Precision clearance

Use of dynamic under-keel clearance technology on the St. Lawrence River

Montreal is working to maximize safety, clearance for ships coming into port.

The St. Lawrence DUKC® system is an e-Nav solution designed to ensure every deep-draft passage maintains safe under-keel clearance, while making use of the full water column to safely maximise cargo. The system provides an intelligent way to manage the shift to larger, deeper vessels by managing UKC and air draft in a scientific and consistent way. The St. Lawrence DUKC® system successfully integrates data from a range of user groups and disseminates passage planning information to the relevant stakeholders on the river.

Details of how the system works and where it's being used are covered in a two-part series, with part one below. Part two will run in the fall edition of Great Lakes/Seaway Review.

A Quick Look

Utilizing technology • System overview and drafts • Existing navigational rules • Static vs. dynamic allowances • The technology

LAURENCE BENN
Senior Engineer
OMC International

DANIEL DAGENAIS
Vice President Operations
Montreal Port Authority

MATTHEW TURNER
Project Management Officer
OMC International

In 2013, the Port of Montreal awarded OMC International a tender to implement a Dynamic Under Keel Clearance (DUKC®) system in the St. Lawrence River to allow river stakeholders (port, Coast Guard, pilots and industry) to optimize use of the water column and ensure the safety of vessels. Today, this system is in operational trial with regulatory approval underway.

Located on the St. Lawrence River, the Port of Montreal provides access to overseas goods for over 100 million people. It is estimated the port provides more than C$2 billion of value to the Canadian economy, according to a Canadian Coast Guard Waterway Management report.

The port handles a mix of trades, including containers, dry bulk and liquid cargo. In 2016, 35.2 million metric tons of freight was handled, an increase from 32 million metric tons the previous year. The most recent tonnage represents a record year at the port, with distinct gains being noted in grain and liquid bulk, according to the port.

These goods were transported on more than 2,000 vessels, many sailing near the maximum draft limit in the river.

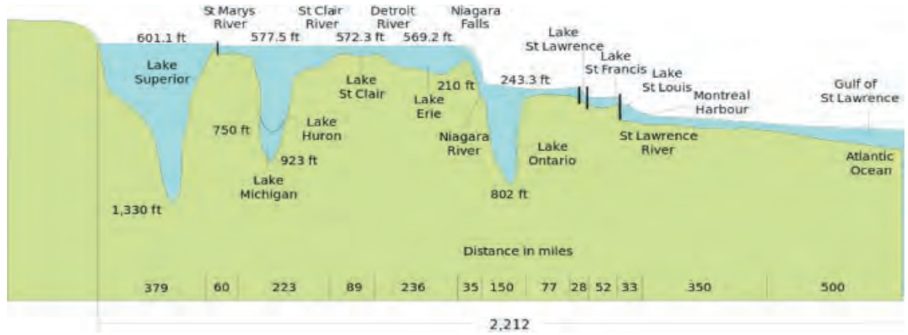
Utilizing technology. The decision to implement a DUKC® was made as part of an electronic navigation project by the Port of Montreal, in collaboration with the Canadian Coast Guard, the Canadian Hydrographic Service (CHS) and the Laurentian Pilotage Authority. This project also received Canadian federal funding.

One factor influencing the implementation of a DUKC® system for the port was the desire to optimize use of the water column. Historically, additional draft for vessels was obtained through dredging. Between 1850 and 1910, the navigation channel between Quebec City and Montreal was dredged three times, increasing the depth from 4.9 meters to 7.5 meters and then to 10.7 meters. Since then, the only major dredging occurred in 1992 to increase maximum drafts to 11 meters.

System overview and drafts. The St. Lawrence River connects the Great Lakes with the St. Lawrence Estuary and the Atlantic Ocean. Because of the locks, the maximum dimension of vessels entering the Seaway is 225.6 meters long, 23.8 meters wide, with a draft of 8.08 meters. As the last port before the start of the Seaway, Montreal is the terminal port for the larger Post Panamax vessels.

