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Inshore hydrographic charting involves a huge commitment of infrastructure, time and finances. If those surveys do not maximize the amount of information gathered, then this represents a lost opportunity. A collaborative, hydrographic, oceanographic and geophysical survey was conducted in Shippagan Bay, New Brunswick using a standard hydrographic survey platform (CSL Heron).

Heron is equipped with a non standard suite of instrumentation, including a 300 kHz multibeam echo-sounder, keel-mounted 200 kHz sidescans, 28 and 3.5 kHz subbottom profilers, 600 kHz ADCP and towed undulating oceanographic profiler. The aim was to acquire as much data as possible simultaneously and to use the marginal weather windows to acquire data with the less motion sensitive instruments.

The requirements of the survey were to examine fisheries habitat issues (lobster, crab and herring) that might be influenced by either aquaculture activity (mussels and oysters) or fish plant discharges. Habitat requires a combined understanding of fine scale bathymetry (bottom roughness), surficial and shallow subsurface sediments and estuarine oceanography (currents, temperature and salinity distribution and tidal variability).

Acquiring multi-parameter data provide new demands on data display and distribution not met by traditional electronic charting technologies. As a test case, all the data were collected and are being distributed on-line to the various interested parties. The full resolution data can be accessed directly at:

<http://www.omg.unb.ca/Projects/Shippagan/>

**H**

Whilst there will always continue to be a requirement for coastal hydrographic surveys for navigational purposes, there has been a considerable growth in the demand for environmental, scientific or engineering surveys in the same region. An underlying requirement for all operations is precise bathymetry, although the specifications are different (hydrography favours shoal biased conservative minima, whereas environmental surveys are more interested in morphology and short wavelength roughness characteristics).

The needs of environmental, science and engineering surveys require quite different sensor suites (oceanographic, bottom type and subsurface sensors for example). All these sensors however, are still ideally deployed over the same area, with as much spatial density as can be afforded. Oceanographic measurements are normally of lower spatial density, but require temporal resolution. Thus with care it should be possible to combine a subset of the requirements of both survey types into a single platform.

This paper presents results of a collaborative experiment conducted between the Ocean Mapping Group at UNB and the Gulf Fisheries Centre within DFO. The aim was to combine survey requirements for a region of overlapping interests and to explore the operational demands of the different sensors and to develop new display methods and distribution methods so that a multi-disciplinary dataset can be best made available to the wider range of clients. The survey was based in Shippagan Bay, northern New Brunswick and employed the C.S.L. Heron.

**H**

The CSL Heron is a state-of-the-art 34ft (10m) survey launch. She is utilised to acquire data in multi-disciplinary fields of scientific research, predominant amongst them hydrography, geophysics and oceanography. The Heron is owned by the Canadian Hydrographic Service (CHS) and is currently on a 10 year loan to the Ocean Mapping Group at the University of New Brunswick (UNB). The loan is part of a Joint Partnering Agreement between the CHS and UNB. The Heron is provided for the purposes of conducting Ocean Mapping related research and training.



Figure 1. The Canadian Survey Launch Heron

Originally built in 1983, the Heron operated as single beam survey launch attached to CSS Baffin, a 100m Arctic survey vessel, for operations in the Arctic and on the Grand Banks during the 1980's. The Heron was professionally rebuilt and outfitted to modern standards over the winter of 2001-2002 at the Bedford Institute of Oceanography. She is equipped with a unique suite of acoustic survey instruments funded through the Canadian Foundation of Innovation, Kongsberg Simrad, ACOA and sponsors of the Chair in Ocean Mapping at UNB. She is currently being used in support of a series of collaborative research projects in the coastal waters of New Brunswick.

PHYSICAL DIMENSIONS AND MARINE EQUIPMENT	
Length	10.0 m
Draft	1.15 m
Weight	15,000 lbs (including full payload)
Propulsion	Caterpillar 3208, 300 HP turbo charged diesel (keel cooled)
Operating Speed	12 knots cruising at 2100 rpm, 8 knots at 1800 rpm.
AC Power	Kohler 5KW generator - with UPS
DC Power	24 Volt with inverter to 12 Volts
Navigation sounder	Interphase probe (200 kHz) downward and forward looking

Table 1. CSL Herons Physical Dimensions and Marine Equipment.

Flush mounted into the hull are a Kongsberg Simrad EM3000S (a 300kHz multibeam), and a 3.5kHz transducer. Attached to the keel port and starboard are 200kHz sidescan staves. To port is the dual (28 & 200 kHz) frequency transducer. The sidescan and the two sub-bottom transducers data is acquired using Knudsen 320 systems. In addition the Heron has a Brooke Ocean Technologies Moving Vessels Profiler (MVP) 30 winch and sheave onboard with the fish containing an AML CTD probe. On a pole mount to port is a RDI Workhorse Monitor 600kHz Acoustic Doppler Current Profiler. The EM3000S uses the proprietary software (Merlin) for acquisition, the survey planning and monitoring uses the ICAN Aldebran Survey software and data from all sources in processed using the OMG SwathEd software suite.

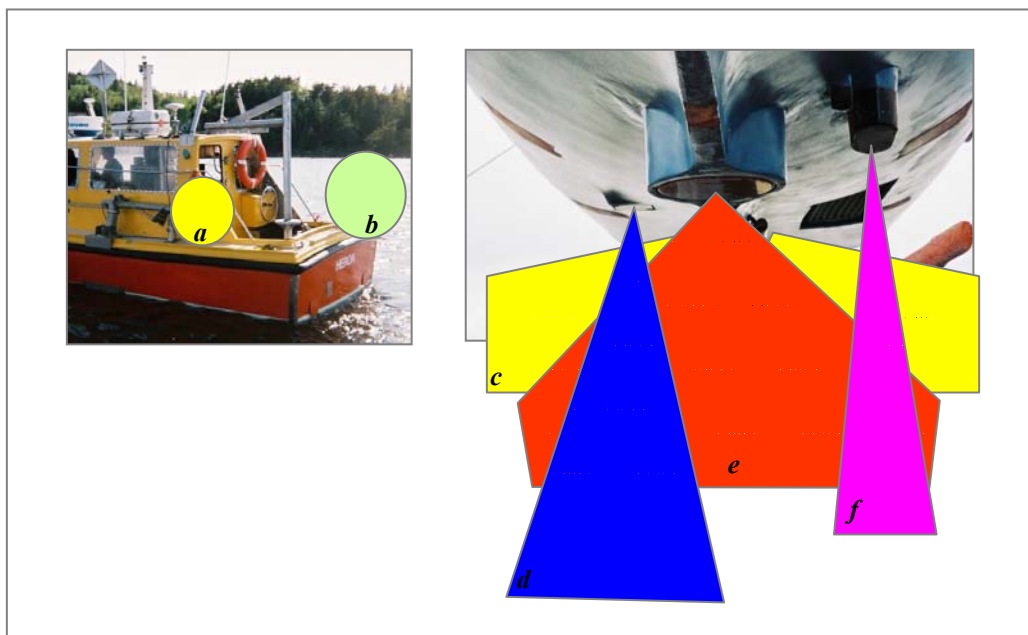
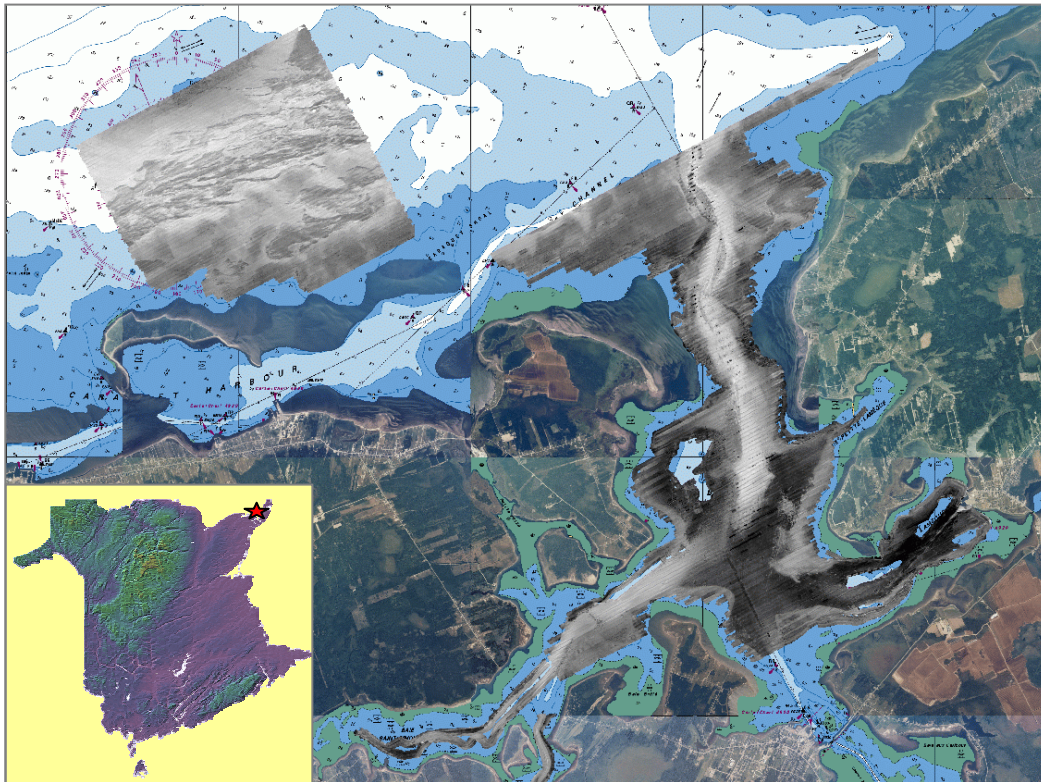


Figure 2. The Acoustic Sensors aboard the Heron: a. RDI 600 kHz ADCP, b. Brooke MVP-30 CTD, c. Knudsen 200 kHz sidescans, d. 3.5 kHz subbottom, e. 28 kHz subbottom and 200 kHz water column dual transducer, f. Simrad EM3000 multibeam.



