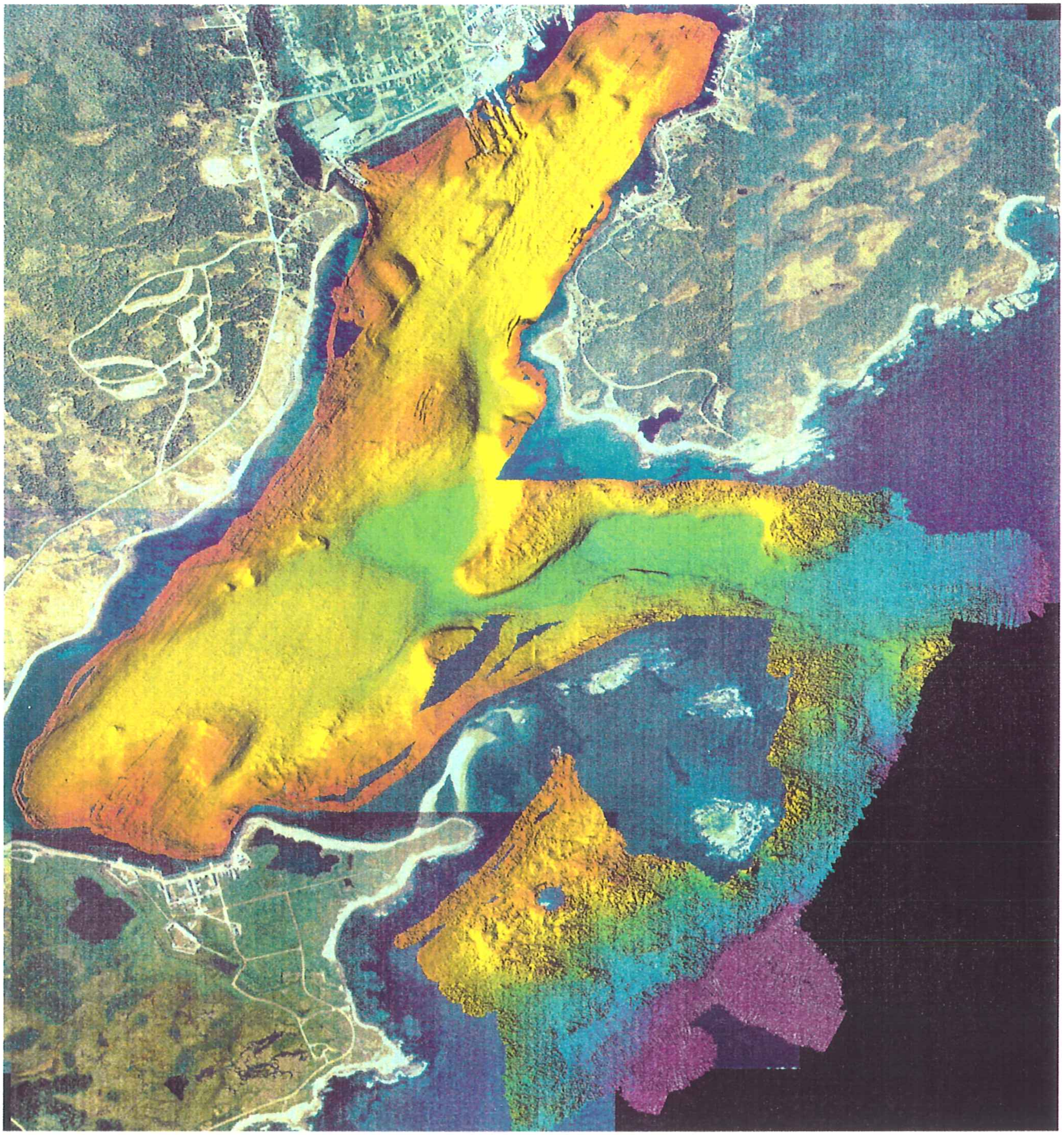
GSC Open File 3504

CRUISE REPORT C.S.L. PETREL 96-001

Louisbourg Harbour and Approaches, Nova Scotia

October 4 to 10, 1996



Natural Resources Canada

Ressources Naturelles Canada

CRUISE REPORT

C.S.L. PETREL 96-001

LOUISBOURG HARBOUR AND APPROACHES, NOVA SCOTIA

OCTOBER 4-10, 1996

R. Taylor[1], R. Currie[1], H. Josenhans[1], B. MacGowan[2], A. Crépeau[3], and R. Covill[4]

[1] Geological Survey of Canada (Atlantic)
P.O. Box 1006,
Dartmouth, Nova Scotia
B2Y 4A2

[2] Canadian Hydrographic Service
P.O. Box 1006,
Dartmouth, Nova Scotia
B2Y 4A2

[3] Parks Canada,
Fortress of Louisbourg National Historic Site
P.O. Box 160
Louisbourg, Nova Scotia
B0A 1M0

[4] TekMap Consulting
P.O. Box 2016
Fall River, Nova Scotia
B2T 1K6

March 1997

CONTENTS

GENERAL INFORMATION

Cruise:	C.S.L. Petrel 96-001
Dates:	October 4 to 10, 1996
Area of Operation:	Louisbourg Harbour and Approaches, Nova Scotia
Agencies:	**Geological Survey of Canada (Atlantic)** and **Canadian Hydrographic Service** Bedford Institute of Oceanography P.O Box 1006 Dartmouth, Nova Scotia B2Y 4A2 **Heritage Canada** Fortress of Louisbourg National Historic Site, P.O. Box 160 Louisbourg, Nova Scotia B0A 1M0
Coxswain:	Carmen Read
Scientists:	Bob Taylor (GSCA) Heiner Josenhans (GSCA)
Hydrographers	Bruce MacGowan (CHS) John Cunningham (CHS)
Technical Staff:	Randy Currie (GSCA) Jim Wilson (DFO) George MacHattie (DFO) Mike Ruxton (CHS)
Park Warden:	Doug Pearl (HC)
Senior Archaeologist:	Andrée Crépeau (HC)
Post Cruise Data processing:	Bob Covill (TekMap Consulting)

INTRODUCTION

A study was begun in 1995 to investigate the coastal stability and geological evolution of the shoreline along the Fortress of Louisbourg National Historic Site (Brown, 1996, Taylor and Brown, in prep). Rising sea level and continued landward migration and erosion of the shoreline threaten archaeological resources lying close to the coast, as well as the Fortress (PWC, 1985; Taylor, 1992). There is a need for a comprehensive management plan for the protection of these historic resources at Louisbourg. Documentation of the physical characteristics of the marine and coastal environment provide one of the basic building blocks in developing such a plan because they provide critical information on how the coastline has evolved and will likely change in the future.

The study has three phases. The first two are geological, including shoreline and marine surveys, and the third involves engineering and dynamic modelling components, including the modelling of marine processes and the development of a shore protection plan that works in harmony with nature. Results from the first two phases will be used in the documentation of the coastal evolution. The detailed mapping of the shoreline has been completed, the rates of historical shoreline changes are presently being compiled (Taylor and Brown , in prep), and a series of benchmarks have been established along the coastline for monitoring future shoreline changes (Brown, 1996, Taylor and Brown, 1996).

The cruise of the CSL *Petrel* marks the beginning of the marine phase of the study which is to document the detailed bathymetry of Louisbourg Harbour and its approaches. The bathymetric surveys were extended farther seaward and alongshore into Gabarus Bay using the F.G.*Creed* in November 1996. A digital image of the seafloor is being compiled using the information collected from both surveys. The bathymetric surveys complement the 1991 sidescan sonar survey completed within and at the entrance to Louisbourg Harbour by the Federal Archaeology Office, Ottawa (Bennett, 1991, Stevens, 1994, Shearer, 1996). The surveys also provide the framework for planning future geological seismic surveys and sediment coring. Detailed bathymetry is also a critical input for the modelling of wave dynamics in the third phase of the study. Ground truthing for the seafloor images was acquired using the *Pisces* , a National Defence submersible, deployed from H.M.C.S. *Cormorant* in November 1996 as well as from a diving program planned for the summer of 1997 by Willis Stevens, an underwater Archaeologist with the Federal Archaeology Office, Ottawa.

This report describes the bathymetric surveys in Louisbourg Harbour and its approach using the Canadian Survey Launch CSL *Petrel ,* October 6-10, 1996. The investigation was a cooperative effort with Parks Canada and the Canadian Hydrographic Service.

OBJECTIVES

1. To gain experience with, and further test the digital Simrad EM3000 sonar system, one of a new generation of high resolution multibeam sounders operated by the Canadian Hydrographic Service.

2. To produce a high resolution, digital bathymetric mosaic of the seafloor of Louisbourg Harbour and its approaches.

3. To identify geological targets for future marine seismic and coring surveys required for documenting the glacial history and coastal evolution of the Louisbourg area.

4. To map the distribution of seafloor sediment types and bedforms to provide an indirect measure of seafloor sediment dynamics and transport paths.

5. To document known marine archaeological resources in the harbour, e.g. 18th century ship wrecks *Célèbre* and *Prudent.* ; to resurvey unidentified targets, which were selected from the previous side scan survey as potential artifacts by archaeologists; and to search for new artifacts, such as the 18th century ships sunk in the entrance channel ("channel wrecks") that may have been uncovered by marine processes or other ships that might exist farther alongshore or offshore from the Fortress, in areas that have not been previously surveyed.

OPERATIONAL SUMMARY

In less than four days of actual survey time a spectacular, high resolution, digital image of the seafloor of Louisbourg Harbour and its approaches was completed (Figs.1-4). The seafloor of Louisbourg Harbour was surveyed with a digital Simrad EM3000 sonar system, one of a new generation of high resolution multibeam sounders operated by the Canadian Hydrographic Service. This instrument measures the water depth below and to the sides of the survey vessel, collecting a swath or strip of information about the seafloor as the vessel traverses the harbour. The vessel utilizes precise satellite navigation and position and vessel motion sensors to derive highly accurate measurements of water depths. Each night the soundings were processed on a computer workstation and viewed on the screen, but final processing and hard copy images could not be completed until returning to BIO. The sonar data files were processed using the public domain software GRASS and GRASS extensions developed by GSC (Atlantic) to grid the data. The raw field data was put through an automatic filtering process in CARIS HIPS (Hydrographic Information Processing System); and predicted tides were incorporated. Roughly 108 million data points were collected requiring in excess of 4 GB of disk storage. Final processing, which initially took 5 days, was completed by R. Covill (TekMap Consulting). The raw sonar data files were used and put through the same processing procedure as in the field plus the survey lines with bad navigation were eliminated. The large size of the data file necessitated breaking it into two parts- the inner harbour, and the outer harbour and approaches. After reviewing the seafloor images, a couple more days of refinements and corrections were required. The two data sets were later merged and an air photo mosaic of the surrounding terrain was added to complete the final images shown in Figures 1 to 4. The total size of the final binary files was ~30 MB.

This cruise was the first experience for staff from the Geological Survey of Canada in working with the EM3000 sonar system. Also, the hydrographers and technical staff had not completed much field time operating the system, so gaining experience with the system was the reason for the large number of personnel involved. Extra time was required to prepare the vessel for surveying. It had been a last minute decision to intercept the C.S.S. *Hudson* on route back to Halifax from the Arctic, remove the *Petrel* , and deploy it in Louisbourg. Originally the *Petrel* would have returned to Halifax for maintenance before being deployed again. Considerable effort was made by the coxswain and hydrographers to clean the vessel and prepare it for surveying.

