computer Operating Centers

SeaTA could be implemented as a separate application from the current system used by Traffic Control Center operators to view AIS-sourced vessel information. However, it will be most effective if integrated with existing applications. This would allow users to either: (1) select a vessel and view its AIS data and travel time estimates to waypoints along the remainder of its voyage; or (2) select a waypoint and view the estimated arrival times and approach directions for all vessels within the operational boundaries of SeaTA.

7.1.2 Changes in Procedure

The implementation of the basic SeaTA application will not impose any significant procedural changes for traffic management in the Seaway, but will instead provide additional information to traffic management personnel, which they can use how they wish. The SLSDC and SLSMC can continue to grant lock order turns on a first come, first served basis, though SeaTA will allow them to anticipate these turns farther in advance.[9] Furthermore, the SLSDC and SLSMC can continue to follow their general principle of only issuing speed or course adjustment recommendations or requests in situations where these adjustments are justified to avoid a safety hazard.

7.1.3 Use of New Data Sources

SeaTA will largely rely on existing data sources, particularly real-time AIS data. Depending on the level of sophistication desired for deriving travel time estimates, SeaTA may rely upon historic AIS data (e.g., average speed over each leg or segment recorded during previous voyages) as well as environmental data (e.g., time of day, weather and wind conditions, water levels, and currents). If SeaTA is to provide travel time estimates through a vessel's entire transit, it will also require destination broadcasts via AIS, which are not currently provided by all vessels on a consistent basis.

[9] The scenario for SeaTA Traffic Management described in section 6.2 would potentially involve an adjustment to how lock order turns are assigned, but is intended only to provide a suggestion for how future phases of SeaTA could be developed. The core focus for this document is the basic SeaTA application, limited to providing information to support existing traffic and infrastructure management practices and procedures.

7.2 Organizational Impacts

As a tool primarily intended to provide additional information to support existing job functions, the initial implementation of SeaTA described in this document would not have any significant effect on the number of positions required, job responsibilities, or skill level requirements. Expanding SeaTA's functionality to enable STM practices and approaches, as discussed in earlier sections of this document, could result in new training needs or position responsibilities. If the SLSDC, SLSMC, and their partners and stakeholders decide to pursue this option in the future, the organizational impacts will be documented as part of a more comprehensive Concept of Operations for this enhanced application of the foundational SeaTA system.

7.3 Financial Impacts

Volpe has identified potential cost drivers that would affect various stakeholders throughout the Seaway system, including potential impacts across the intermodal transportation system. However, specific vessel operating costs or service fees were not publically available, making a detailed financial assessment unfeasible at this time. Further research should be conducted to quantify the overall financial impact of various scenarios described in this ConOps document.

The benefits and costs outlined in this section are based on system coordination that SeaTA could enable in its basic form (described in Section 6.1) through voluntary coordination between vessels, or as part of a more compressive STM-based traffic management approach (described in Section 6.2).

7.3.1 Beneficial Cost Drivers

Table 8 (continued on the next page) identifies a number of potential beneficial cost drivers or cost reductions that can be accrued to various stakeholders through implementation of a comprehensive Seaway Traffic Management System with SeaTA as its core functionality.

Table 8: Beneficial Cost Drivers (Cost Reductions)

Action	Benefit(s)	Primary Beneficiary	Comments
Reducing overall system delays	Increased efficiency and general cost savings through a net reduction of waiting times.	Vessel operators, SLSDC, SLSMC	Will also achieve reductions in delays of surface traffic (trucks, automobiles, trains)
Enabling vessels to travel at reduced speed with no overall delay (facilitating passing lock entries	Lower fuel costs, less wear on vessel machinery, safer navigation	Vessel operators	Reduced emissions will also benefit the environment

Action	Benefit(s)	Primary Beneficiary	Comments
Reducing unnecessary tie ups to wait for lockage	Reduced cost of dockside line handlers, reduced cost of calling out off-watch crew	Vessel operators	
Reducing unnecessary anchoring to wait for lockage	Reduced waiting time and crew costs	Vessel operators	
Reducing unnecessary lock cycling (empty transits)	Reduced wear and tear on equipment	SLSDC, SLSMC	
Improving coordination of port operations	Reduced waiting times or call-outs for towing vessels, line handlers, etc.	Vessel operators	For example, a towing vessel can assist in undocking one vessel then immediately assist in docking a second vessel as it arrives
Improving coordination of intermodal connections	Reduced waiting or idling times for trucks	Commercial carrier services	Highly accurate SeaTAs will better support just-in-time arrival of shipments or chassis at each port.
Improving Seaway safety	Potential reductions in insurance premiums	Vessel operators	A long-term safety and risk analysis of an operational SeaTA system could be used to make a case for reduced insurance premiums.