The Ocean Mapping Group primarily utilises the launch CSL Heron as a test platform for the group's research. During any given survey season, we use her in; operational testing of in-house software developments; tests of motion and positioning sensor performance; sonar resolution trials; and undergraduate and graduate training. The primary role does not utilise the launch for an entire survey season therefore, a secondary role of the Heron is collaborating with government and other academic research organisations in projects directed by their research requirements. From the point of view of the OMG, these projects are used as a basis for developing and testing new data processing and manipulation software tools.

The Shippagan Bay survey was a collaborative research project between the Ocean Mapping Group, UNB, Fredericton, and Gulf Fisheries Centre, DFO, Moncton. As a group we were able to combine respective available resources to effectively and efficiently conduct the survey. The aim of the survey was to test the effectiveness of acoustic mapping tools for the purposes of delineating seabed habitat. The end products of the survey meet the diverse requirements of the collaborating participants. The survey was conducted between July 2nd and August 13th of 2003.



*Figure 3. Shippagan Bay Habitat 2003 Survey location. The image is of the 200kHz sidescan acquired during the survey geographically referenced within aerial photographs and bathymetric charts.*

The main survey was focused within Shippagan Bay. The Bay is approximately 15 km long in a north south direction and the main exchange of water is to the Bay of Chaleur to the North. A small, but not insignificant exchange of water takes place through Shippagan Gully to the South, bringing in water from the main Gulf of St. Lawrence. The area is one of extensive inshore fisheries (lobster, crab and herring) as well as aquaculture (mussels and oysters) and there are a significant number of fish processing plants that discharge effluent into the bay.

In addition to the main Shippagan Bay survey, a second survey was conducted to cover a region north of Caraquet Island where there has been extensive groundtruthing. In this area, video-tow, grab, towed sidescan and QTC view echo character data have been acquired. The aim is to compare the data collected by the Heron with previous attempts to characterise seabed habitat.

Logistic issues of conducting such an involved nearshore mapping survey are compound. Operations were conducted in daylight within usable weather windows. The vessel is run with a single coxswain and a single operator for all sonar systems. An additional person maintained the shore-based processing approximately one day behind.



The inshore survey environment in Shippagan posed for the survey team a number of fundamental questions. Namely, in a bay that has an average depth of around 4 metres, how serious can one be about 100% bathymetric coverage using acoustics? Had this been a hydrographic operation only, the role of airborne lidar would have been seriously considered. We answered this question by allowing ourselves to be guided by our collaborator's primary interest, the character of the bay floor (both surficial and shallow subsurface) and the watermass characteristics in the bay. These extra requirements cannot be met from aircraft at this time. As a compromise, we dropped back to the old single-beam (in this case incomplete multibeam) with 100% sidescan coverage model. There was the added bonus that bathymetric coverage increases from 10% up to perhaps 50%, where deeper waters occurred, in the dredged channels and further offshore. During marginal weather windows, which produced poor quality sidescan, noisy ADCP and sub-bottom measurements, relatively high speed multibeam is still viable. We used these 'windows' to 'fill-in' our bathymetric coverage.

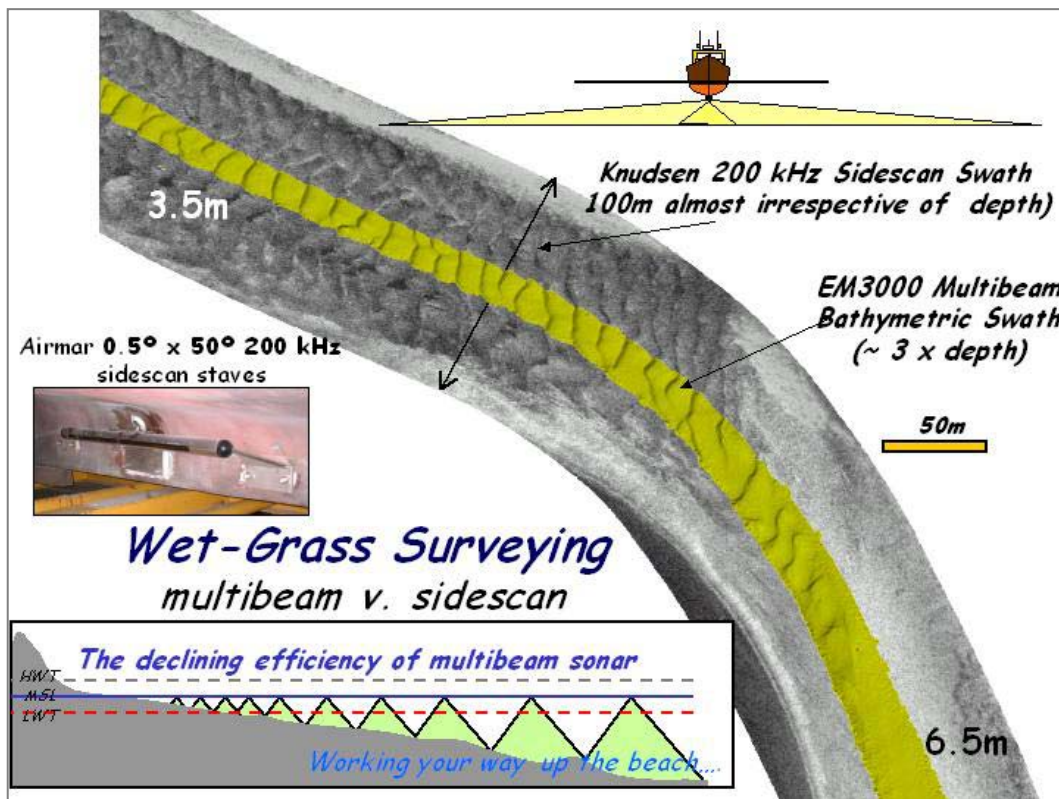


Figure 4. Wet-Grass surveying - multibeam versus sidescan efficiency

The water depths in Shippagan Bay ranged between 2 and 15 metres. Our planned survey lines running WSW-ENE, were spaced 80m apart. This is based on the usable Knudsen 200kHz sidescan swath width, which attains 100m almost irrespective of water depth. At 200 kHz in deeper water one can actually usefully use 100m per side range settings but in depths less than ~ 7m, surface interference significantly corrupt the outermost data. The EM3000 multibeam bathymetric swath width is limited to approximately 3 times the sonar altitude (depth –draft of 0.85m). Up to 4 times is actually collected under ideal conditions, but with roll and requiring a minimum sounding density, 3 times is a good guide. If we were forced to make the choice between multibeam versus sidescan for this survey environment we would have to, for efficiency and coverage, choose sidescan. Luckily with the Heron a choice need not be made, we plan the survey based on the sidescan coverage, but we acquire simultaneously with multiple acoustic sensors giving overall increased efficiency. We acquire more than 100% sidescan coverage, which is tied spatially and temporally to the bathymetric and orientational accuracies of the limited multibeam swath coverage. Along with the sidescan and multibeam we are simultaneously acquiring quality subbottom, ADCP profiles and occasionally MVP -30 CTD (concerns in shallow water and snagging the fish, restricting its use).

In Shippagan combined operations were at approximately 7.5 knots, this optimized the sidescan, ADCP and subbottom data quality. In depths less the five metres the vessel speed was normally slower than this for safety reasons. Flush mounted multibeam allows high speed 10 - 12 knot operations; this however was only attempted in water depths exceeding 10 metres.

Other considerations were very specific to this survey. The Mussel Aquaculture sites featured largely in Shippagan Bay proper and the bays and inlets off it. We were attempting to provide data that could help the DFO researchers determine the impact their presence was having on the environment. We wished to compare the sediment distribution outside and within the buoyed areas to see if the moorings were disrupting the natural circulation of the bay. Using the multibeam in depths less than 5m we could not safely look within or under the moorings, but with a 50m slant range on the sidescan we could image into the sites whilst lying safely outside the buoys (compare Fig 5 top right and bottom left). Even then, unmarked and submerged relict mooring gear proved a hazard.

To illustrate the complimentary nature of the all the sensors an example is presented of data acquired in the vicinity of the Lameque Bay, fish plant effluent plume.