Normally the staff required for a launch survey of this type would include a coxswain, a hydrographer and possibly one other. However, during this survey there were commonly 2 to 3 extra persons observing the operation, so space was at a premium. Nevertheless, it was the combined technical experience of the technical crew and several calls to Simrad, that overcame many of the early problems with the system and kept it functioning. The single most important problem was the locking or stoppage of the Simrad system during surveying. The problem was partially overcome by only displaying a minimum of windows on the Sun Sparc 20 workstation.

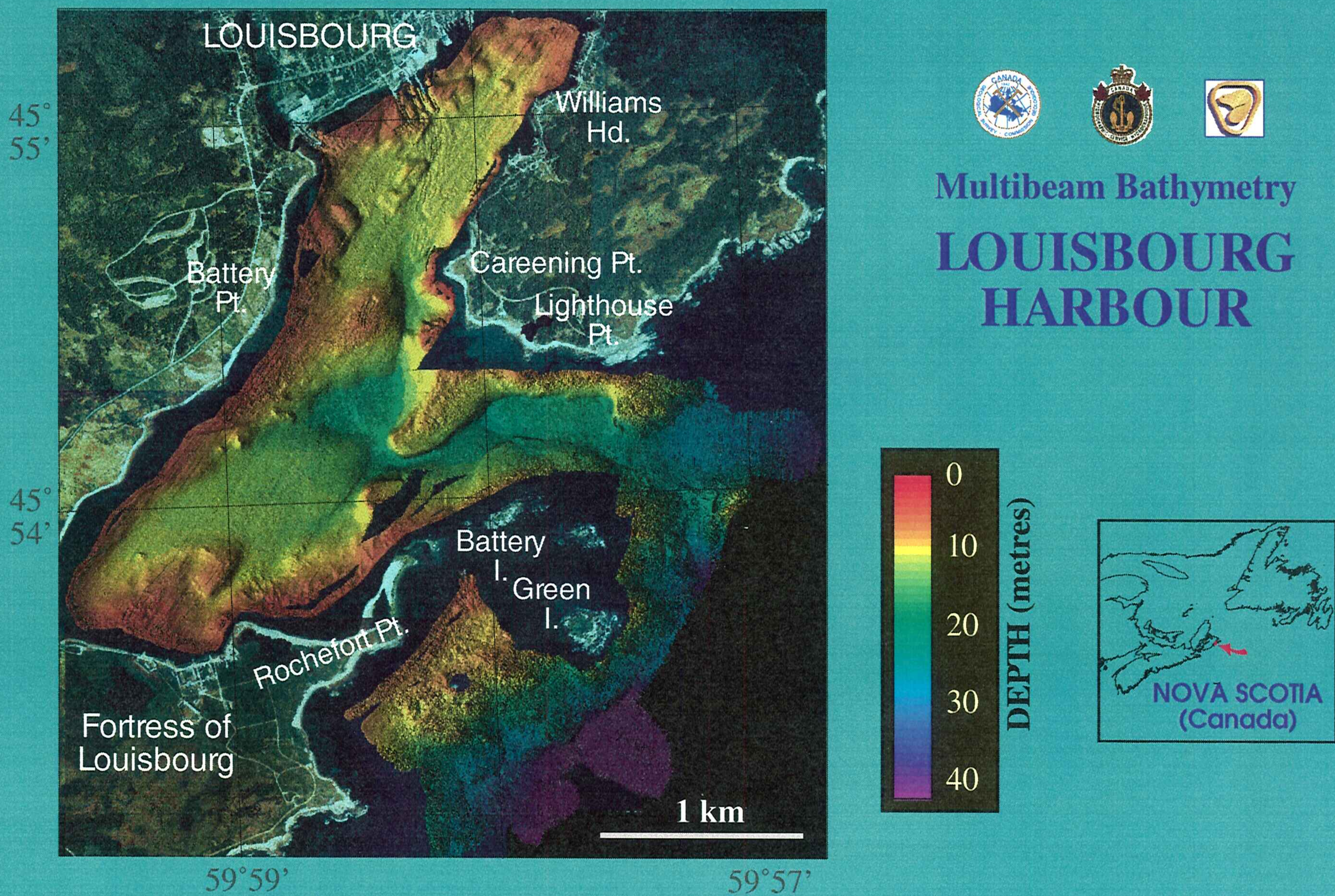
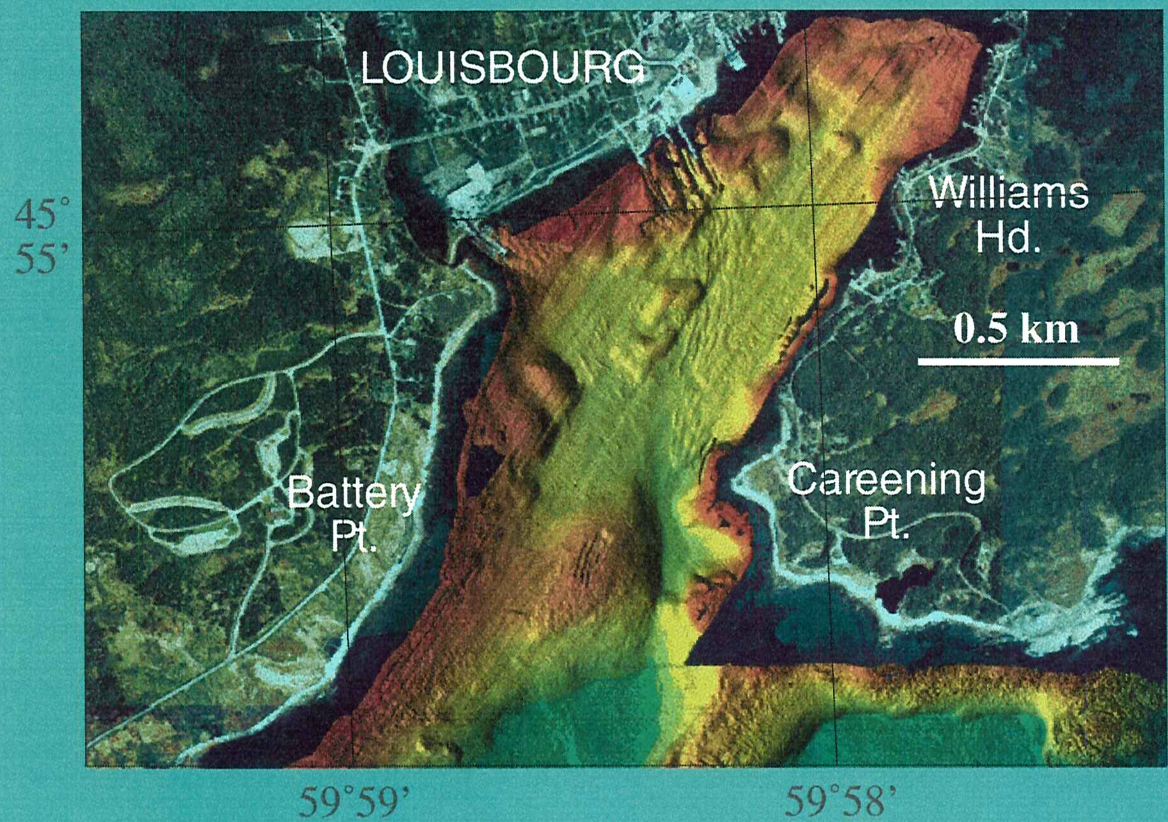


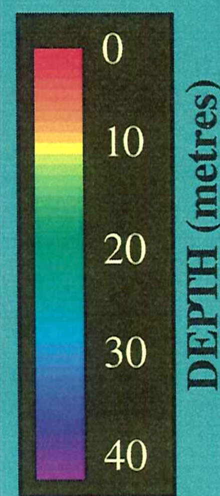
Figure 1. Composite of EM3000 multibeam sonar data and digitally rectified vertical air photos of Louisbourg Harbour and approaches, Nova Scotia. Information was collected during the C.S.L. Petrel cruise October 4-10, 1996.

n153601

Multibeam Bathymetry

LOUISBOURG HARBOUR





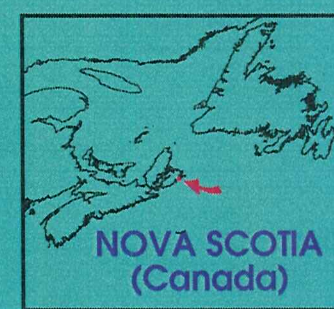


Figure 2. View of Northeast Arm, Louisbourg Harbour showing the detailed seabed morphology obtained from EM3000 sonar surveys, October 1996. Note the furrows on the large shoal near the bottom of the figure, probably the result of dredging, and the streaked pattern extending seaward along the seabed from the main wharf area. These marks may be the result of anchors dragging the bottom, as vessels approach and leave the Louisbourg wharves or the grounding of heavily laded ships as they leave port.

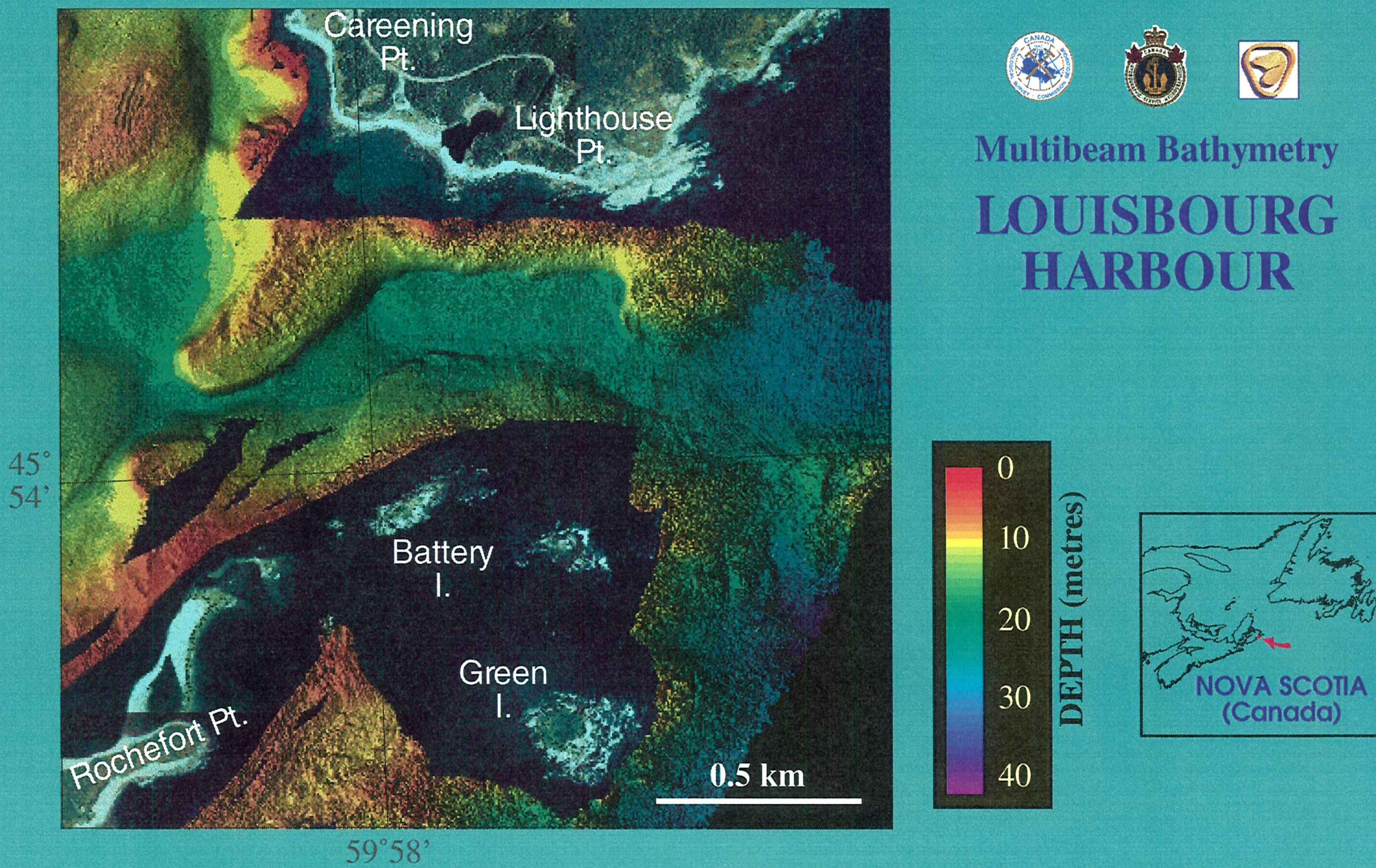


Figure 3. View of the entrance to Louisbourg Harbour showing the morphology of the channel and ridges at the inner entrance to the harbour. The outer entrance to the harbour is flanked by exposed bedrock. The EM3000 multibeam sonar data used to compile the image were collected in October, 1996.