7.3.2 SeaTA System Development Costs

Development of cost estimates to design, develop, and implement a SeaTA system was beyond the scope of this project. However, the Volpe Center identified several general classes of costs:

- System design.
- Software development.
- System testing and analysis.
- Rollout.
- Training.

- Hardware and equipment costs (these costs are expected to be low, since the system would run on existing network hardware, use existing computer terminals. AIS equipment is already in place).
- Implementation costs for vessel operators (these costs are also expected to be minimal, since AIS systems and Internet communications are already installed aboard nearly all commercial vessels operating on the Seaway. Since it is likely that the SeaTA system will use a web-based interface, there may be a small number of vessels that will need to install some form of Internet communications service).

7.4 Impacts During Development

The key users of the SeaTA application outlined in this document, particularly SLSDC and SLSMC traffic control center personnel, will be engaged to provide detailed input on the specifications for the proposed system. Vessel operators and pilots will also be consulted to determine how the use of SeaTA will affect navigation of the Seaway from the vessel perspective (if at all). These groups would also be involved in reviews, demonstrations, and evaluation of SeaTA's initial operating capabilities.

8 Analysis of the Proposed System

8.1 Summary of Improvements

As mentioned at the beginning of this document and more thoroughly described in the Volpe Center's first white paper on this topic, the Seaway currently experiences quite robust safety, reliability, and efficiency performance.[10] Therefore, opportunities for significant, large-scale improvement—exclusive of expanding the size and capacity of locks, adding redundant locks, or extending the operating season—appear to be somewhat limited. With that in mind, the application described in this document originated when it became apparent that the Seaway's pervasive coverage and use of AIS could be leveraged to achieve operational improvements and provide additional information and situational awareness to Seaway personnel and users. These improvements are summarized below and organized by use area:

- **Seaway Lock and Traffic Management—**The use of SeaTA by traffic management personnel should result in greater use of passing lock entries, thereby avoiding delays to vessels. SeaTA may also avoid instances of "empty" lock transits, whereby locks are filled or emptied, without moving a vessel, only to ready the lock for the next arriving vessel. SeaTA will aid traffic management in identifying, with greater lead-time, potential safety hazards, particularly instances where two vessels are likely to meet or one is likely to overtake another in a location where such maneuvers are prohibited, discouraged, or otherwise undesirable.

  Finally, lock management staff may use SeaTA to more effectively manage the availability of line-handling personnel, particularly to accommodate vessels that are not compatible with the hands free mooring system installed at certain locks. In these cases, since line-handlers may be needed somewhat sporadically, being able to foresee a need for their assistance well in advance could allow their time to be more efficiently managed.
- **Moveable Bridge Operations—**SeaTA could allow moveable bridge operators and vessel masters or pilots to foresee potential schedule conflicts between vessels and trains, thereby allowing additional to adjust either the speed of the vessel or the train.
- **Vessel Operations—**If the SeaTA application is made available to vessel operators, they should be able to use it to facilitate more efficient and coordinated voyages through the Seaway. In particular, though the SLSDC and SLSMC are constrained in their ability to make course and speed change recommendations to vessels, unless they are deemed safety-critical, vessel masters would be able to make informed changes to course and speed to account for traffic they will are encounter along their route, as identified through SeaTA. They may also be able to act on the information contained in SeaTA to coordinate movements with other vessels—for example, when a slower vessel agrees to

[10] *St. Lawrence Seaway: Overview of Safety, Efficiency, Operational, and Environmental Issues*

momentarily slow down even further to allow a faster vessel to overtake it in open water before reaching the confines of a canal, where overtaking may not be allowed.

8.2 Disadvantages and Limitations

Table 9 (below and continued on the next page) summarizes potential disadvantages and limitations of the SeaTA application. Table 9 also identifies some initial mitigation strategies.