Vessels with up to an 11-meter draft can travel along the St. Lawrence River between the naturally deep St. Lawrence Estuary and

Figure 1: The cross section of water levels and depth of various components of Great Lakes/St. Lawrence system.



SOURCE: U.S. ARMY CORPS OF ENGINEERS

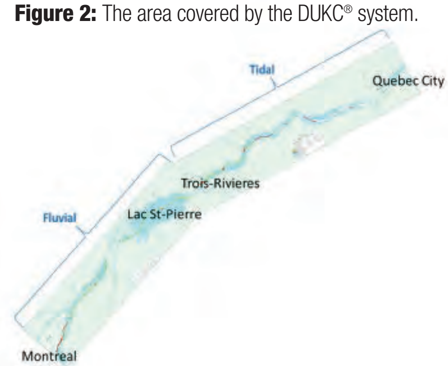
the 8-meter draft limit of the locks. Thus, partially loaded Post Panamax vessels can sail this section of the St. Lawrence River to discharge at the Port of Montreal. This section of the St. Lawrence River between Montreal and Quebec City is covered by the DUKC® system.

From a hydraulic perspective, the section of the St. Lawrence River between Montreal and Quebec City can be understood as two separate systems. The division of these two systems is about halfway between Montreal and Quebec City, at the city of Three Rivers at the northern end of Lake Saint Pierre.

The upper section is a pure riverine system with no tidal influence. As a non-tidal riverine system, maximum draft is the main focus for vessels transiting this section of the river and the maximum drafts available are governed by water level.

Water levels in this upper half of the river are controlled by the upstream river discharge primarily coming from Lake Ontario. As the upstream is a regulated system,

Figure 2: The area covered by the DUKC® system.



there is some ability to control the water level. For an arriving deep-draft vessel that exceeds maximum draft in the river and water levels not meeting forecasted levels, the port has the ability to request additional flows to increase the water level to accommodate this deeper vessel. This "borrowed" water, to a certain extent, is paid back via reduced flows (lower water levels) over the subsequent weeks.

The water level of the downstream section of the St. Lawrence River—from Three Rivers to Quebec City—is tidally influenced and can be classified as a hydraulically mixed system. For navigation there, the focus changes from maximum draft to the availability of sailing windows for a given draft: At what times can a vessel with a certain draft safely sail through the river?

As these two sections are connected, the maximum drafts of vessels travelling between Montreal and Quebec City are controlled by the upstream water levels and the times of transit are controlled by the sailing windows in the downstream section. (Refer to Figure 3 to the right.)

Existing navigational rules. The present rules—controlling the times of sailing and maximum drafts—can be classified as advanced static rules. Two tables, one for container vessels and one for other vessels, are used to determine the squat estimation based on the vessel's beam. The squat estimation is only made for a post-panamax vessel traveling at 10 knots, with some exceptions for vessels complying with set requirements. An extra safety allowance of 0.61 meters is also made to cover all other unknowns.

Water level forecasts by the Canadian Coast Guard are done using the St. Lawrence model and accounts for prevailing conditions in their estimations. The under-keel clearance (UKC) requirements are checked at nine predefined locations for each vessel transiting the river. At six of those locations, where water levels are tidally influenced, times of sailing restrictions are also determined.

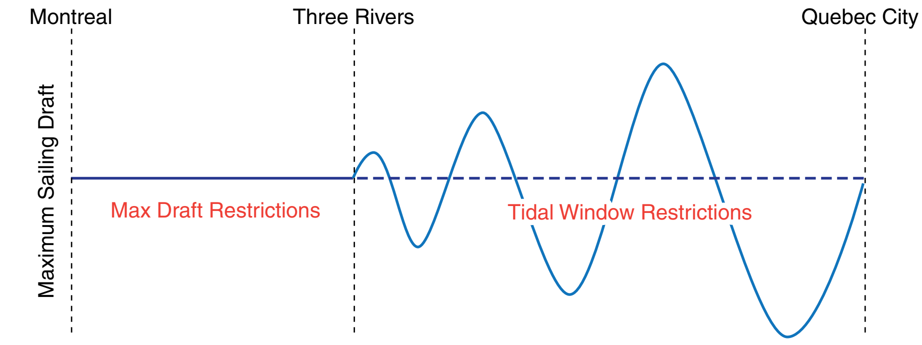
While this UKC check is performed for passage planning by the Coast Guard, it does not ensure that the UKC is maintained for the actual passage. It is a manual and static process not easily modified to take into account deviations from the planned transit, such as changes in speeds or in water level or currents. Most vessels travel faster than 7 knots along the river, exceeding the squat allowances made in the initial UKC check. Analysis of the manual water level forecasts has also shown that a greater level of accuracy can be achieved by using automated real-time forecasts provided by the Canadian Hydrographic Service.