Multibeam Bathymetry

LOUISBOURG HARBOUR

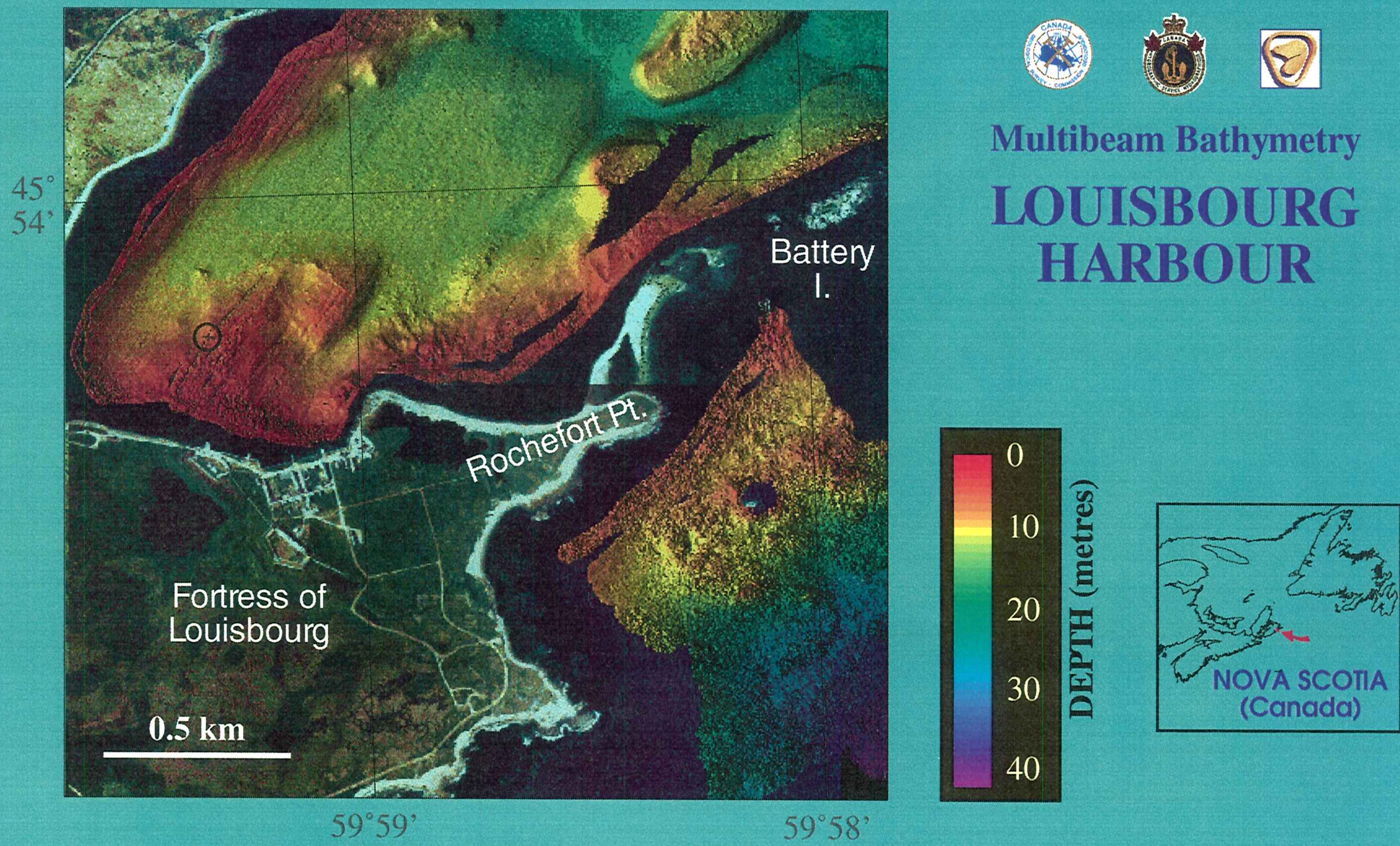


Figure 4. View of the Southwest Arm , Louisbourg Harbour, showing the seabed morphology of the area near the fortress, the 18th century ship wreck Célèbre (circled) and the inner basin at the entrance to the harbour. Information was obtained from EM3000 surveys in October, 1996.

rt153603

However, it restricted real time viewing of the sonar beam information, data quality and track coverage. This was one reason for the unfortunate gap in the sounding coverage at the inner part of the harbour entrance.The occurrence of a severe storm associated with hurricane Josephine on day 283 also limited the area of coverage completed in the harbour approaches and made surveying on day 283 and 284 unpleasant.

SCIENTIFIC SUMMARY

The multibeam sonar images reveal important clues about the Quaternary history and coastal evolution of Louisbourg Harbour and offer potential targets to examine in more detail. The physical character of the channel extending from the inner harbour to offshore is very well defined. The present depth at the outer entrance is 20 m (Fig. 3). The depth of the post-glacial sill is unknown. It is thought to lay beneath an undetermined thickness of Holocene sediment. The channel cuts through a large submarine ridge that extends across the inner entrance to the harbour. Two submerged features that will require more detailed investigation are an unconsolidated deposit, resembling a coastal spit, which is draped around the ridge extending from the east side of the harbour entrance (Fig. 1, 2). The 'spit' appears to have built around a bedrock core (Fig.5a, profile A-B runs west to east). The surface of the 'spit', at roughly 10 m water depth, was formed when sea level was lower than today. On the basis of the sea level curve developed for the Eastern Shore of Nova Scotia (Shaw et al. 1993) the spit may date about 4 to 6 ky BP. Its distal end is marked by a steep slope that extends to 20 m water depth (Fig 5a). In the south to north direction the eastern ridge has an assymetrical shape, with the steeper slope on the inner harbour side (Fig.5b, profile c-d). The submerged ridge on the western side of the harbour entrance does not resemble a spit at present, but it is marked by a higher rim at 6 m water depth which may be a relic glacial deposit overlying bedrock (Fig. 2,3). It is possible that the glacial deposits extended across the harbour entrance and the submerged spit along the eastern side is only the surface expression of a thicker glacial deposit that lies beneath.

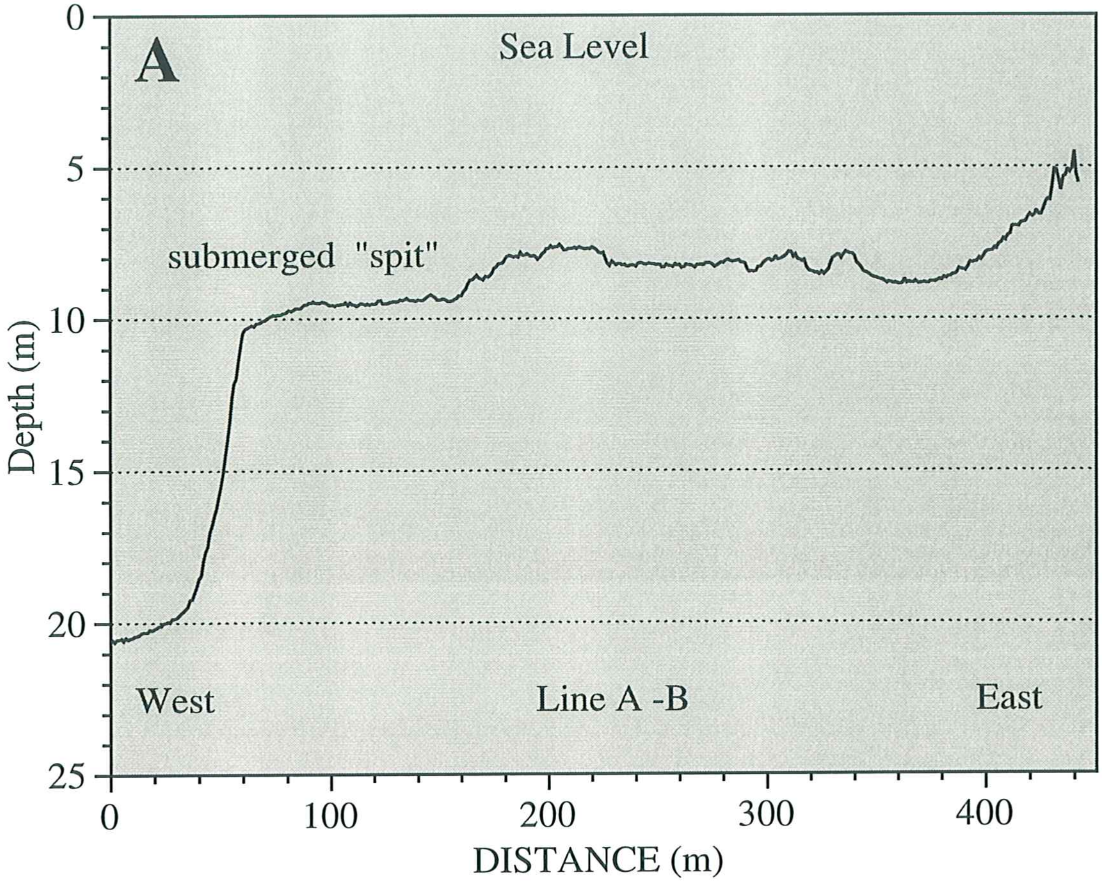
A small basin lies just inside the harbour at a depth of just over 20 m. It contains an undetermined amount of Holocene sediment (Fig. 3). Future seismic surveys will confirm how much sediment has accumulated and whether it can be cored to recover samples that can assist with dating when the entrance sill was overtopped by seawater.

Along the outer coast, close to the fortress and Rochefort Point, the sonar image reveals a predominance of bedrock (Fig. 3). The absence of mobile sediment just offshore confirms that the only sediment supply for beach building near the fortress is the present shoreline.