Table 9: Disadvantages and Limitations of SeaTA and Potential Mitigation Strategies

Disadvantage/Limitation	Potential Mitigation Strategy
If implemented as a standalone application, SeaTA might prove cumbersome to use in parallel with other applications for traffic management and operations.	The SeaTA system could, at a minimum, ultimately replace the current manual system used to report, record and distribute ETAs via radio, web and other means. SeaTA could be integrated with existing applications used to view AIS data (which may require some reconfiguration of these applications).
In the basic form described in this document, SeaTA's functionality, may be somewhat limited. And, the extent to which traffic management personnel can act upon the information provided may also be somewhat limited (e.g., traffic managers may be able to foresee potential inefficiencies or conflicts; but, unless the conflict presents a safety hazard, traffic managers would not otherwise issue recommendations to avoid these conflicts).	Extending SeaTA access to vessel operators could diminish this limitation by allowing them to act independently or in cooperation with each other to mitigate potential conflicts. The SeaTA system could be deployed across the entire Seaway system enterprise—including Seaway TCCs, vessels, ports, service providers, and other stakeholders—and allowed to mature "organically," based upon user demands and interests. In this way, it might follow the model of other technologies that were once viewed as curiosities or expensive "toys," only to become ubiquitous, widely used systems with ever-changing and improving capabilities (such as the internet, smartphones, and even AIS).
Although the SeaTA concept includes several enhanced ways for deriving travel time estimates, all of them are subject to uncertainty in light of navigational decisions that masters or pilots may make	The Volpe Center recognizes that under existing international, U.S., and Canadian treaties, conventions, laws and regulations, the vessel master has ultimate responsibility for nearly all navigation-related decisions. If the master deems

Disadvantage/Limitation	Potential Mitigation Strategy
independently, due to unexpected circumstances (relative to predictions). Basing travel time estimates on historic transit data can help account for recurring voyage decisions (e.g., vessels that routinely travel well below posted speed restrictions), but cannot help foresee sporadic changes in speed and course that masters or pilots may make in light of prevailing conditions, or which are made due to completely unforeseeable reasons, such as actions of other vessels, or their own loss of propulsion or other onboard engineering casualty.	it advisable to arrive at a designated waypoint earlier or later than the time calculated by the SeaTA system, the SLSDC and SLSMC have little recourse to compel compliance with recommendations (unless there are changes to the aforementioned regulations). However, effective policy and technological design, combined with early coordination and consultation with vessel operators, pilots, ship owners, and other Seaway stakeholders should help convey the application's value. It is hoped that such an approach would help build a strong consensus among the stakeholder community to make the most of the SeaTA system and use it to improve decision-making by all entities, whenever possible. In this way, the most appropriate approaches to development and deployment of the SeaTA system are likely to evolve somewhat organically, but ultimately with a more solid foundation of support.

8.3 Alternatives and Trade-Offs Considered

As discussed in previous sections of this document, the project team considered, but did not pursue, a more active traffic management system that would seek to coordinate vessel transits of the Seaway for maximum system-wide efficiency. The system considered would project all vessel courses and speeds, based on AIS and sharing of onboard voyage planning data, in order to allow vessel masters, with recommendations from Seaway Traffic Control Centers, to adjust their voyage to account for traffic conditions not just in their immediate vicinity, but potentially much farther ahead in their voyage.

The project team ultimately did not pursue this more complex concept in light of concerns that this may extend beyond the authority of the agencies involved. However, the idea is presented and discussed at various points throughout this document because it could potentially be adopted through a collaborative effort amongst the SLSDC, SLSMC, and their users and stakeholders. The basic functionality envisioned for SeaTA could also form the foundation for this more comprehensive traffic management system

Moreover, if SeaTA is made available to vessel masters, they may be able to replicate some of this functionality in an independent manner (i.e., making course and speed adjustments well in advance based on awareness of expected vessel movements beyond the range of their AIS broadcast). Experience with this basic system may build interest in more adopting a system that more formally enables predictive traffic management in the St. Lawrence Seaway.

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Appendix A: Stakeholders

This appendix lists the principal stakeholders identified during the research for this report. The list is not exhaustive, but represents the major public and private entities in each category.