Today, this system is in operational trial with regulatory approval underway.

As well as maximum draft rules, there are some other (non-UKC) restrictions in place that limit times of sailing. These restrictions include "air draft," an upper limit for ships where bridges or high voltage power lines cross the river. In this case, higher water levels tend to restrict sailings by reducing the distance between the water and the lowest part of the structure.

Static vs. dynamic allowances. Tradi-

Figure 3: A schematic of draft limits for vessels transiting between Port of Montreal and Quebec City.



As the individual UKC component allowances are calculated on a vessel-by-vessel, transit-by-transit basis, the economic inefficiency associated with the static rule is avoided.

tionally, static rules have been used by authorities to ensure the safe transit of a vessel from a UKC perspective. Static rules combine the various factors that influence the UKC requirements of a vessel into a single gross value used to determine times of sailings.

However, there are multiple factors that influence the UKC requirements of a transiting vessel. In reality, these factors change dynamically depending on vessel, channel and environmental conditions. A general summary of the factors that influence UKC is presented in Figure 4.

For a riverine environment, where swell waves are not present, squat is the generally dominant UKC component. While many various squat formulas exist, actual squat depends on characteristics of the vessel, the channel being traversed, speed through water as well as water depth.

The static rule approach can be viewed as a top-down approach to UKC management. A gross allowance is assumed to be sufficient to cover all cases, but at any particular time, the net UKC is effectively unknown.

The static approach yields two observations, which have both a safety and an economic element. As a gross static allowance is assumed to cover all situations, the actual net UKC varies and the risk of grounding for any given sailing is unknown and situations may exist where the gross allowance is actually insufficient and the navigator is violating safety margin rules.

Further, the gross static allowance is selected with a conservative perspective (to cover all situations); the static rule should be safe in the worst case/conditions. For transits other than in the worst conditions, the draft or sailing times of vessels are unnecessarily restricted, with obvious economic costs.

DUKC® stands for Dynamic UKC and takes a different approach to UKC management, which can be described as a bottom-up approach. It defines a minimum net UKC allowance that must be maintained throughout the transit. Each of the relevant UKC components is assessed and an individual allowance is calculated and added. The final UKC requirement is a summation of the individual component allowances and the net UKC allowance.

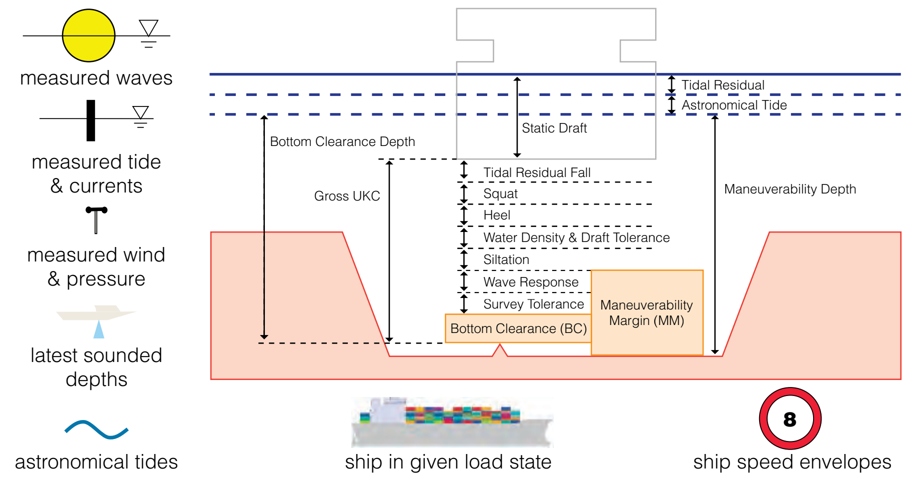
The UKC requirement calculated by the

DUKC® approach is safety-assured because the guaranteed safety margin will not be breached. Effectively, the UKC requirements dynamically adjust to meet the requirements of a particular vessel at its particular time of sailing.