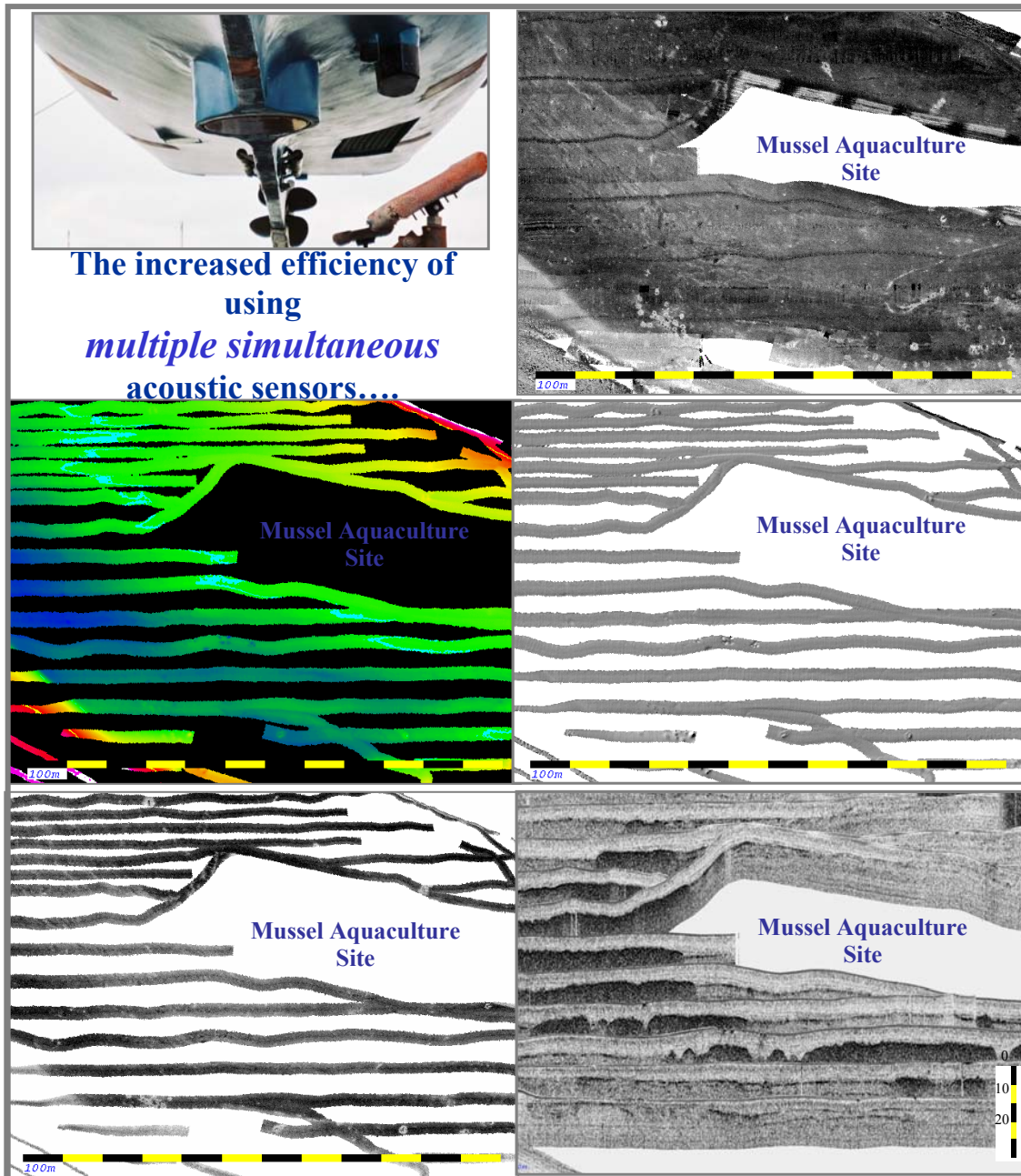


Figure 5. Example of multiple acoustics sensors simultaneously acquiring data. Note: the line spacing was 80 metres. The survey was being conducted around a Mussel Aquaculture site.:

- Top right – Knudsen 200 kHz sidescan (note 100% coverage)
- mid-left – EM3000 depth encoded bathymetry (navigational surface, regional topography).
- mid-right – EM3000 sun-illuminated bathymetry (bottom roughness)
- bottom-left – EM3000 300 kHz backscatter
- bottom-right – fence diagram of 3.5kHz subbottom profiles.



Whilst the CSL Heron Shippagan Bay survey was designed to cover the whole of the Shippagan Bay region, there was naturally a particular interest in the Lameque Bay area, especially in the vicinity of the fish plant effluent plume, just east of the Lameque harbour mouth. The acoustic findings from the survey answer some but not all of the questions about the fate of the effluent plume. They do clearly show a high-backscatter anomaly that radiates from the effluent outfall pipe suggesting that the extent of the seabed influenced by the plume can be delineated.

***Extent of the backscatter anomaly in the vicinity of the Harbour breakwater.***

If we examine the available aerial photo of Lameque Harbour, which was probably taken in 1996 or 1997, we can see the harbour breakwater, the processing plant and the beach to the east of the breakwater. Most significantly one can actually see a bright plume in the water off that beach, emanating from a single point (the effluent outfall pipe mouth), which is drifting off to the east.

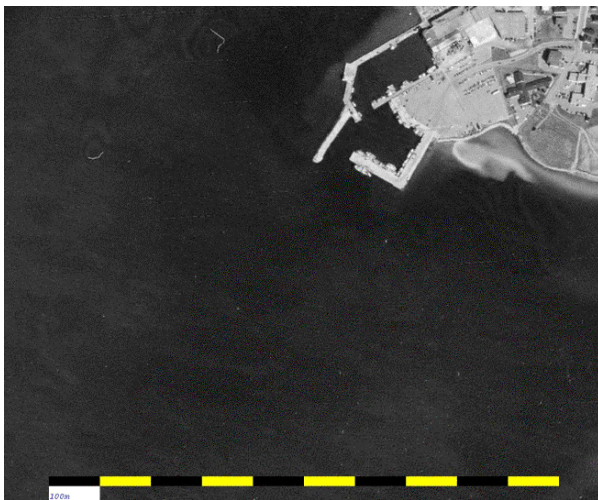


Figure 6. Lameque, Harbour, the aerial photograph.

The CHS bathymetric chart for the identical area, provided additional features of note, the dredged channel, which is maintained at a minimum depth of 5.5 metres, and the fact that actual bay has average depths of only 2.5 to 3 metres. The eastern harbour breakwater extends beyond the 2 metre contour but significantly there is a gradual sloping beach front to the east of the breakwater where the effluent plume is located.

Initially the area was surveyed with the 80 metre line spacing. We went back in to acquire 100% bathymetric coverage in the dredged channel, the harbour itself and just outside the mouth of the harbour. The deepest point in the dredged channel was a little over 6 metres and the North East face of the outer harbour had also been dredged to in excess of 6 metres. The morphology of the bathymetric surface was then examined by producing a synthetic sun illuminated image (Figure. 7). The illumination is to the North West. The main bay floor is almost entirely featureless; the only relief 'illuminated' is seen in the dredged channel, which is produced by the random motion of the dredger head.



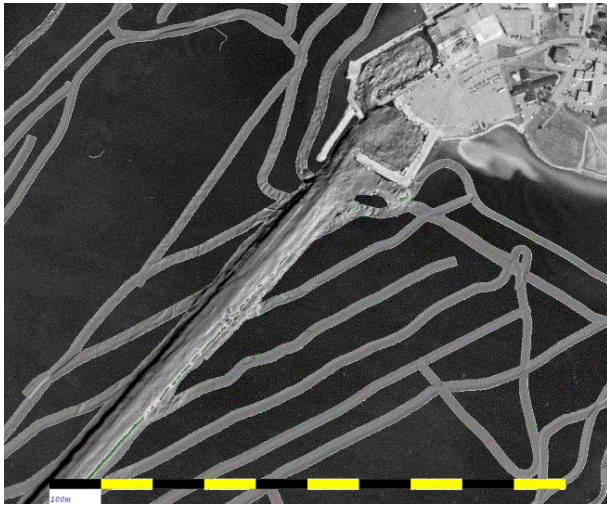


Figure 7. Synthetic sun illuminated image.

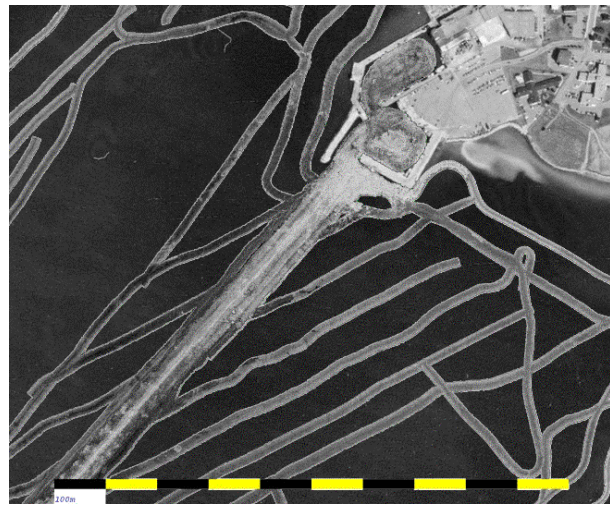


Figure 8. 300kHz Backscatter image.

Of more interest is the 300 kHz backscatter strength signal (Figure 8.) derived from the same multibeam data. One can see that the highest backscatter (lightest colour) exists just outside the mouth of the harbour and extends around to the east toward the effluent outfall. Most significantly the high backscatter anomaly does not extend into the outer or inner harbour suggesting that the source of this anomalous sediment is not from within the harbour itself.

Looking at the 200 kHz backscatter signal image (Figure. 9), which comes from the keel-mounted sidescans, we get a much better picture of the entire harbour approaches area. From this we can clearly see that the high backscatter anomaly (bright area) sweeps around the mouth of the harbour to the east and suggests a source right on the beach at the location of the outfall pipe.

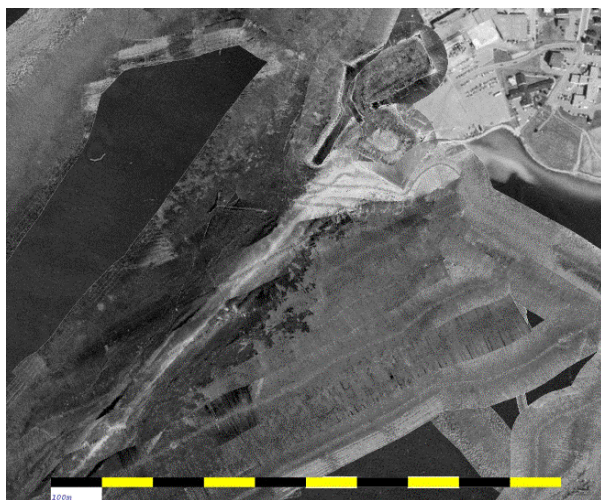


Figure 9. 200kHz sidescan image.



Figure 10. 200kHz with the high backscatter sediment plume highlighted.

More 200 kHz sidescan was collected when we collected the additional bathymetric data in the dredged channel and the inner harbour. This data set confirms that the high backscatter sediment is not extending into the harbour itself (and thus is not originating from in there). As the inner harbour is extensively dredged, it suggests that the dredging itself is not the cause of the high backscatter.

The next question is how far away from the beach does this high backscatter sediment plume extend? For that we have to look at the same data but now extending out into the main part of Lameque Bay.