Infrastructure Operators

- Canadian Coast Guard (Ottawa, ON)
- Canadian Pacific Railway (CP) (Calgary, Alb.)
- Canadian National Railway (CN) (Montréal, QC)
- St. Lawrence Seaway Development Corporation (Washington, D.C.)
- The St. Lawrence Seaway Management Corporation (Cornwall, ON)
- Transport Canada (Ottawa, ON)
- U.S. Coast Guard, 9th District (Cleveland, OH)

Non-port government entities

- U.S. Coast Guard, Great Lakes Pilotage Division (WWM-2), Washington, D.C.
- Canada-United States Collaboration for Great Lakes Water Quality , ,
- Canadian Coast Guard (Ottawa, ON)
- Canadian Transportation Agency (Ottawa, ON)
- Environment Canada (Gatineau, QC)
- Federal Maritime Commission (Washington, D.C.)
- Fisheries and Oceans Canada, Great Lakes Environment Office (Ottawa, ON)
- Great Lakes Fishery Commission (Ann Arbor, MI)
- Infrastructure Canada (Ottawa, ON)
- International Joint Commission (Washington, D.C.)
- International Maritime Organization (London, U.K.)
- Maritime Administration (Washington, D.C.)
- Transport Canada (Ottawa, ON)
- U.S. Coast Guard (Washington, D.C.)

- U.S. Environmental Protection Agency, Great Lakes National Program Office (Chicago, IL)
- U.S. Geological Survey, Great Lakes Science Center (Ann Arbor, MI)

Vessel owners/operators

This list reflects the largest or most influential vessel owners and operators that utilize the Great Lakes-St. Lawrence Seaway system, including the port of Montréal.

- Algoma Central Corporation (St. Catherines, ON)
- American Steamship Company (Williamsville, NY)
- BBC Chartering (Leer, Germany)
- Bridge Tankers (Med Maritime) (London, U.K.)
- Canada Steamship Lines (Montréal, QC)
- Canfornav (Montréal, QC)
- Fednav Limited (Montréal, QC)
- Grand River Navigation Company, Inc. (Traverse City, MI)
- Great Lakes Fleet/ Key Lakes, Inc. (CN) (Duluth, MN)
- Groupe Desgagnés Inc. (Québec, QC)
- Hansa Heavy Lift (Hamburg, Germany)
- Hapag-Lloyd (Montréal, QC)
- Lakes Shipping Company, Inc. (part of Interlake) (Middleburg Heights, OH)
- Interlake Steamship Company, The (Middleburg Heights, OH)
- McKeil Marine Limited, Hamilton, ON)
- Mediterranean Shipping Company (MSC) (Montréal, QC)
- Orient Overseas Container Line (OOCL) (Toronto, ON)
- Polsteam (Szczecin, Poland)
- Rand Logistics, Inc. (New York, NY)
- Rigel Shipping Canada Inc. (Shediac, N.B.)
- Spliethoff's Bevrachtingskantoor B.V. (Amsterdam, Netherlands)
- Wagenborg Shipping (Montréal, QC)

Public and private advocacy groups

- American Great Lakes Ports Association (Washington, D.C.)
- American Maritime Officers (Washington, D.C.)
- American Pilots Association (Washington, D.C)
- Canadian Shipowners Association (Ottawa, ON)
- Chamber of Marine Commerce (Ottawa, ON)
- Conference of Great Lakes and St. Lawrence Governors and Premiers (Chicago, IL)
- Consumer Energy Alliance - Midwest (Columbus, OH)
- Freight Management Association of Canada (Ottawa, ON)
- Great Lakes Boating Federation (Chicago, IL)
- Great Lakes Commission (Ann Arbor, MI) (binational)
- Great Lakes Maritime Research Institute (Superior, WI)
- Great Lakes Maritime Task Force (Toledo, OH)
- Great Lakes Protection Fund (Evanston, IL)
- Healing Our Waters-Great Lakes Coalition (Washington, D.C.)
- International Association of Machinists and Aerospace Workers (Lancaster, NY)
- International Longshoremen's Assoc. (ILA), Great Lakes District Council (Cleveland, OH)
- International Organization of Masters, Mates & Pilots (Cleveland, OH)
- International Ship Masters' Association (Berkley, MI)
- Lake Carriers' Association (Rocky River, OH)
- Lake Michigan Forum (Chicago, IL)
- Marine Engineers Beneficial Association (MEBA), AFL-CIO (Washington, D.C.)
- Mining Association of Canada (Ottawa, ON)
- Ontario Marine Transportation Forum (Toronto, ON)
- Regional Economic Development Council - North Country (Watertown, NY)
- Seafarers International Union (Algonac, MI)
- Seaway Task Force (Washington, D.C.)
- Shipping Federal of Canada (ShipFed) (Montréal, QC)
- St. Lawrence Economic Development Council (Québec, QC)
- St. Lawrence Shipoperators (Québec, QC)