As the individual UKC component allowances are calculated on a vessel-by-vessel, transit-by-transit basis, the economic inefficiency associated with the static rule is avoided. Each transit is conducted against its own UKC requirements. If a particular transit has less UKC requirements than the average, then the vessel could load more cargo or sail with wider tidal windows than the average.

As well as vessel conditions and information about the state of the channel, the DUKC® takes a more considered account of the environmental situation influencing the UKC of vessels. For rivers, the major elements are water levels and currents; in the open sea, waves are an additional consideration. Inputs of spatially varying measured and predicted environmental conditions are used by the DUKC® to accurately calculate the UKC requirements for each point along the channel at the times the vessel is expected to pass. Figure 5, on this page, shows the minimum UKC of each transit as a dot.

Figure 4: A schematic of the various factors that influence UKC.



The technology. DUKC® is a computer system based on the DUKC® methodology. The first DUKC® system was developed and installed in 1993 at the Hay Point coal terminal in Queensland, Australia. Since then, the technology has been installed in over 20 ports and has ensured the safety of more than 100,000 transits. Today DUKC® is recognized as best-practice for UKC management.

Now in its fifth generation, the latest version of DUKC® is web-based, allowing authorized users to connect with the system. Such authorized users could include planners, VTS operators, regulators and pilots.

The core functionality of the DUKC® has been to provide users with dynamic passage planning advice on:

- Maximum sailing draft (fixed sailing times)
- Sailing window times (fixed sailing draft)
- UKC for specific transit (fixed times and drafts)

One factor influencing the implementation of a DUKC® system for the port was the desire to optimize use of the water column.

This core functionality remains in DUKC® Series 5 and has been augmented by more flexibility in transit planning through speed control and a gating engine, as well as transit monitoring capabilities. The following figures describe this functionality.

For long-term planning, a draft and sailing time planning service exists. This service uses preconfigured speed profiles and climate or user specified environmental conditions to obtain advice on maximum drafts or sailing windows for planning purposes.

Closer to the time of sailing, a transit planning service allows more detailed planning of the transit to occur. The service allows the transit to be planned with a higher level of refinement. This includes more detailed information about the load state of the vessel and more control over the planned speeds rather than the preconfigured profiles used in voyage planning.

The transit plan provides more detailed transit planning advice. The upper panel indicates the input data used to calculate the result, including vessel particulars and loading. The lower panel presents an along channel view of the UKC anticipated over the course of the transit. For long transits with numerous controlling points along the way, the display from the gating engine indicates the interaction between planned speed at the various critical points, the available windows at the critical points for those various planned speed options and how the planned transit interacts with the availability of windows at the various critical points.

If an AIS feed is made available to the DUKC® system, the Transit Monitoring Service can be configured. The service links a vessel's position with its DUKC® planned transit information through its MMSI number. It allows the vessel's passage along the transit to be tracked. As the vessel's position and speed change, the UKC advice can be regularly recalculated using the latest environmental information.

The additional feature in the transit monitoring results is the display of the actual speeds undertaken by the vessel and the planned speeds for the remainder of the transit. Because the speeds can be edited during the transit monitoring stage, the system can be used to safely adapt the transit plan to changing situations, whether there are issues with the vessel, such as engine problems, or deteriorating environmental conditions. ■

The authors would like to acknowledge the support of the Canadian Coast Guard, the Canadian Hydrographic Service, the Central St. Lawrence Pilot Corporation, the Laurentian Pilotage Authority and Montreal Gateway Terminals Partnership in assisting with this project.