Within the inner harbour, the sonar image reveals a number of submerged 'hills'. The largest one near the centre of the harbour has four large grooves cut across its crest (Fig. 4). The marks suggest one or more attempts at dredging this shoal, but with little success, possibly because of the cohesive nature of the material. The 'hill' resembles the shape of a drumlin and future seismic surveys should be extended across this and other shoals to determine their internal structure. A second linear 'hill' exists at the northwest corner of the harbour closer to the fortress (Fig. 3). The depth of the 'hills' is comparable to the depth of the submarine ridge at the inner harbour entrance.

A number of smaller mounds are found within the inner harbour close to the town of Louisbourg (Fig. 4). They have a variety of shapes and their origin is unknown. They may be natural, or the result of human activities in the harbour, e.g. ballast piles.

Sidescan sonar records collected from the area in 1991 show well defined gravel ripples and other bedforms in the entrance to the harbour (Bennett, 1991, Shearer, 1996). One objective of the



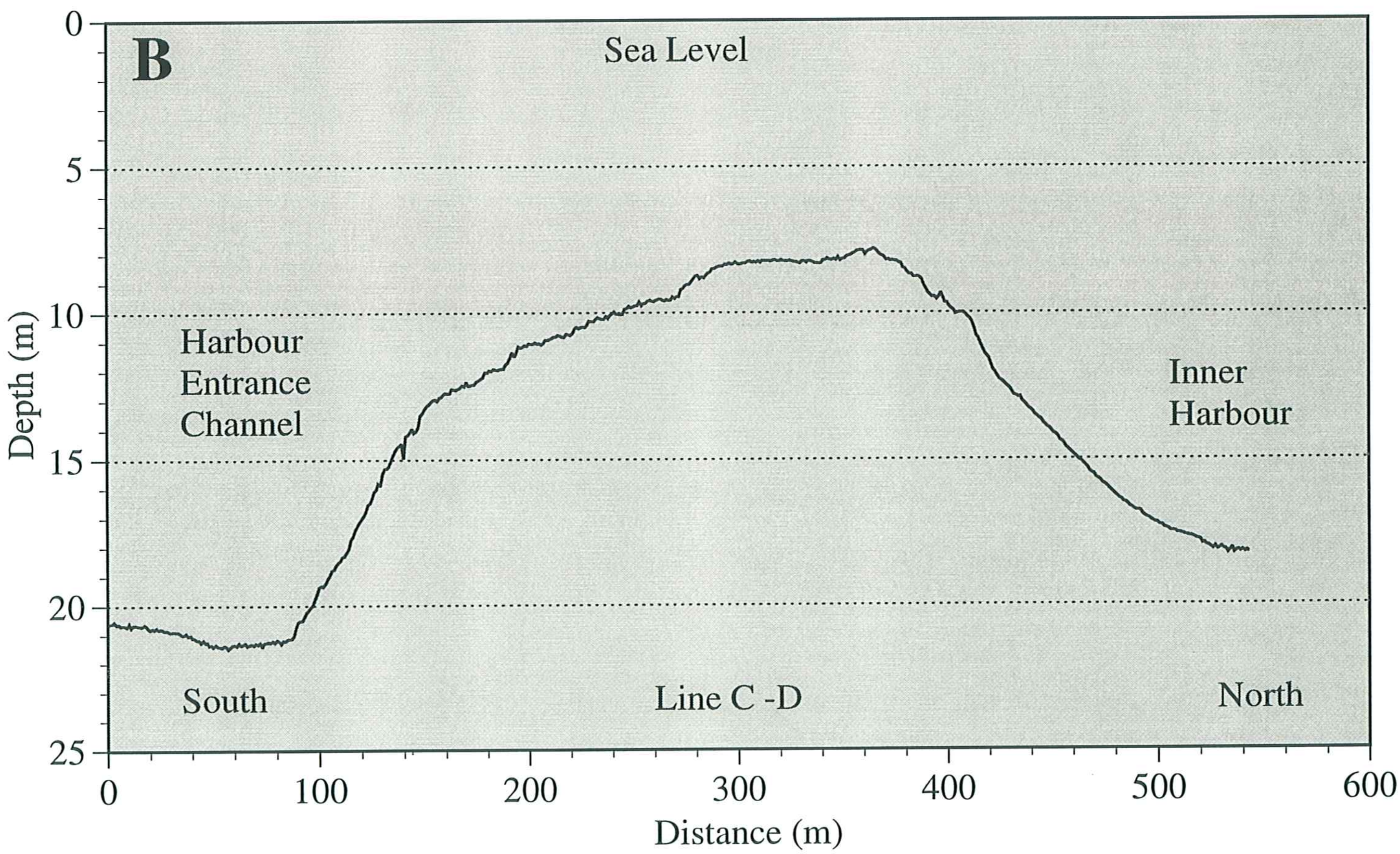


Figure 5. Cross-sectional seabed profiles of the large submerged ridge (Fig. 3) at the eastern side of the entrance to Louisbourg harbour. (A) line A-B crosses the ridge and submerged coastal spit (flat topped feature at the top edge of the channel) from west to east; (B) line C-D crosses the same ridge from offshore to onshore.

present cruise was to map the sediment types and bedforms to better define seabed sediment dynamics. Unfortunately, the gravel ripples could not be resolved by the soundings. Further analysis of the sonar data and changing artificial light angles may help to resolve these features. Using the multibeam images it is fairly easy to map bedrock and non bedrock bottoms and to differentiate coarse deposits from soft muds. Further differentiation of unconsolidated sediment should be possible with processing of the backscatter data (measures the amount of energy reflected off a seabed surface) collected during the surveys. Only a preliminary backscatter plot has been completed at the time of this writing.

The objective of the archaeologists was to assess the use of multibeam technology in mapping shipwrecks and other artifacts. A diving expedition by Acadia University (Hansen and Bleakney, 1962) had discovered as many as 10 possible shipwrecks including evidence of the five channel wrecks. Since then the 18th Century wrecks *Célèbre* and *Prudent* have been mapped in detail by underwater archaeologists (Stevens, 1994, Grenier 1994), but in the early 1990s only the anchor of one of the channel wrecks had been found. The multibeam surveys made several passes over the location of the *Célèbre* . Shallow water prevented detailed surveys over top of the *Prudent.* A couple of quick passes were made over the *Anvil* a more recent, metal hulled ship which sank off Rocky Island. A deteriorating sea state prevented more detailed surveys.

The *Célèbre* was not easily identified at first because some of the survey lines that ran over it were initially eliminated because of bad navigation. Further processing of the data and the insertion of soundings from day 280 provided a complete view of the wreck. No new wrecks were positively identified, however several features with a sharp positive relief were identified on the images. Two targets observed in the harbour entrance have the shape and size of a ship. Another target lies near the base of the slope close to the final resting place of the *Prudent.* The *Prudent* was set on fire near the Fortress by the British. It drifted across the harbour and part of the ship sank near Careening Point. The feature observed may be another part of the *Prudent* .

Artifacts from more recent human activity that were clearly visible on the sonar images included the pilings from the old coal pier east of Old Railway Point; possible anchor drag marks, or relict ship-grounding marks in the bottom sediment leading offshore of the government wharf and the former fish processing plant; scour and dredge scours from the late 1960s near the Fortress of Louisbourg; large dredge scours across the top of a large shoal in the central harbour; a large pipe extending offshore just east of the former fish processing plant and possible mounds of dredge spoils or ballast at the head of the harbour.

The soundings and seabed images have already been used in the engineering assessment of a proposal to build a new saltwater intake pipe for Fortress Louisbourg from the harbour offshore of the main quay wall. The water intake system is part of the upgrade and reconstruction of the fire suppression system for the fortress.

Future plans include additional processing of the sonar data using advanced state of the art GIS and computer imaging techniques which allow scientists to view along the "virtual" seafloor using specialized 3-D graphics workstations. This technology, plus geological and archaeological knowledge of the area, will be used to produce new exhibits about the evolution of the marine environment. The exhibits could be displayed at the fortress visitors centre or used as part of an underwater museum (Grenier, 1994). One possible presentation could be a video simulation of a view along the seafloor at the time of the seige of Louisbourg, showing where the French sank several ships at the harbour entrance.

CRUISE ITINERARY
(all times listed are UTC)

Day 278 (October 4, 1996): Jim Wilson, and George MacHattie pack navigation gear, tide gauge, software and extra hardware for Simrad EM3000 multibeam system and transport to Sydney, Nova Scotia. Bruce MacGowan and John Cunningham depart for Sydney in afternoon.

Day 279 (October 5, 1996): Weather: Morning- sunny, clear winds from NW at 5 km^{-1}. Afternoon- Scattered clouds and 0.3 mm precipitation, winds increasing to 17 km^{-1}.
Bruce and John establish tide gauge at the government wharf, Louisbourg. George and Jim set up differential global positioning system (GPS) base station at the Louisbourg lighthouse. Carmen Read and Mike Ruxton depart for Louisbourg in early afternoon, Survey launch *Petrel* dropped off by C.S.S.*Hudson* on route back to Dartmouth from Hudson Bay; launch secured along new public wharf at Louisbourg about 2030; major cleaning effort required to make launch ready for surveys. Mike Ruxton and Jim Wilson load new software for Simrad EM3000 onto launch.

Day 280 (October 6, 1996): Weather: Morning- Sunny, clear, winds from NW at 5 km^{-1}. Afternoon- cloudy with SW winds 25-30 km^{-1}. Sea State: small wind waves within harbour.

Bob Taylor and Randy Currie depart for Louisbourg at 1000, arrive at 1430 while others continue to prepare the launch for surveying. *Petrel* departs wharf at 1720 and proceeds to deepest part of harbour (near buoy) for a water sound velocity cast. Velocity profile made using an Applied Microsystems Ltd. Sound Velocity Profiler in 17 m of water (45° 54.32' N, 59°58.08'W). Start test survey run at 1801. Problems trying to input the sound velocity profile into the EM3000; problems encountered with navigation inputs, probably related to problems with Pos MV. Problems with EM3000 corrected by 2100. Run a second test survey line from central part of harbour to the west arm near Louisbourg Fortress and the 18th century wreck *Célèbre*.. Surveys stop at 2130 with all systems functioning properly. Survey data transferred from the EM3000 system onto Exabyte 8 mm cartridges for downloading and processing at the hotel.

Day 281(October 7,1996): Weather: Morning- broken cloud, SW winds 8-10 km^{-1}; Afternoon- sunny, S winds 3-5 km^{-1}. Sea State: small wind waves within inner harbour,1-2 m waves outside harbour.

Doug Pearl, one of the wardens at Fortress Louisbourg joins the survey launch to provide local knowledge of marine hazards. Survey launch underway by 1030. Water sound velocity profile obtained at 1043 off mouth of harbour (45° 53. 98 N; 59° 57.28 W) but then encounter problems with transferring velocity profile data into the EM3000. Sound profile finally entered, then EM3000 crashes. Launch returns to wharf for Jim Wilson and George MacHattie to assess the problems. Media arrive from ATV, interviews with survey personnel, while technicians assess the software problems. Launch leaves wharf to survey harbour entrance at 1500. Survey system functioning correctly. Complete survey lines 6 to 27 along the central part of the harbour between Careening Point and Fortress Louisbourg (Fig. 1). Launch returns to wharf at 1730-1815. Complete lines 28 to 42 in the harbour entrance between 1816 and 2043 when a system failure occurs with the EM3000. It is decided to shut down for the day. Collect tide data from gauge at the wharf at 2130. Most of the major problems during the day involve the locking of data screens on the Simrad EM3000 which are solved by powering down the Pos MV and rebooting the Simrad system which takes about 15-20 minutes.