- Supply Chain Management Association (Toronto, ON)
- The Chartered Institute of Logistics and Transport (Ottawa, QC)
- The Great Lakes and St. Lawrence Cities Initiative (Chicago, IL)
- U.S. Great Lakes Shipping Association (Cleveland, OH)
- Western Grain Elevator / Lakehead Terminal Elevators Association (Thunder Bay, ON)
- Western Transportation Advisory Council (Vancouver, B.C.)
- Wisconsin Commercial Ports Association (Green Bay, WI)

Port and terminal and shipyard owners and operators

- Becancour Industrial Park (Becancour, QC)
- Central Dock Company (Benton Harbor, MI)
- Cleveland-Cuyahoga County Port Authority (Cleveland, OH)
- Conneaut Port Authority (Conneaut, OH)
- CSX Transportation, Toledo Docks (Toledo, OH)
- Detroit/Wayne County Port Authority (Detroit, MI)
- Dock 63 Inc. (St. Joseph, MI)
- Duluth Seaway Port Authority (Duluth, MN)
- Erie-Western PA Port Authority (Erie, PA)
- Goderich Port Management Corporation (Goderich, ON)
- Hallett Dock Company (Duluth, MN)
- Hamilton Port Authority (Hamilton, ON)
- Illinois International Port District (Chicago, IL)
- Lorain Port Authority (Lorain, OH)
- Midwest Energy Resources Co. (Superior, WI)
- Montréal Gateway Terminals Partnership (Montréal, QC)
- Montréal Port Authority (Montréal, QC)
- Nicholson Terminal & Dock Company (River Rouge, MI)
- Norfolk Southern Corporation (Norfolk, VA)
- Ogdensburg Bridge & Port Authority (Ogdensburg, NY)
- Oshawa Port Authority (Oshawa, ON)

- Port Colborne (Port Colborne, ON)
- Port de Valleyfield (Salaberry-de-Valleyfield, QC)
- Port of Ashtabula (Ashtabula, OH)
- Port of Buffalo (Buffalo, NY)
- Port of Duluth-Superior (Duluth, MN)
- Port of Green Bay (Green Bay, WI)
- Port of Johnstown (Johnstown, ON)
- Port of Milwaukee (Milwaukee, WI)
- Port of Monroe (Monroe, MI)
- Port of Muskegon (Muskegon, MI)
- Port of Oswego Authority (Oswego, NY)
- Port of Sept-Îles (Sept-Îles, QC)
- Ports of Indiana (Indianapolis, IN)
- PortsToronto (Toronto, ON)
- Québec Port Authority (Québec, QC)
- Thunder Bay Port Authority (Thunder Bay, ON)
- Thunder Bay Terminals Ltd. (Thunder Bay, ON)
- Toledo-Lucas County Port Authority (Toledo, OH)
- TPG Chicago Dry Dock, LLC (Chicago, IL)
- Trois-Rivières Port Authority (Trois-Rivières, QC)
- Verplank Dock Co. (Ferrysburg, MI)
- Windsor Port Authority (Windsor, ON)

Service providers

- Algoma Ship Repair (Port Colborne, ON)
- Allied Marine & Industrial (Port Colborne, ON)
- American Bureau of Shipping (ABS) (Houston, TX)
- Basic Marine (Escanaba, MI)
- Bay Shipbuilding Company (Fincantieri Marine Group, LLC) (Sturgeon Bay, WI)
- Bell Marine & Mill Supply Ltd. (Port Colborne, ON)