#### ***Extent of the backscatter anomaly along the Lameque Harbour Channel***

In order to delineate the extent and the distal limits of the high backscatter sediment plume, we need to examine a larger area and begin to compare our simultaneously gathered acoustic data sets.

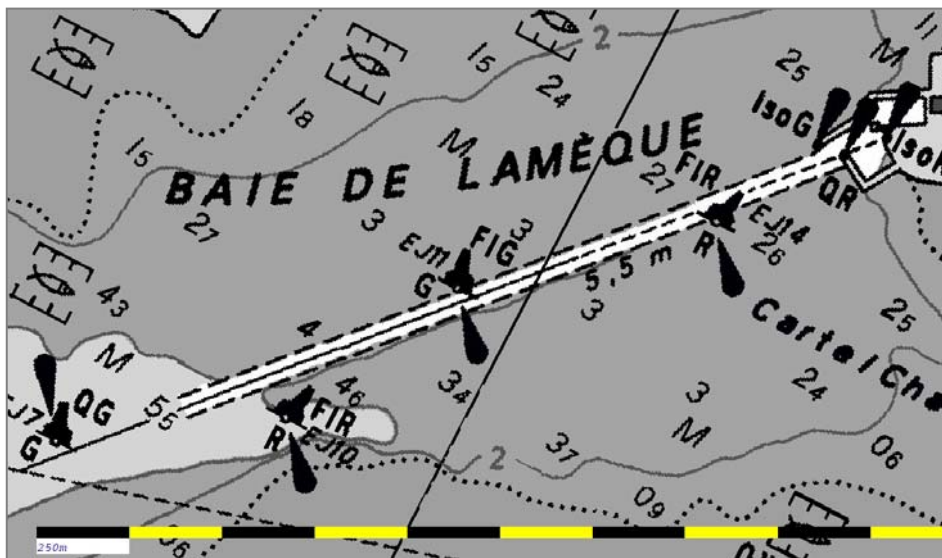


Figure 11. Lameque Bay Dredged Channel; Can we delineate the extent of the effluent plume in the surficial sediments?

Examination of the multibeam bathymetric coverage in the bay on its own provides little indication of the anomalous region. However, from the same dataset we can examine the distribution of 300 kHz backscatter strength in the area. We can then compare the backscatter signature with the depth distribution.

The 300 kHz backscatter clearly shows that the northeastern half of the channel floor is high backscatter (bright), changing gradually to a lower backscatter than the surrounding sediments of the bay as one moves to the southwest. Interestingly the high backscatter data is restricted to the central axis of the channel but includes a series of circular high backscatter anomalies on either side of the centre of the channel. If we look at the bathymetric model in more detail we see that the channel is deepest along its central axis, but that there are a series of small depressions on either side of the channel axis, which match the locations of the small circular high backscatter anomalies.



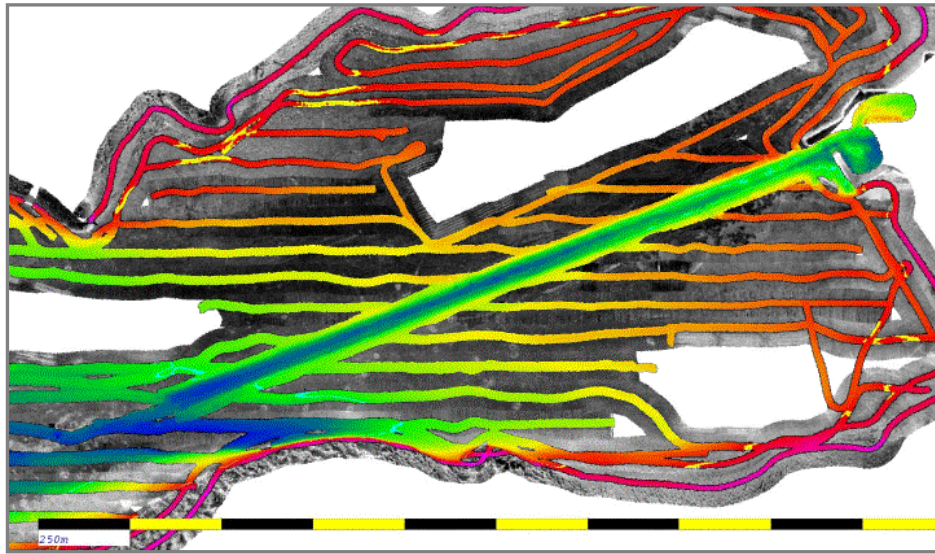


Figure 12. EM3000 Bathymetry overlaid onto the 200kHz sidescan image.

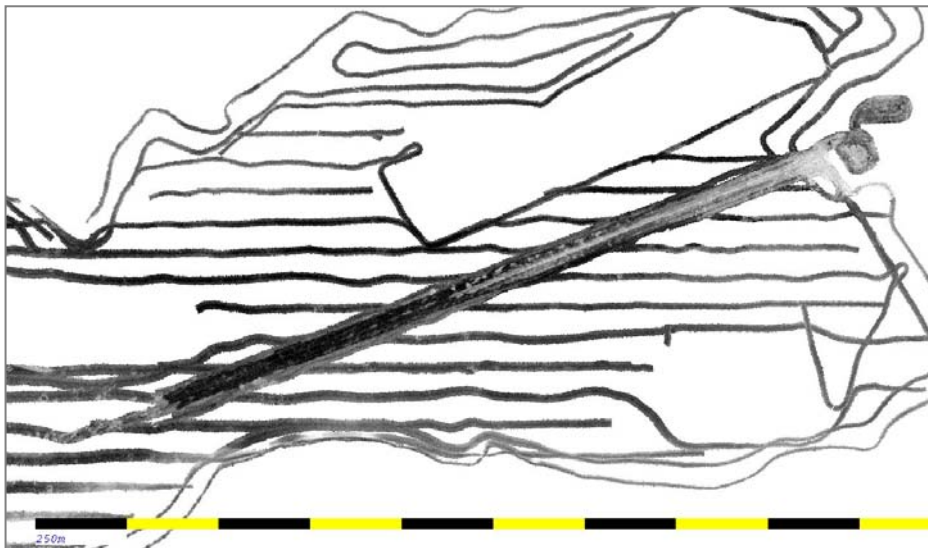


Figure 13. 300kHz backscatter imaging the extent of the high backscatter anomaly in the dredged channel .

Based on the available acoustic data, the assumption at this time is that whatever is causing the high backscatter anomaly (possibly excess organic material) is preferentially settling in the deepest points of the channel. The fact that the positive backscatter anomaly is strongest to the NE and fades away to the SW suggests that the source of this anomalous sediment is coming from close to the harbour mouth. As is shown in the close up set of images of Lameque Harbour proper, the most likely source is not the harbour floor, but the beach immediately to the east of the harbour which is the source of the effluent.

The multibeam-derived 300kHz backscatter is better than the 200kHz keel mounted sidescan staves at delineating the sediment distribution on the floor of the dredged channel as it casts less shadows than the lower-aspect-ratio sidescans. Nevertheless, the sidescan provides the only complete picture of the sediment distribution on the bay. One can recognise the individual deposits of the dredge spoil at the SW end of the dredged channel. The ultimate limit of the dredging is seen as an abrupt change in the bottom backscatter. The SW end of the dredged channel is clearly filled with a very uniform sheet of low backscatter sediment.

Combining the multibeam and the sidescan imaging, we have a very clear picture of the lateral extent of this anomalous high backscatter seabed signature. Although, we do not know what sediment is giving us this seabed signature, the simultaneous sub-bottom profiles obtained provide a further clue.

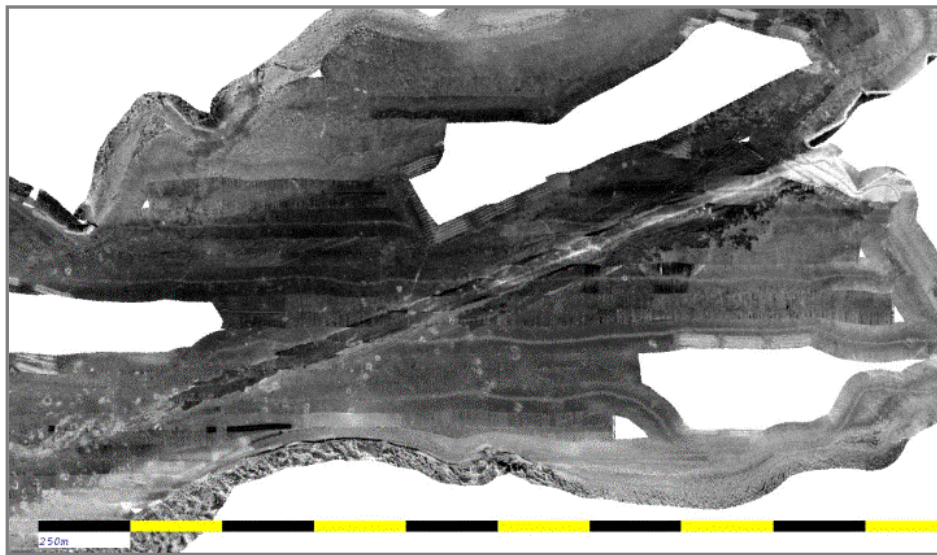


Figure 14. 200kHz sidescan.