Day 282 (October 8,1996): Weather: Morning- Sunny, clear but with fog patches during day, NW winds 3-5km-1. Afternoon- winds changing to SSW, 15 km-1. Sun dog in evening sky. Sea State: 0.5 to 1.5 m waves, 10 sec period swell outside harbour.

Launch leaves wharf at 1115. Travel outside harbour entrance for a sound velocity profile (SVP) at 1127 in 55 m of water (45° 53.65N, 59° 56.06 W). Surveys begin between Green Island and Black Rock initially running lines onshore -offshore but then switch to running lines parallel to shore despite the swell. Complete lines 1-16; a survey line jumps 80 m in position at 1345 and George and Jim rectify the problem by rebooting the GPS base station at the lighthouse. Continue surveying along the outer shore (Fig. 1) and Green Island until 1523 when launch returns to inner harbour because sea conditions are deteriorating offshore. Just before returning to the inner harbour an attempt is made to survey over the wreck *Anvil* , marked by a buoy off Rocky Island, but sea conditions limit the launch to only two passes. Launch returns to wharf by 1600. Sound velocity profile taken in 18 m of water at inner harbour site by the entrance buoy at 1720. Ran survey lines 32 to 37 trying to fill in the area between the harbour entrance and Rochefort Point area until 1848 hrs. Because of higher tides, launch begins surveying close to the Fortress. A new day stamp is set up for continuing the surveys next day (Day 282/283) but water levels are insufficient so the launch returns to infill the area (lines 40 to 43) that we missed close to the shoal off Rochefort Point. Seas breaking over the shoal keep the launch from getting close to it. Seas are increasingdue to the approach of tropical storm Josephine which is expected to strike tomorrow. Depart for the wharf at 1945 hrs after computer system locks up. Many of the stoppage or freezes in the Simrad system are prevented by reducing the number of windows open on the screen (Fig. 7,8). System can also be brought back up by closing the Merlin screen (Fig.8) and the waterfall screen, and then bring them back up onto screen. It seems that the system can not handle or keep updating information on the computer screens if too many windows are displayed. New evidence suggests that only the ping rate needs to be shut off and restarted. Currie and Taylor meet with Josenhans to brief him on the status of the surveys. At 2130 they departed for Dartmouth, arriving 0230 hrs.

Day 283 (October 9, 1996): Weather: Morning- overcast, 6 mm of rain, winds 20-25 km-1 from NNW; Afternoon- overcast, light rain 22 mm, winds SE at 20-30 km-1. Seastate: 0.5 m waves in harbour increasing to 1 m by mid day.

Launch leaves wharf by 1030. A sound velocity profile is taken at the harbour buoy where profiles were collected on previous days. Began running lines at 1053 along the shoreline then fill in lines along central part of the harbour. At 1242 the computer system locked and a problem with the navigation (DGPS) at 1257 occurs. Launch returns to wharf to check the GPS Navigation and pos MV. Bad navigation for part of lines 12, 13 and 14 (Appendix 1). The DGPS has to be rebooted at the lighthouse at 1434 . By 1730 (Line 30) the waves are much higher. Concentrate on infilling the lines at the northeast end of the harbour where there is some shelter from the waves. Complete last line at 1933.

Day 284 (October 10, 1996): Weather: Morning- Broken cloud, 1.4 mm of rain, winds from WNW 20-30 km/hr; Afternoon-mainly sunny, trace precipitation, WSW winds at 10-12 km-1.

Maintenance on Simrad system and rebooting before departing for buoy at harbour mouth for a sound velocity profile. Continue line numbers from day 283. Line 41 began at 1238 at the south end of the harbour -complete lines 41 to 66 but several problems with system freezing up or bad navigational data. Fill in bathymetry around town of Louisbourg. Ran lines until 1430 when the launch returns to the wharf for refuelling. Heiner departs for Dartmouth at 1500. Launch continues filling in data within the harbour until 2103. CSL *Petrel* departs for Sydney, Nova Scotia the next day.

TECHNICAL SUMMARY

Navigation:

Horizontal positioning for the launch surveys was provided with a Novatel 12 channel (model 3151R) differential transmitter and receiver and Pacific Crest (RFM96W 35 watt) radios established on land and on the launch *Petrel* .. The land based station was established at Louisbourg Lighthouse (45° 54.3964 N, 59° 57.5071 W) at the southeast entrance to the harbour (Fig.1). The transmitter and antenna were attached to the railing of the deck that circles the top of the lighthouse at 32.7 m elevation (Ellipsoid). The elevation of the antenna, assumed the same as the lighthouse, and the polar offset from the centre of the lighthouse to the transmitter antenna was a slope distance of 2.120 m, using a true bearing of 338°.

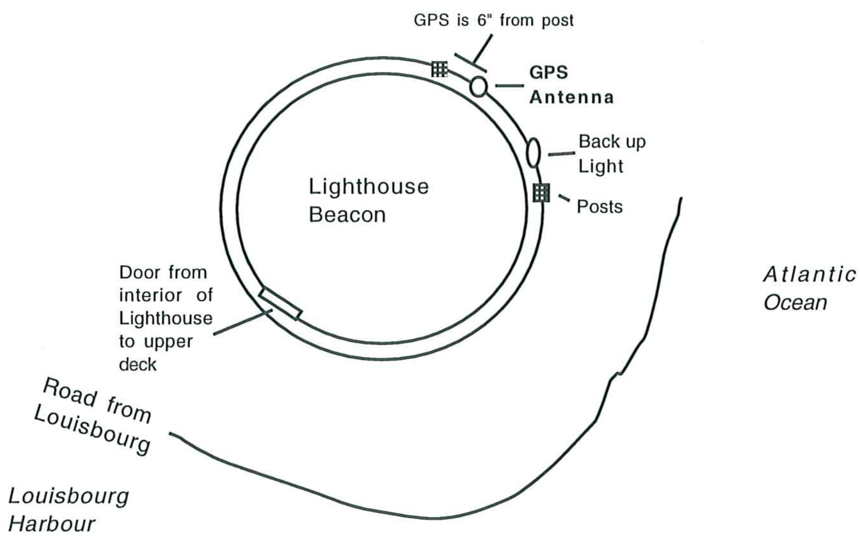


Figure 6. Navigation base station showing the location of the GPS antenna established on the railing of the top deck of the lighthouse Louisbourg, Nova Scotia.

The location of the antenna is shown in Figure 6. On the launch the POS-MV uses one Novatel performance series GPS receiver for integrated position determination and one standard receiver for heading sensing. DGPS corrections are received from the landbased Novatel transmitter via UHF radio (Pacific Crest) link. DGPS positions are integrated into the EM3000 sounding data files.

Corrections from the Canadian Coast Guard beacon at Fox Island in Chedabucto Bay were not required since all of the launch surveys were within 4 km of the lighthouse.

AGC Nav was used during the survey to provide heading and course lines. This type of navigation is excellent for setting up survey lines before the cruise and for keeping track of lines during the actual survey. Minor problems arose using the AGC Nav system because the sequence of lines were prearranged to be run in a Zamboni grid pattern. This type of survey pattern is best for larger vessels which require a wide turning space, but since the launch can make tight turns, the line sequence would have been better suited to the launch if it had been set up to follow each consecutive line. An inconvenience for the Coxswain arose when he was surveying gaps between previous survey lines. To see the previous track line and where he was surveying, he had to watch the Merlin screen on the Sun workstation which was near the stern end of the cabin and not beside or in front of him.

Seawater Sound Velocity Measurements:

An Applied Microsystems Ltd Sound velocity profiler Model SVP-16 was used in conjunction with Soft-16 SVP software in a PC computer. Velocity profiler measured pressure, salinity and speed of sound at 1 m sampling intervals or whenever the difference in sound values were> 1m/s. The velocity profiler was connected to a PC computer with a RS232 2400/300 baud rate. The velocity profiler was activated by connecting a shorting plug which completes the circuit. The instrument was deloyed by hand over the stern of the launch and left in the water for 5 minutes and then lowered to the bottom. The delay in lowering the instrument is to prevent thermal drifting in the sensors (the variation of sensor readings at different temperatures).

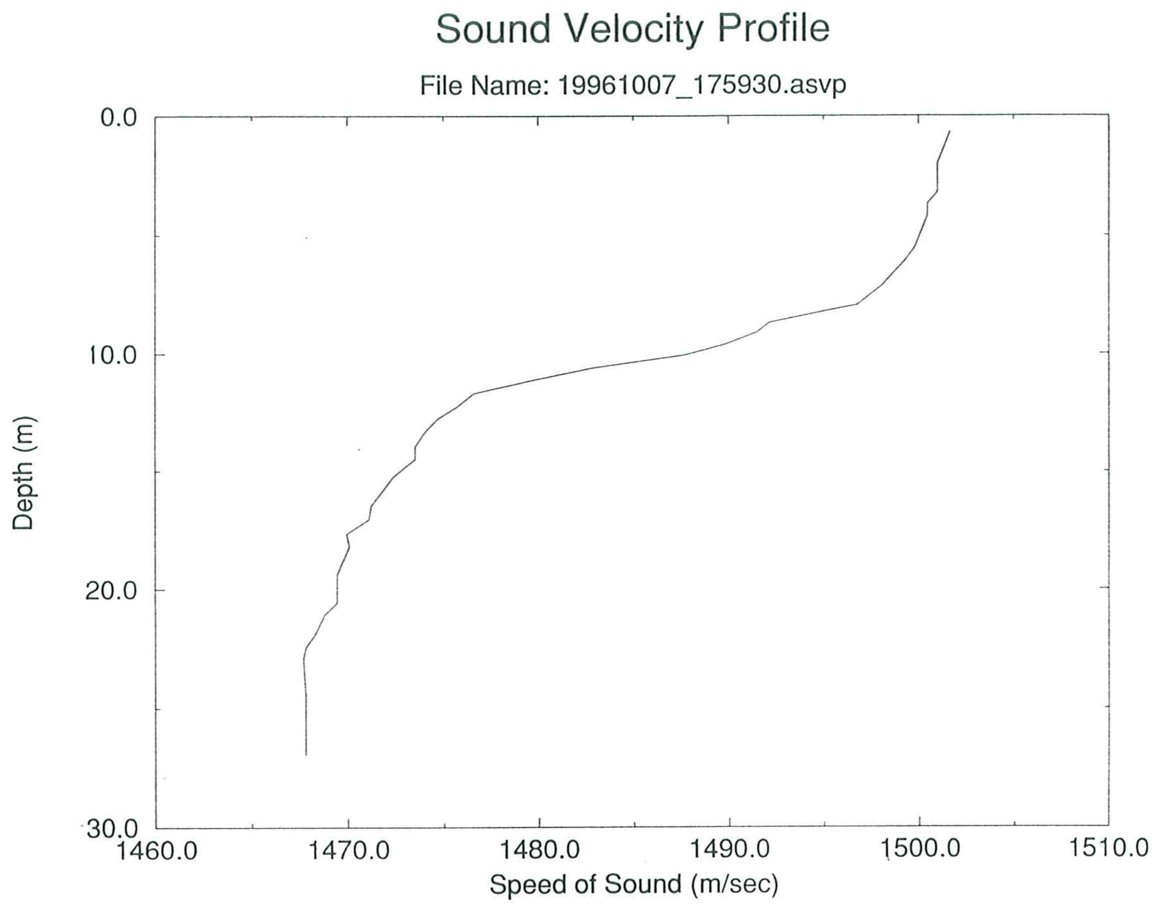
Most casts in the harbour were at depths of 18-22 m (Fig. 7a) and others were just offshore of the harbour mouth in depths of 50-60 m (Fig.7b) . Once the velicometer was brought to the surface it was connected to the computer; the velocity profile was taken off and edited. Spikes in the data and duplicate data points caused by ships motion were eliminated. The data file was then input to the SUN computer where the values were utilized directly by the Simrad EM3000 swath system .