- Brown County Port & Resource Recovery Dept. (Green Bay, WI)
- Burger Boat Company (Manitowoc, WI)
- Canadian Marine Pilots' Association (Ottawa, ON)
- Chantier Davie Canada Inc. (Lévis, QC)
- Cleveland Ship Repair Company (Cleveland, OH)
- Donjon Shipbuilding & Repair, LLC (Erie, PA)
- Donjon Shipbuilding and Repair, LLC (Erie, PA)
- EMS-TECH Inc. (Belleville, ON)
- Fraser Shipyards, Inc. (Superior, WI)
- Great Lakes Pilotage Authority (Cornwall, ON)
- Group Ocean (Québec, QC)
- Heddle Marine Service Inc. (Hamilton, ON)
- Hermont Marine Inc. (St. Laurent, QC)
- Hike Metal Products Ltd. (Wheatley, ON)
- Ironhead Marine, Inc. (Toledo, OH)
- Lakes Pilots Association (Port Huron, MI)
- Laurentian Pilotage Authority (Montréal, QC)
- Lloyd's Register North America, Inc. (Burlington, ON)
- Lock/Port Sales & Services Inc. (St. Catherines, ON)
- Logistec Corporation (Montréal, QC)
- Marine and Offshore Canada (St. Catherines, ON)
- Marine Clean Ltd. (Niagara Falls, ON)
- Marinette Marine Corporation (Marinette, WI)
- Mount Royal /Walsh Inc. (Montréal, QC)
- Navamar Inc. Ship Repairs (Montréal, QC)
- Nicholson & Hall Corporation (Buffalo, NY)
- Palmer Johnson Incorporated (Sturgeon Bay, WI)
- Provmar Fuels Inc. (Hamilton, ON)
- Purvis Marine Limited (Sault Ste. Marie, ON)
- RWDI Air Inc. (Toronto, ON)
- Somavrac Inc. (Trois-Rivières, QC)

- St. Lawrence Seaway Pilots' Association (Cape Vincent, NY)
- Sterling Fuels Ltd. (Hamilton, ON)
- Walter Hiltebrand Marine Services Ltd. (Welland, ON)
- Western Great Lakes Pilots' Association (Superior, WI)

Major shippers of commodities and finished products

This list is based upon analysis of membership of several advocacy and promotional groups engaged in supported commerce on the Great Lakes-St. Lawrence Seaway system, including the Chamber of Marine Commerce and the Great Lakes Maritime Task Force.

- ADM (Archer Daniels Midland Company)
- Agrium Inc.
- AK Steel Corporation
- Alcan Smelters & Chemicals (Rio Tinto)
- Aluminerie Alouette
- ArcelorMittal
- Atlantic Minerals Limited
- Badgeley Island Aggregates (Coco Group)
- Bunge North America
- Canadian Slag Services Inc.
- Cargill Limited
- Carmeuse Lime, Inc.
- CertainTeed Gypsum Canada
- CGC Inc. (Canadian Gypsum Company)
- Cliffs Natural Resources, Inc.
- Compass Minerals (Sifto Canada)
- Construction Aggregates (Fairmount)
- Consumers Energy
- CRH Canada Group, Inc. (Holcim (Canada) Inc.)
- DTE Electric
- Edw. C. Levy Co.
- ESSROC Italcementi Group

- FeX Group, LLC
- G3 Global Grain Group (formerly Canadian Wheat Board)
- Georgia Pacific
- Grain Farmers of Ontario
- Grande Cache Coal Corporation
- Greenfield Ethanol
- Hansen Mueller Company
- Hensall Global Logistics
- HTS America LLC
- International Minerals Inc.
- Iron Ore Company of Canada
- Island Construction
- K + S Windsor Salt (Canadian Salt)
- Keystone Coal Canada Inc.
- Koch Carbon, LLC
- Kraft Foods Global, Inc.
- Lafarge North America
- London Agricultural Commodities Inc.
- Louis Dreyfus Canada Ltd.
- Mondelez International
- Moran Iron Works
- Morton Salt
- Mosaic Company
- Norton Lilly International
- Nova Scotia Power
- Omnisource Corporation
- OMYA, Inc.
- Ontario Trap Rock Ltd. (Tomlinson Group)
- Ontario Wheat Producers Marketing Board
- Osborne Concrete & Stone Co.
- Oxbow Carbon and Minerals LLC

- Palmerston Grain
- Parrish & Heimbecker Ltd.
- Pittsburgh Logistics Systems, Inc.
- Potash Corporation of Saskatchewan
- Redpath Sugar Ltd.
- Richardson International
- Rio Tinto Fer et Titane
- Riverland AG
- Smelter Bay Aggregates Inc.
- Southwestern Sales Corporation Limited
- Tata Steel
- Teck Coal
- U.S. Steel Canada
- U.S. Steel Corp.
- Unimin Canada Ltd.
- United States Gypsum Corporation
- Viterra
- Votorantim Cement North America

Recreational users

Since this report is focused primarily on the commercial or non-recreational use of the Great Lakes-St. Lawrence Seaway system, we have not identified specific stakeholders in this category. (The Great Lakes Boating Federation is included as a stakeholder.)

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