#### ***The Plume Signature, as seen from subbottom profiling.***

The simultaneously gathered 3.5 kHz sub-bottom profiles across the Lameque Bay dredged channel show a high surface reflection coefficient anomaly (extra dark surface echo in Fig. 15) just on the dredged channel floor. This anomaly looks similar to the buried gas reflectors seen elsewhere in the bay, except it is at the surface and only occurs on the dredged channel floor. There are a number of possible causes, including:

- increased surface roughness (e.g. gravel rather than sand or mud)
- increased impedance contrast (e.g. harder, more consolidated)
- increased volume scattering (e.g.: gas bubbles within the otherwise soft smooth sediments)



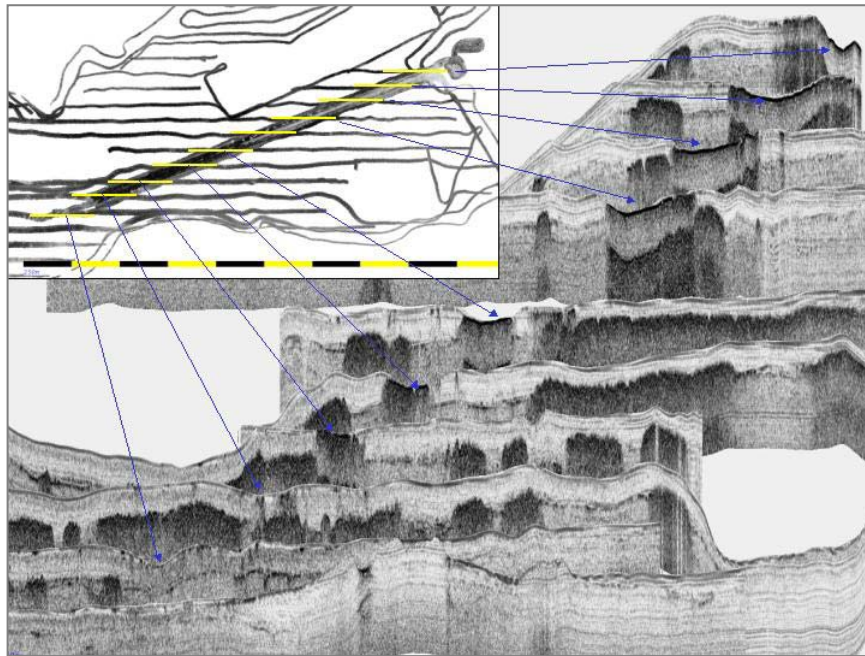
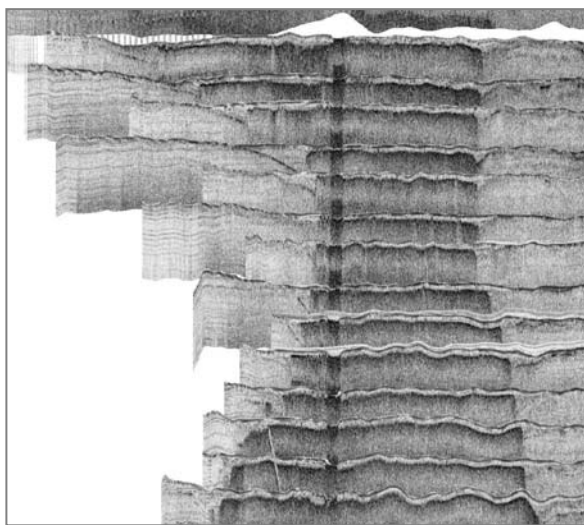


Figure 15. 3.5kHz profiles correlated to the simultaneously acquired 300kHz backscatter image.

From the regional 3.5 kHz sub-bottom profiles, we have already established that there is a buried gas-rich horizon underlying much of the bay. Strong but diffuse reflectors exist normally about 2-5m below the modern seabed. These reflectors are probably a result of buried peat horizons, which contain organic matter that decomposes releasing CO<sub>2</sub> and CH<sub>4</sub> into the sediments. If the sediments above are of low permeability, that gas is trapped within the sediment. Because the gas has a much lower impedance than the surrounding sediments (low density and sound speed) it shows up as a very strong acoustic reflector. One possible explanation for the high reflectivity of the dredged channel floors might be that it is this gas rich horizon that has been exposed by the dredging.



Figures 16. 3.5 kHz subbottom across Shippagan dredged channel.



Figure 17. 200 kHz sidescan across Shippagan dredged channel.

However, in the vicinity of the dredged channel NW of Shippagan Harbour (Pointe Brule), it is also clear from the sub-bottom profiling (Fig. 16) that the dredging has extended down into this gas rich horizon. When one looks at the sidescan image of the same dredged channel (Fig. 17), one can clearly see that the channel floor is distinctly low backscatter, as would be expected if it is actively being filled in by fine grained sediment deposited through current action.

By a comparison to the analogous situation in the Shippagan dredged channel, exposure of the gas rich horizon would not be expected to produce a positive backscatter anomaly as is seen in the Lameque Bay dredged channel. In fact, if we look at the sidescan image of the outer part of the Lameque channel (Fig. 17), it is also low backscatter.

Correlation of the 3.5 kHz transects across the dredged channel shows that there is a pronounced high surface reflection coefficient on the channel floor where the high backscatter anomaly is seen in the EM3000 300 kHz backscatter images. Based on the results from the Shippagan dredged channel, this high reflectivity is not expected to be the result of exposing the buried gas-rich horizon. We therefore interpret the anomaly as being due to the presence of an unidentified deposit derived from the fish plant effluent plume.

Based on a comparison to the acoustic signature of rotting excess organic material seen off other fish plants (as has also been seen off Blacks Harbour fish plant outfall site and Letang Estuary salmon farm waste deposits), it is assumed that there is a layer of organic material that is being slowly transported along the deepest axis of the dredged channel floor. This hypothesis needs to be tested by recovering sediment samples either from a grab or from divers.



### ***Regional Underway Acoustic Doppler Current Profile Measurements.***

Whilst the regional simultaneous multibeam, sidescan and subbottom survey was being conducted, a pole-mounted 600kHz acoustic doppler current profiler (ADCP) was deployed to measure instantaneous current profiles beneath the vessel wherever she went. The aim was to make measurements of the current field through the bay as a function of the M2 and K1 tides. It should be kept in mind that during the approximately 40 day survey window, the tides ranged from neaps to springs, from dominantly diurnal to dominant semi-diurnal.

The ADCP data acquisition could be carried out with no additional survey costs or time and allowed us to establish the typical direction and magnitude of currents in the Bay during the ebb and flood periods. Using this data we compiled all data obtained at common phases of the M2 tide period. The exact survey sequence and data density was dictated by weather and seafloor data acquisition, the primary survey being at 80m line spacing.



Figure 19. The pole mounted 600kHz Acoustic Doppler Current Profiler

In an initial attempt to randomise the observations as a function of phase of tide, we tried to survey every second line and return to do the intermediate lines approximately seven days later, when the phase of the tide would have shifted by around a 1/2 M2 tidal period. This novel sampling approach ended up being redundant as the time disruptions due to mechanical and weather delays ensured that the survey proceeded in a pseudo-random manner anyway.

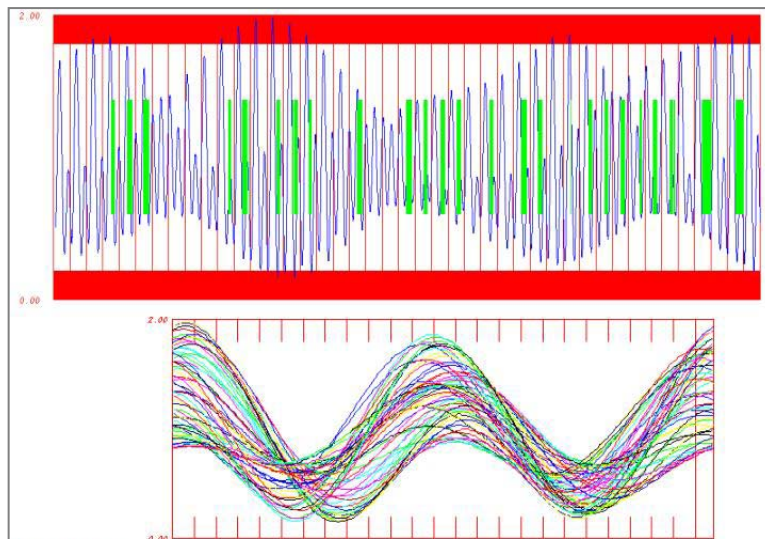


Figure 20. Top: The semi-diurnal tidal cycle over the 40 day period of the survey in Shippagan Bay. The green bars denote periods of ADCP acquisition. Bottom: The predicted tides over the survey period wrapped (2 x M2 tidal cycle).

The data was depth averaged and data in depths less than 3 metres was rejected. The data was binned by phase of the M2 tide. We then produced an animation which shows the depth average current vectors obtained, sorted by phase of the M2 tide (example still are reproduced below in Fig. 21).