Simrad EM3000 Multibeam Sonar System

The Simrad EM3000 MBS system (built by Simrad Subsea, Horten, Norway) was used in the Louisbourg survey. A detailed description of the technical aspects of the EM3000 sonar system is provided by Dinn and Crutchlow (1996) which is summarised here.

The EM3000 system consists of a keel-mounted transducer, an electronics unit and a workstation with software to control the sounding operation and monitor survey coverage and data quality. The system is capable of creating 127 separate sonar beams that cover slightly more than 120° swath coverage of the seafloor. This provides a sounding width of 3.5 to 4 times the water depth. The EM3000 is intended for mapping in water depths of up to 200 m but the use of a high (300 kHz) acoustic carrier frequency means that the maximum depth attainable is a function of the water temperature and salinity (because they affect the acoustic absorption loss). Cool, low, salinity waters provide best conditions for sounding. In Louisbourg Harbour it was common to find uniform salinity / temperature profiles with depth. However on some occasions, a sharp, shallow thermocline was observed (Fig. 7a). The maximum water depth recorded during these surveys was just over 40 m where the seafloor dropped sharply, just off the harbour.

Two factors which affect the transmit angles of the beam at the transducer face are the roll angle and the water sound velocity. The electronics unit with the system includes a POS-MV Model 320 (Applied Analytics Corp, Markam Ontario) vessel position and attitude measurement system. This system integrates the motion information with the DGPS information to determine position and heading for the vessel. The transducer attitude, position and heading are then used to transform slant ranges and ray angles into georeferenced depths. Dinn and Crhlow (1996) reported that it is not uncommon for the sound velocity to vary by ± 20m/s over the survey area due to solar



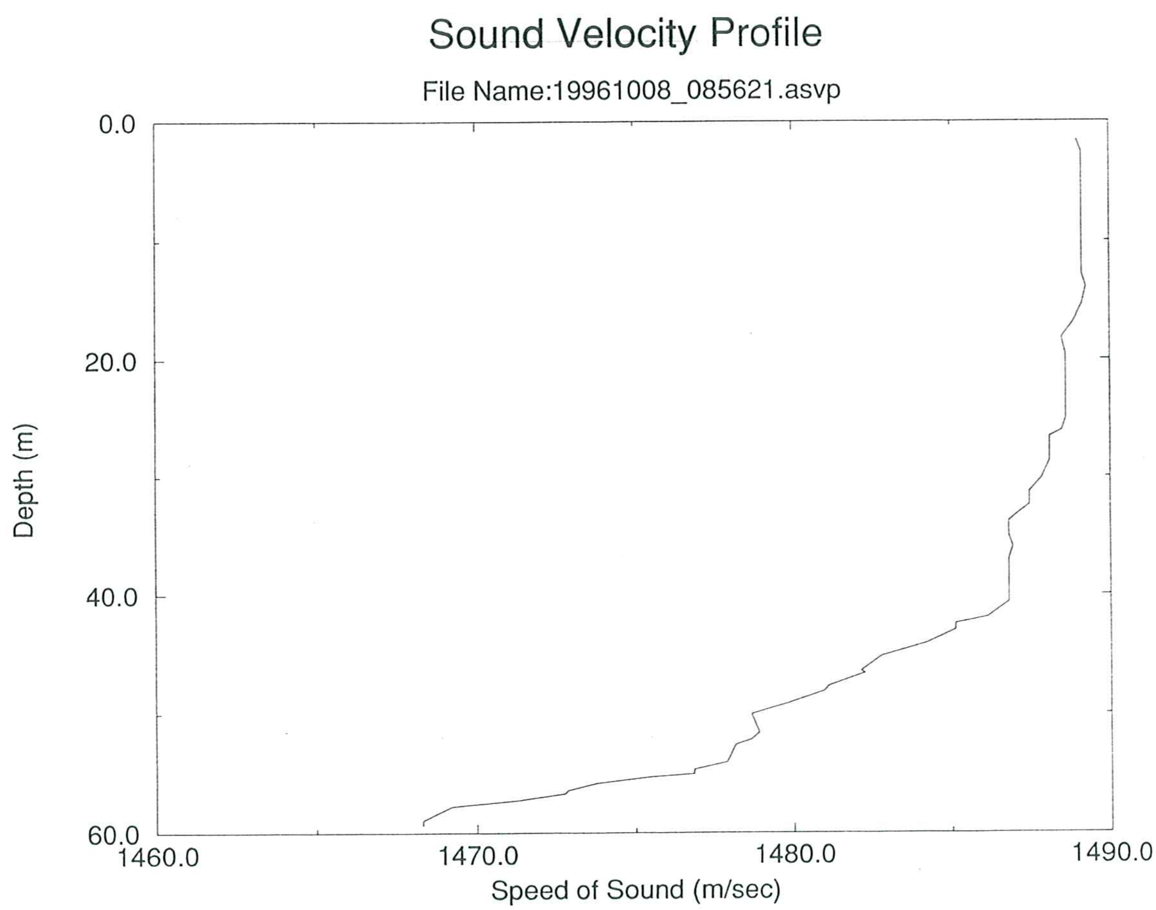
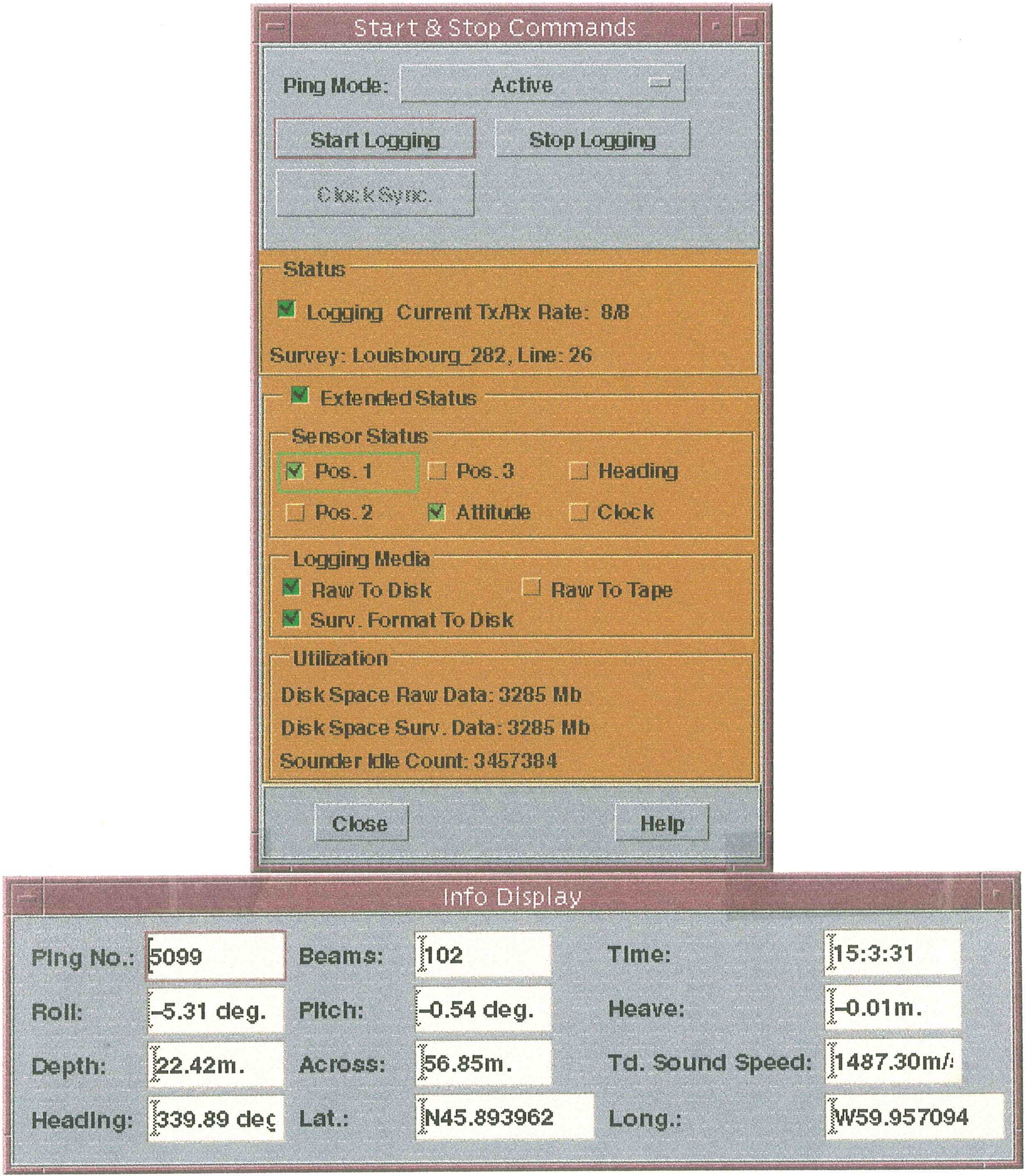


Figure 7. Examples of the seawater sound velocity profiles collected: (A) on October 7, 1996 at the inner entrance to Louisbourg Harbour; (B) on October 8, 1996, offshore of the harbour entrance. The sound velocity profile of seawater is constantly changing in response to sea state, tidal mixing and solar heating. The sound velocity profile is input to the EM3000 Simrad system where it is used in the calculations for seawater refraction. The corrections are applied to the sonar beams to obtain correct water depths.

Figure 8. Examples of the information displayed on the SUN Sparc 20 workstation which was mounted in the C.S.L. *Petrel* during the 1996 bathymetric surveys of Louisbourg harbour. (A) example of the numeric information display, (B) example of graphic displays (see next page).