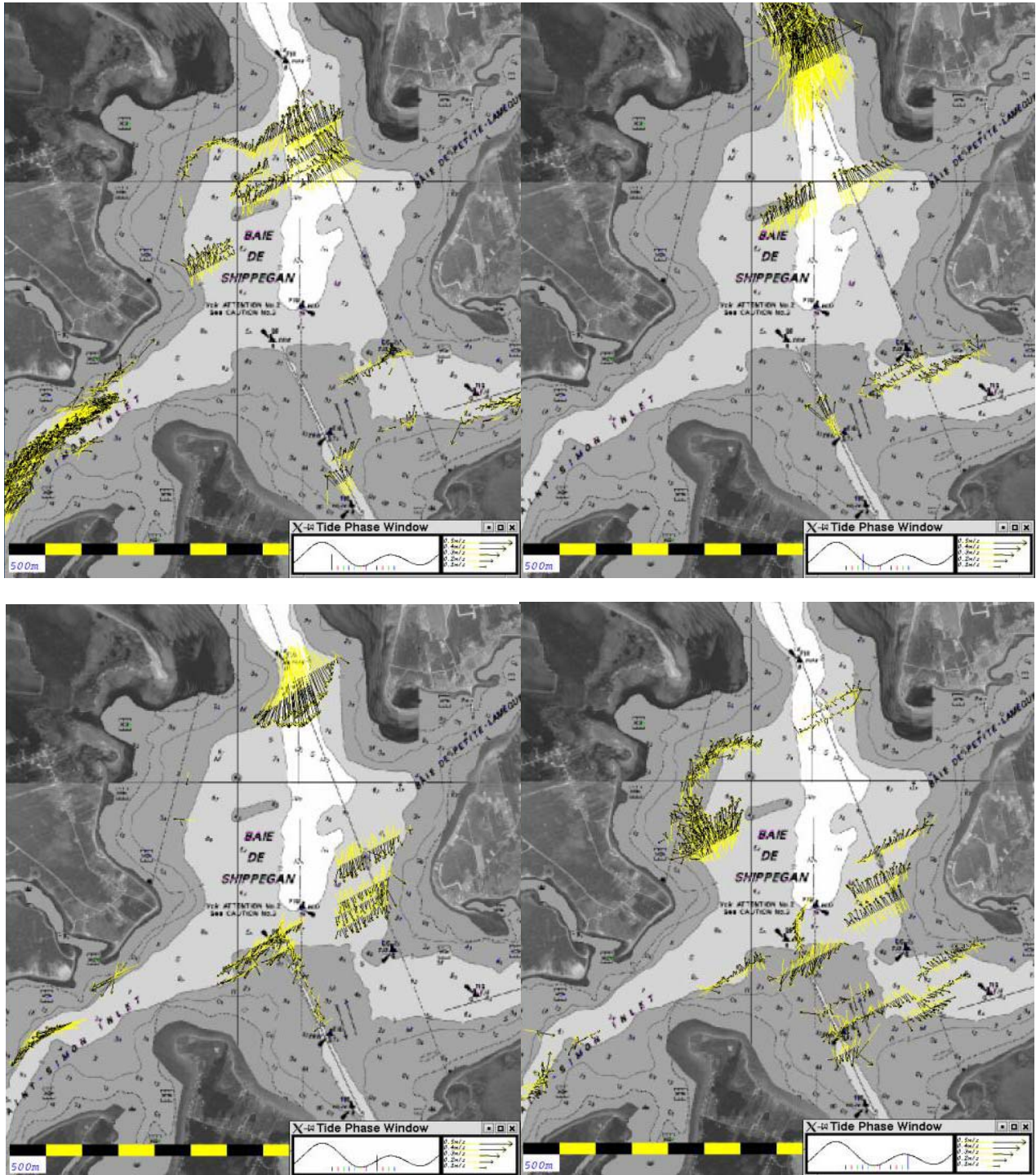


Figure 21. A selection of snapshots showing the current magnitude and direction for Shippagan Bay at various stages of the tide.

Based on the observed current patterns seen during the 30 day regular survey period, two critical transects were identified along which we would like to obtain denser observations throughout an M2 tidal cycle. These transects were selected to better understand the exchange of water between the main bay, the inflow from Shippagan Gully and the resulting effect on Lameque Bay wherein the effluent plume was located.



Unlike the layer-averaged plan view display (Fig 21) that effectively addresses the barotropic component of the circulation, these transects are vertical sections that can look at the baroclinic, estuarine circulation of the Bay.

Two such surveys were completed, one on the 9<sup>th</sup> and the other on the 11<sup>th</sup> of August 2003. The first combined ADCP and MVP oceanographic survey was a Shippagan Bay Axis Transect, running roughly north south up the deeper channel into the dredged channel of Shippagan Harbour. This was designed to compare the relative influence of the Bay of Chaleur inflow from the north with respect to the southern contribution of Gulf of St. Lawrence water leaking through Shippagan Gully.

The second combined ADCP and MVP survey was a Lameque Bay Transect, zigzagging out of Lameque Bay into Shippagan Bay. Based on the previous transect (which it intersects at 3 points), this directly addresses the relative contribution of the two inflows to the flushing of Lameque Bay, wherein the effluent plume lies.

***M2 tidal-cycle variations along Oceanographic Transects within the Shippagan and Lameque Bays (Semi-Diurnal ADCP - MVP) Surveys.***

The CSL Heron, as previously mentioned, has a Brooke Ocean Technology Moving Vessel Profiler (BOT, MVP-30) winch, sheave, and fish with an AML Smart Sensor installed onboard. We combined the operations of the ADCP and the MVP-30 over a 12.42 hour period in an attempt to cover the semi-diurnal portion of the tidal cycle. The BOT MVP-30 was deployed at 8 knots with the automatic brake set to 1 metre off the bottom. Cycling in 7 metres of water at around 30 seconds or approximately every 120 metres, in 15 metres of water the cycle time was around 60 seconds or approximately every 240 metres. Typically, within a single survey period of 12.42 hours, somewhere in the region of 700 to 1000 casts were made.

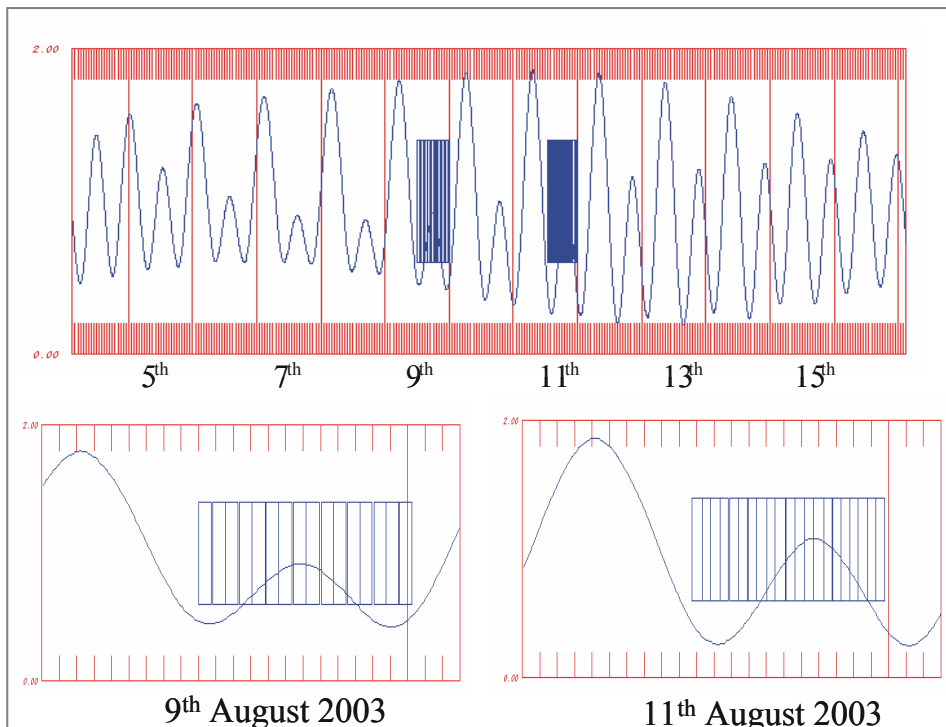


Figure 22. Two separate semi- diurnal oceanographic data sets were gathered on the 9<sup>th</sup> and 11<sup>th</sup> of August.

Broadly, for these two data sets salinity ranges from 27.75 up to 29.95 ppt. The temperatures ranged from a low of 11 up to a high of 17 degrees Celsius. The dominant tidal influx comes from the Bay of Chaleur in the north into Shippagan Bay. This influx is notable cooler, more saline and therefore denser. There is a lesser tidal signature coming through the Shippagan Gully to the south, however this is significant to the flushing/water interchange of Lameque Bay and the Mussel Aquaculture sites and the already mentioned outfall plume. The tidal current vectors are predominately north-south and are directed by Shippagan Bay channel and the dredged channel of Shippagan. However, the shallow waters surrounding the channel waters tend to disrupt the dominant trend direction with eddies and localized rotations of the current (see Fig. 21).

The following 4 figures illustrate the main points of the Shippagan Bay axis circulation. Each image is based on a single transect (of 21 in total). To the right, a plan view of the depth average current field is presented as vectors. To the left, 4 data sets are presented projected onto a common cross-section, from the top:

1. 600 kHz Volume scattering – an indicator of the density of mid water scatterers, often a good indicator of discrete water mass boundaries. Acquired at ~ 1Hz (4m horizontal resolution, 50cm vertical resolution)
2. Vertical Current field. Colour indicates direction and intensity of colour (brightness) indicates magnitude (flood is generally green, red is ebb, yellow and blue are across bay flows). Same resolution as above.
3. Temperature field derived by interpolating between MVP dips. Vertical resolution ~ 10cm, but horizontal resolution of several 100 metres)
4. Salinity field derived in the same way. Note noisy data is generally a result of eelgrass fouling of the conductivity cell and does not represent real variability.

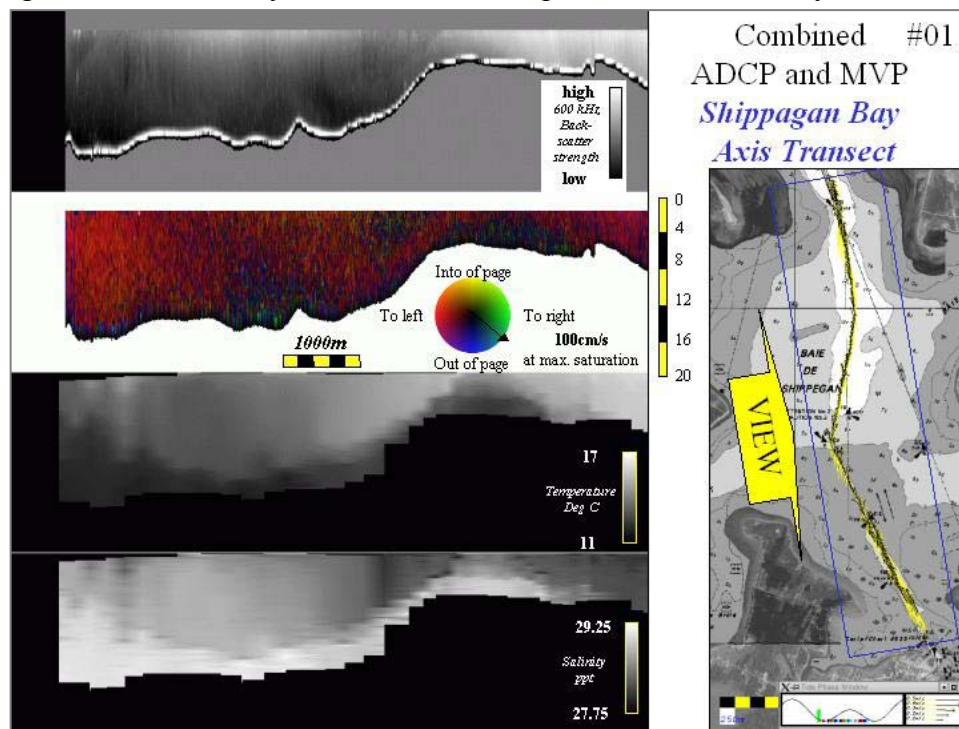


Figure 23. Late on the ebb, almost all flow is directed north out of the bay. There is a residual layer of Bay of Chaleur cold saline water only at the base of the estuary, the upper warmer, fresher water (derived from the Gulf of St. Lawrence through Shippagan Gully and heated within Lameque and St. Simon Bays) now fills the upper section of the bay.