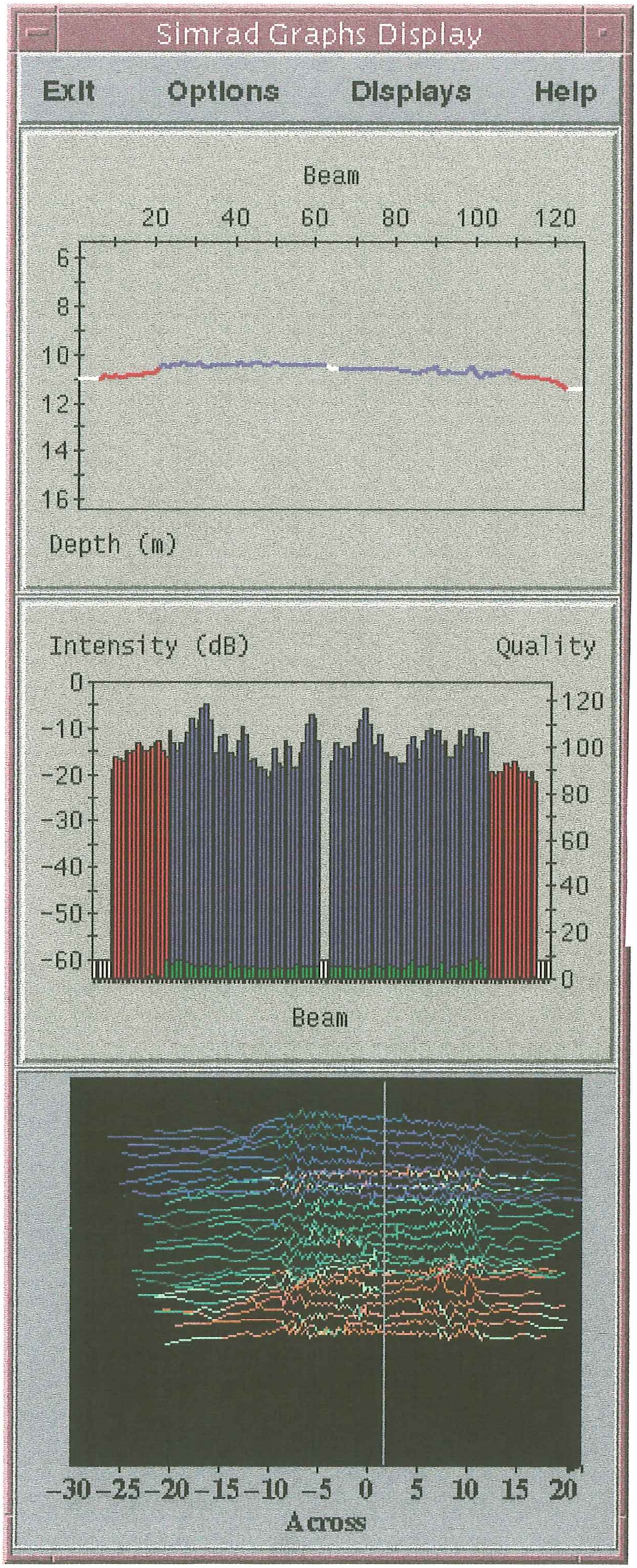


Figure 8B. Graphic displays on the SUN Sparc 20 workstation of: (**top**) the latest or incoming swath of depths; (**middle**) the intensity and quality of individual beams across the incoming swath of depths - nearer the bottom of vessel, (blue beams) depth is calculated based on amplitude of the signal whereas the outer beams (red) use time phase between two signals to calculate the water depth ; and the "waterfall" spectral display (**bottom**) of a sonar swaths; showing the incoming swath as the lowest line and the last 25 or so swaths collected before the present one. The upper swath (line) disappears as each new swath is collected.

heating, freshwater input and tidal mixing. It would be helpful to receive continuous updates of sounding velocities, but that was not possible in the Louisbourg survey. Instead, sound velocity measurements were collected at the start of each survey day at the deepest area of the survey (Fig. 7, normally at the inner entrance of the harbour) and again later in the day, particularly if the sea conditions, or depth ranges changed substantially. Onboard the vessel the technical aspects of the EM3000 sonar system, vessel roll pitch and heading and time, date and vessel navigation were monitored on a series of windows on the screen of a SUN Sparc 20 computer workstation (Fig. 8,9). Unfortunately, one of the main problems in the present survey was the number of times the system locked or "froze". It appeared that if several windows were open on the screen at one time, the system was unable to update all the information in a real time mode. To resolve this issue only a couple of windows were kept open on the screen, i.e. Merlin and beam display (Fig 8a, 9). The beam display showed three graphs, phase, amplitude and depth (Fig 8b). The "Merlin" window (Fig. 9) showed vessel position and previous track lines. It could be expanded to view an actual footprint of the soundings (Fig. 9b). The system failures and screen freezes were often associated with rapid acceleration or deceleration of the vessel as it was steered around rocky islets or in shallow water near the ends of the lines.

Socomar Tide Gauge

A Socomar recording tide gauge (TMS S000828, diaphram group S000666I) was established at the Coast Guard station at the landward end of the government wharf in Louisbourg. The recording staff was established on top of an older staff that was still present. The gauge transducer was attached to the side of the wharf. Power to the gauge was supplied from the Coast Guard station. Tidal observations were downloaded from the gauge each evening using a portable PC computer. A copy of the field sheet is provided in Appendix 2 and a plot of the uncorrected observed tides is shown in Figure 10. The gauge was left in place between the time of the *Petrel* cruise and the *Creed* cruise later in the month. When we returned on October 19 the gauge was no longer working properly because of a power failure that occurred on October 12. In the process of getting the gauge working the data storage buffer was erased and some data were lost. Therefore, predicted tides were used instead of the observed tides in the final processing of the soundings.

Air photo Rectification and Landbased GPS Surveys

Colour vertical air photos take in 1993 by the Nova Scotia government at a scale of 1:10,000 (Appendix 4) were rectified using geographic positions taken off Hydrographic Chart 4376. Rectification was completed for each photo using a GSC modified version of the public domain computer software package, GRASS. Once each photo was rectified, the photos were merged together into a mosaic which was used as a background for the bathymetric data (Fig. 1).

Field surveys of the sites picked for rectifying the air photos were completed on October 20 and 25 1996 using a Geotracer 2000 (Geodimeter of Canada) Real Type Kinematic GPS system. The differential positioning was achieved using a base station at a control survey benchmark and a rover station which completes the measurement at each field site. Corrections are sent to the rover from the base station via radio link (Pacific Crest). Not all sites used in the air photo analysis could be surveyed because of the lack of satellites during the short time available for surveying. The RTK system was used in stop and go mode, UTM projection zone 20 and horizontal datum of WGS84. Where geographic positions were obtained 6 to 8 satellites were being tracked. The standard deviation ranged from 0.009 to 0.019 and the PDOP was usually better than 3.

PDOP (Position Dilution of Precision) is a measure of the accuracy of ranging which is a function of the geometry of the satellites to the point on earth, e.g. PDOP<4 is excellent, PDOP >7 is poor.

Figure 9A. View of the SUN Sparc 20 workstation screen showing the "Merlin" display which shows the present geographic position of the launch (white squares) and the previously completed survey tracklines (orange). The bow of the launch is marked by the white line which shows the launch is travelling toward the top of the screen. (See Fig. 9B for enlarged view).

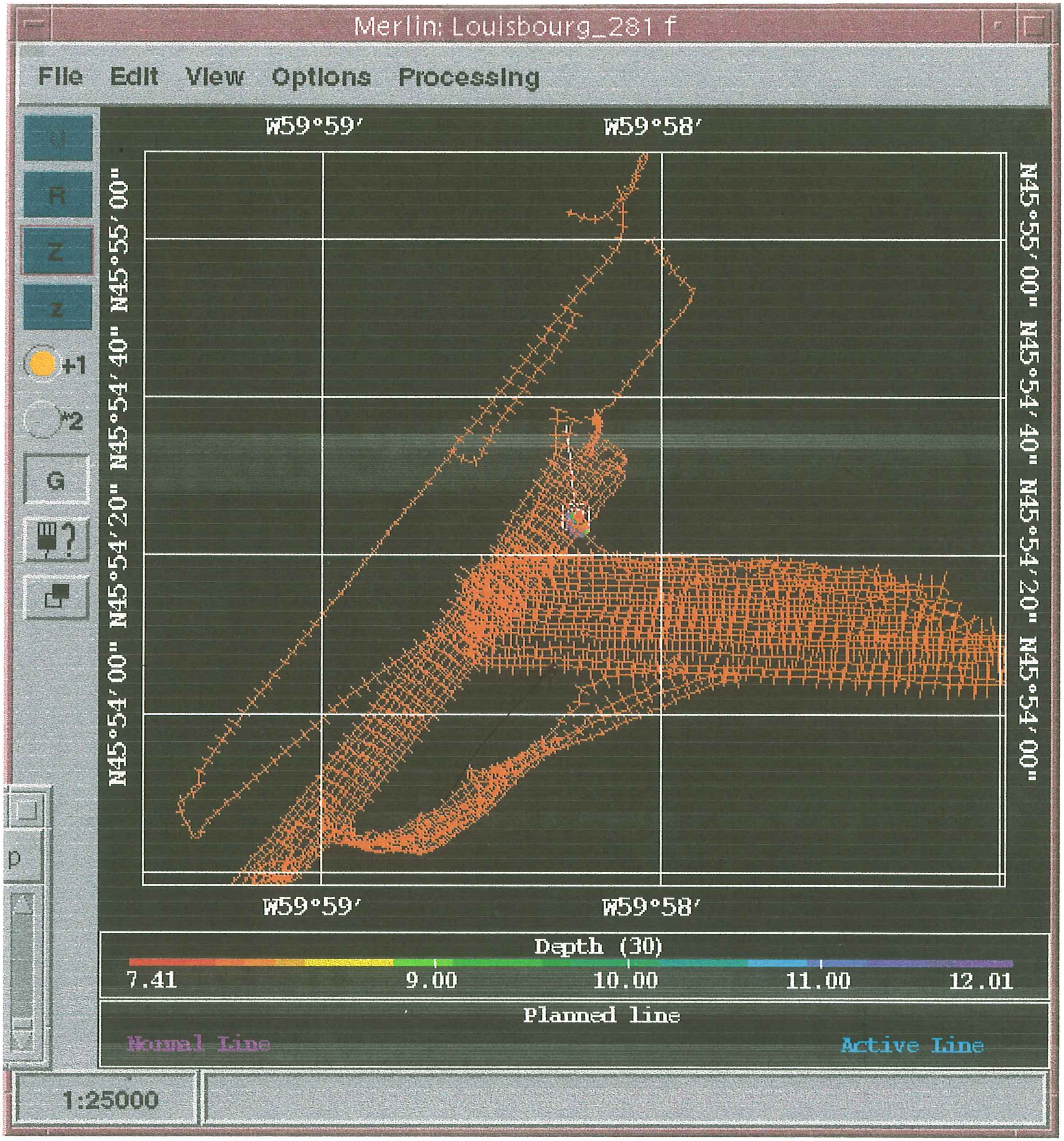
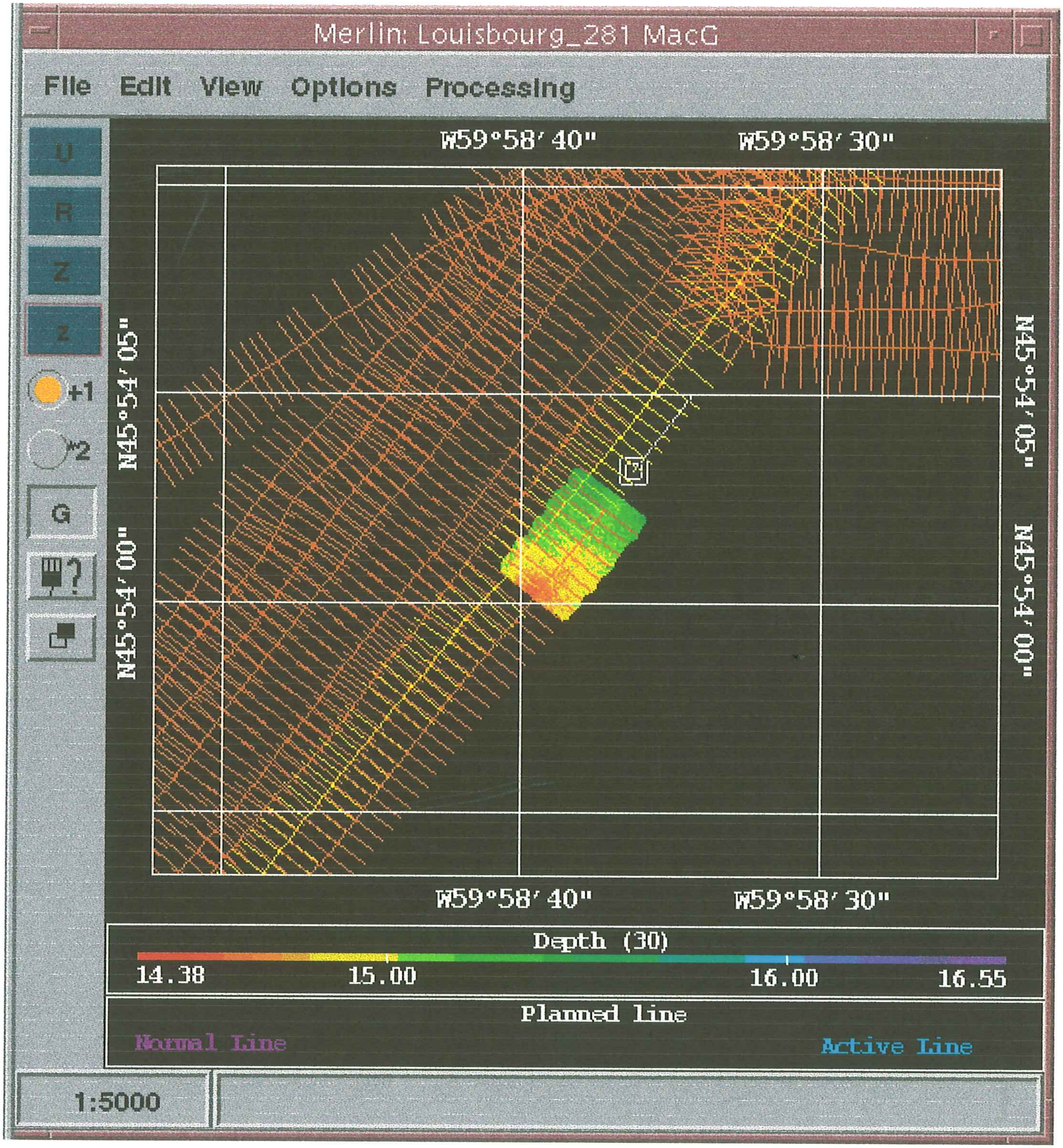