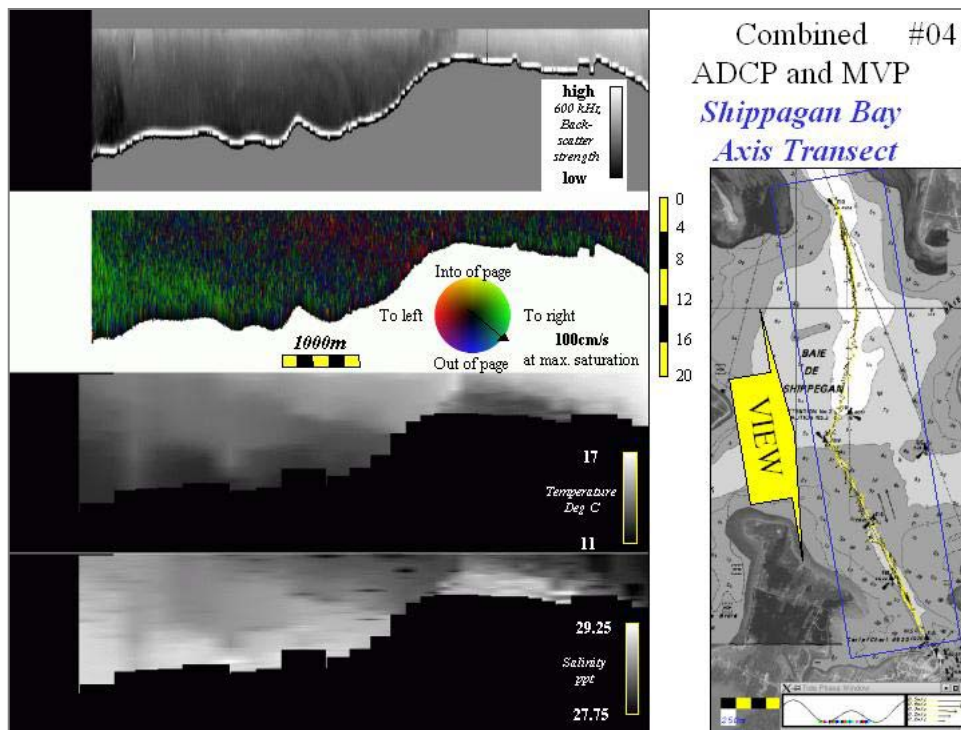


Figure 24. Early on the flood. Most of the bay is stagnant, but the first flood intrusion is initially restricted to the lower layer of southward flowing cooler more saline water entering from the Bay of Chaleur.

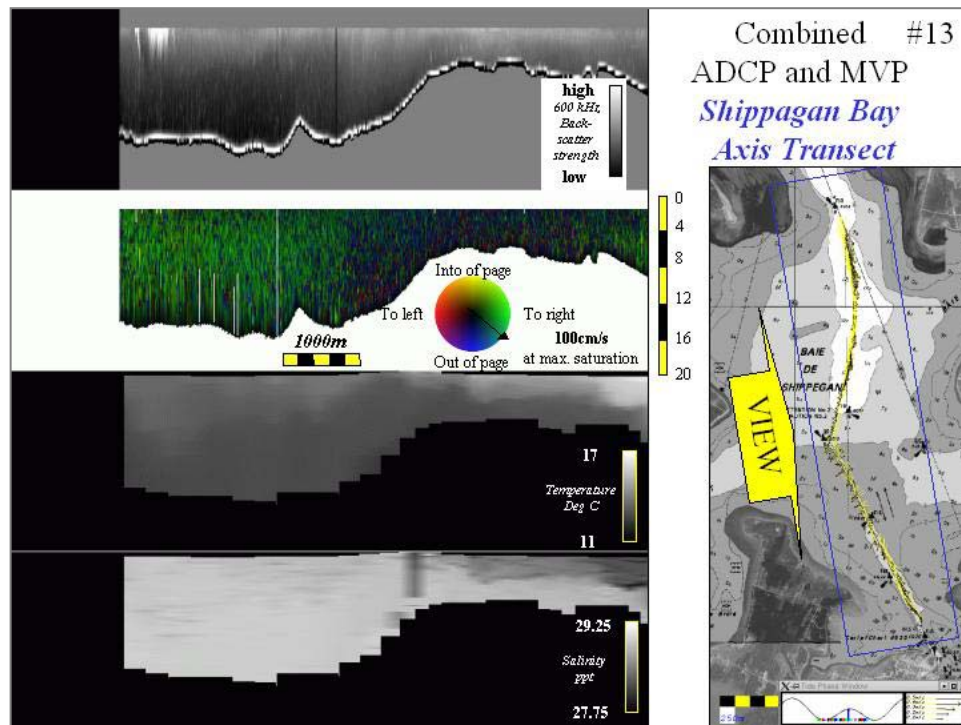


Figure 25. Near high water, the flood now encompasses the full thickness of the bay, the cooler saline waters from the Bay of Chaleur have pushed the Gulf of Saint Lawrence water off laterally (into Lameque Bay).

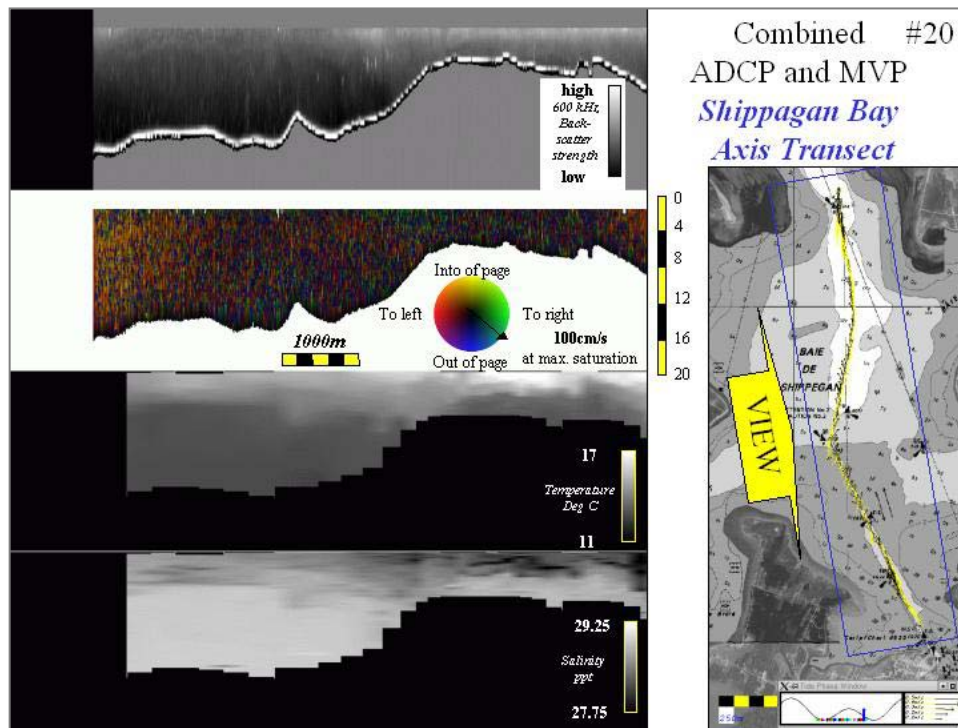


Figure 26. On the ebb tide, one sees new inflow from Shippagan Gully bringing in the warmer fresher water again from the Gulf of St. Lawrence.

The second dedicated oceanographic transit was designed to examine the flushing of Lameque Bay. Based on the first section, it was deemed critical to understand the fate of the inflowing warmer fresher water from the Gulf of Saint Lawrence that comes in through Shippagan Gully. The following set of images (27,28,29) show the principal results of the survey over an M2 tidal cycle.



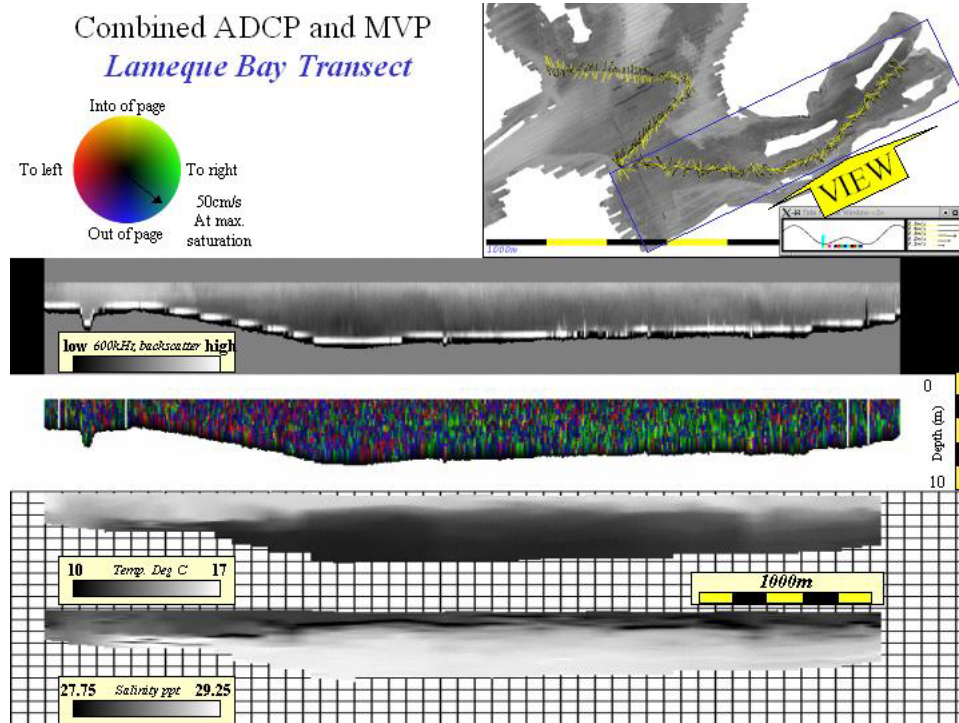


Figure 27. Just before slack water, interestingly, despite the fact that the Gulf of St. Lawrence water has now being flowing in through Shippagan Harbor for several hours, Lamèque Bay is predominantly full of the colder Bay of Chaleur water that had been advected in here during the earlier flood.

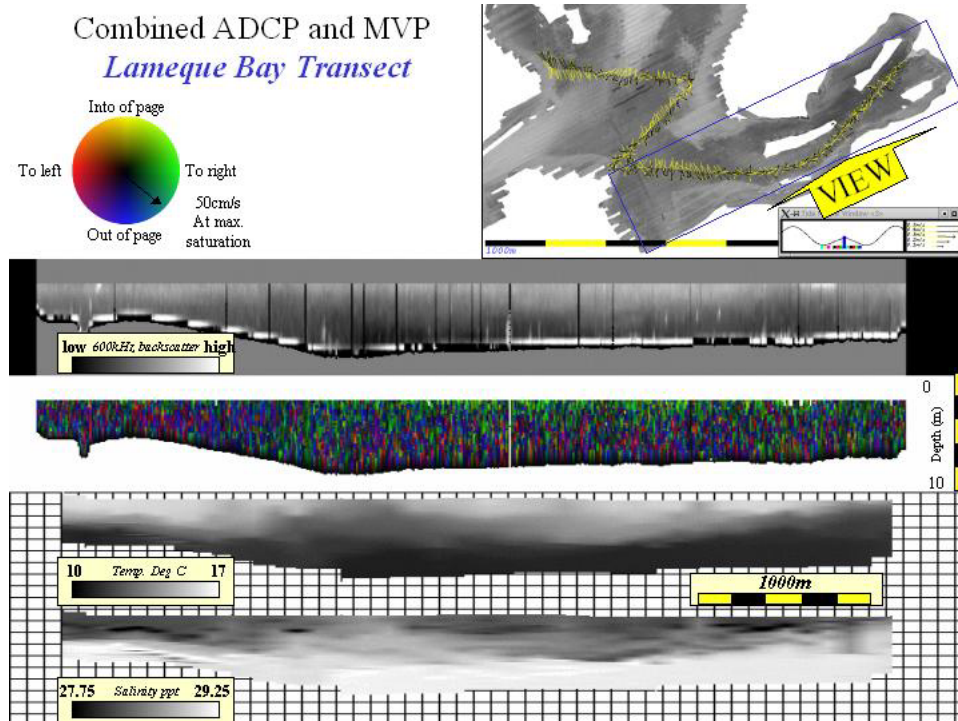


Figure 28 During the flood, the Gulf of Saint Lawrence water, that had previous bypassed Lamèque Bay into the main Shippagan Bay, is now advected back into the bay producing a thicker warmer/fresher surface layer.

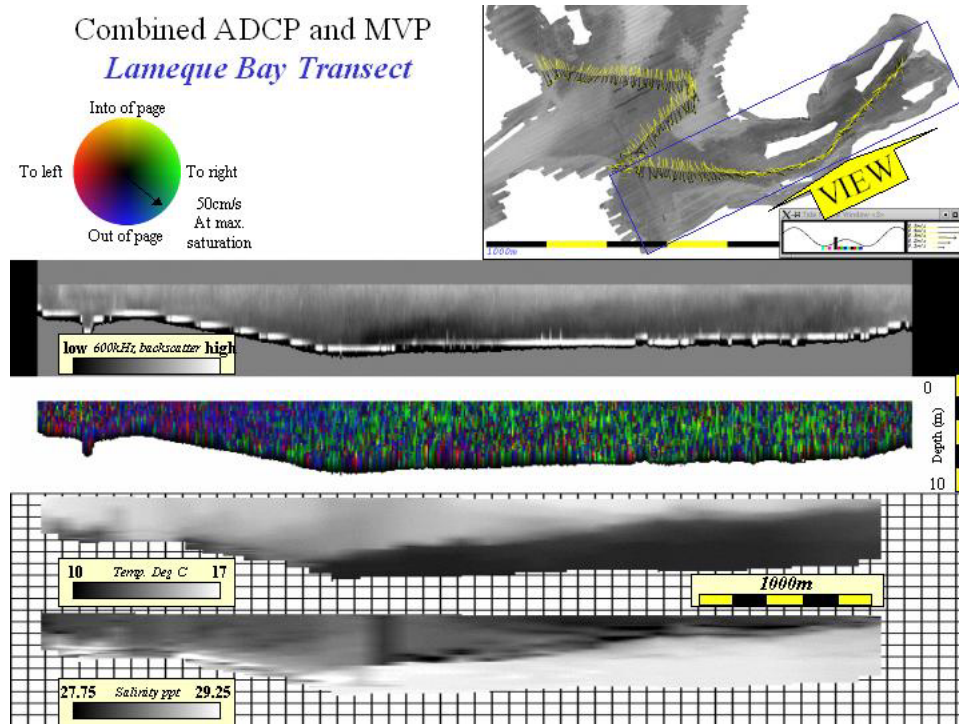


Figure 29. At the top of the tide, the first reappearance of Bay of Chaleur water into Lameque Bay, as noted in Fig 27, this inflow will continue during the ebb, whilst new Gulf of St. Lawrence inflow bypasses Lameque Bay.



For this project, the research interests of the Ocean-Mapping Group – development of improved software methods for processing and visualization of ocean mapping data, and the research interests of the Gulf Fisheries Centre – acquisition of supporting acoustic and oceanographic data to better define surficial habitat were complimentary. The Shippagan Bay survey was a first test of the effectiveness of collecting simultaneous hydrographic, geophysical and oceanographic datasets. Such simultaneous collection will, by necessity, always be a compromise.

Ideally hydrographic surveys are optimized to identify the significant bathymetric anomalies and to quantify minimum depths. For this survey, shoal exams were not performed, even though potential off-track (beyond bathymetric swath) targets were occasionally identified in the sidescan imagery. Interlines were run in marginal weather windows, but based on depth (deeper areas generally rather than suspected shoals). Despite simultaneous operations of a wide range of other instruments, the survey speed (~7-8 knots) was not prohibitively slow.

Geophysical surveys are normally laid out based on suspected grain of the underlying sub-surface structure. As little was known about the likely sediment patterns in the Bay, the parallel line running was realistic. By combining the sub-bottom profiling with the bathymetric surveys, an unusually dense set of lines was run. Because of the rigid parallel line geometry, particularly effective use of fence diagram display methods was achieved. High-cost towed, broad bandwidth subbottom profiling instruments would have provided superior resolution, but at the expense of data density.

As a first step towards habitat delineation a measure of the spatial variability in surficial sediment backscatter is required. For this survey, the requirement for 100% sidescan coverage controlled the effective line spacing. In these extreme shallow water depths, the keel-mounted geometry provides significant advantages over towed geometry, being ahead of the propeller wash and unlikely to snag. The principal disadvantage of this method is that, because the sidescan staves are rigidly coupled to the hull, vessel roll and yaw cause distortion in the imagery.

Current field studies are always a compromise between spatial and temporal sampling density. Bottom mounted ADCP gives the best temporal resolution but sacrifice spatial resolution. Hull mounted systems provide improved spatial resolution at the expense of temporal. To get adequate temporal AND spatial resolution normally requires a prohibitive amount of ship-time. It would have been logistically too expensive to commit a vessel for 30 days just to achieve the desired spatial and temporal resolution. However by acquiring the data on top of an otherwise conventional hydrographic survey, significant cost savings can be achieved.

Based on the current field data collected pseudo-randomly, those critical sections that required denser observations were selected. Dedicated repetitive transects, as were performed at the end of the program, provide the best picture of the oceanography over critical sections. The pseudo random data could be used to allow qualitative extrapolation of the results of the denser repetitive transects over the whole bay.

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At this time the data collection and processing are now complete and a bathymetric model has been constructed. Maps of spatial variability in surficial backscatter exist but require interpretation. A number of critical steps remain, including:

- Comparison of the new bathymetric data with the older (1970's) surveys to see if significant change can be detected.
- Delineation of surficial habitat based on classification of backscatter and bottom roughness.
- Groundtruthing of suspected seabed classes.
- Isopach construction of critical subsurface units.
- Sampling of suspected discharge plumes.

The current-field observations provide control for development of a 3D finite-element baroclinic hydrodynamic model of the bay. Such a model is currently being constructed at UNB and will be tested against the observations.

Lastly, should future funding be available there is the opportunity to do repeat surveys of sections the seabed that are likely to change. Potential targets include:

- The sand wave field developed in the main Shippagan Bay channel.
- The aquaculture site to look at the time scale for decay of historic seabed signatures of the aquaculture.
- The variability and fate of the suspected organic sediment plume in Lameque Bay.



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The successful operation of the survey was critical dependent on the professionalism of the skippers, Theo Gionet, Serge LeMay and Alcide DeGrace of the Canadian Coastguard.