Figure 9B. View of the SUN Sparc 20 workstation screen showing an expanded view of the "Merlin" display showing the present location of the launch (white squares) and seabed depths plotted in real time (colour coded) for the area just mapped. Both examples in Figure 9A and B were selected from surveys completed on Day 281 (October 7) 1996.



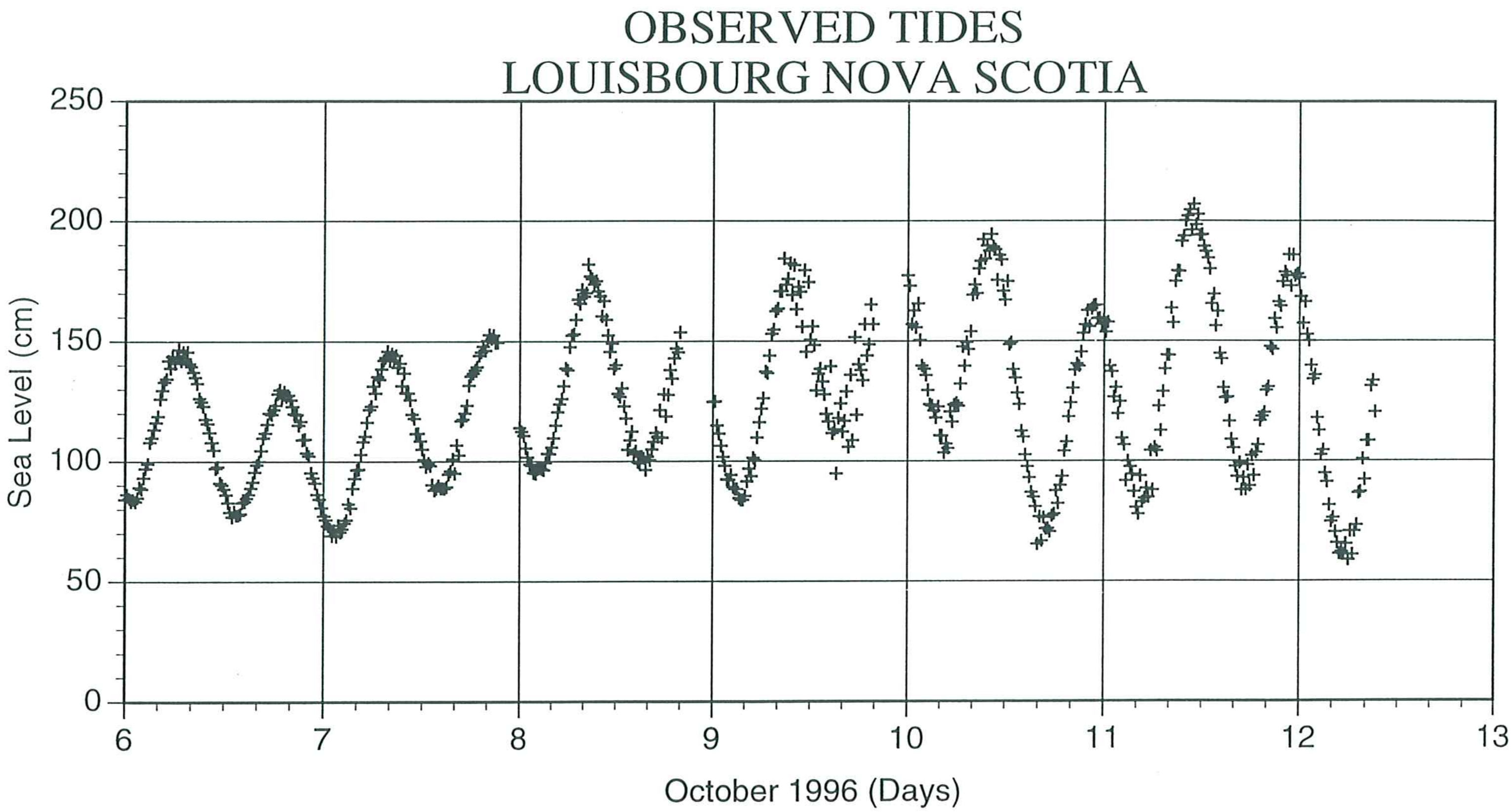


Figure 10. Uncorrected observed tides recorded on the Socomar tide gauge located at the government wharf, Louisbourg, Nova Scotia during the EM3000 sonar survey. The tidal data are listed in Appendix 2.

For sites where fewer satellites were available on October 20 (Appendix 3) the PDOP increased to 4.5 . Positions derived from Hydrographic Chart 4376 were on average different from field values by 27 m in the northing and 12 m in the easting, and individual positions taken from the map varied anywhere from 2 to 34 m from the GPS readings. Wherever possible, field GPS data was used to complete the final air photo rectification.

ACKNOWLEDGEMENTS

Thanks are extended to a number of people who helped make this survey a success. They include: Doug Pearl for providing local knowledge about navigational hazards in the harbour approaches and using some of his leave to accompany us at sea; Canadian Coast Guard, Louisbourg, for permission to use the lighthouse, and for logistics support at the wharf and with refuelling; all who participated in the survey especially Carmen Reid, who safely navigated the the launch around the rocks of the outer harbour and conscientiously tried to fill all gaps in the data. We also thank Dick Pickrill, Julian Goodyear and Paul Bellemare (CHS) for their interest in the Louisbourg project and their support in getting the launch to Louisbourg. DND Route Survey staff Jamie Foote, Leslie Guyomard and M.J. Caron-Delorme assisted with the initial rectifying of the air photos under the direction of Russ Parrott (GSCA) and Larry Johnson (GSCA) assisted with the land-based GPS survey on October 20. Comments on earlier drafts of this report by J. Shaw (GSCA) and B. Bennett (HC) are very much appreciated.

REFERENCES

Bennett, B. 1991. Louisbourg sidescan sonar survey, May 1991; Unpublished Report, Federal Archaeology Office, Parks Canada, Ottawa, Ontario, 4 p.

Brown, A.O. 1996. The Fortress of Louisbourg: Still Under Siege?; unpublished, Environmental Engineering Technology third work term paper, UCCB, Sydney Nova Scotia; 32 p.

CHS (Canadian Hydrographic Service) 1996. Canadian Tide and Current Tables 1996, Volume 1 Atlantic Coast and Bay of Fundy, Department of Fisheries and Oceans Canada, 45 p.

Dinn, D.F. and Crutchlow, M. 1996. A First Look at the EM3000 Multibeam Sonar; In: Proceedings of the Canadian Hydrographic Conference '96, Halifax, Nova Scotia, June 3-5, 1996; 89-97.

Grenier, R. 1994. The concept of the Louisbourg underwater museum; The Northern Mariner, IV, No. 2, 3-10.

Hansen, E.S. and Bleakney, J.S. 1962. Underwater Survey Of Louisbourg Harbour For Relics of The Siege of 1758; Report to Department of Northern Affairs and Natural Resources, Acadia University Institute, Wolfville, Nova Scotia, February 1962; 39 p.

PWC (Public Works Canada) 1985. Fortress of Louisbourg Nova Scotia, Coastal Flooding & Erosion Preliminary Study, Parks Canada, 20 p. + 17 figures.

Shaw, J., Taylor, R.B., and Forbes, D.L. (1993). Impact of the Holocene Transgression on the Atlantic Coastline of Nova Scotia; Géographie physique et Quaternaire, V. 47, N.2, 221-238.

Stevens, E.W. 1994. Louisbourg submerged cultural resource survey. Manuscript on file at Fortress of Louisbourg, Louisbourg, Nova Scotia; 76 p.

Shearer, J. 1996. Side-scan mosaic of the seafloor of Louisbourg Harbour and approaches; unpublished seafloor mosaic; on file at the Geological Survey of Canada, (Atlantic), Dartmouth, Nova Scotia.

Taylor, R.B. 1992. Coastal flooding and erosion at Grand Étang, Fortress of Louisbourg, Nova Scotia; Geological Survey of Canada Open File Report 2548, 25 p.

Taylor R.B. and Brown, A.O.(in prep). Coastal Geology of Louisbourg National Historic Site, Cape Breton Island, Nova Scotia; Geological Survey of Canada Paper.

APPENDIX 1

EM 3000 DATA ACQUISITION LOG BOOK

C.S.L. *PETREL* 96-001

Louisbourg, Nova Scotia
October 7 - 10, 1996

Project:	Louisbourg, N.S.				**Data Acquisition Log Book**					
Vessel: C.S.L.	Petrel					**EM 3000**				Page: 1 of 1
Line No.	SVP File Name	Date JD	SOL Time UTC	EOL time UTC	Operator	Line Spacing	Line Course	Speed Knots	Sea State	Wind	Remarks
	19961006	280			MacG						MacG
	(Oct 6, 1996)										several test runs all morning
5			1505								test runs trying to get system running and incorporate SVP cast data
6			1515								
7			1542								
5			2059	2130							System working: ran line from centre of Harbour toward Fortres and wreck "Celebre"
			2200								EOD

Data Acquisition Log Book

EM 3000

Project: Louisbourg, N.S.

Vessel: C.S.L. Petrel

Line No.	SVP File Name	Date JD	SOL Time UTC	EOL time UTC	Operator	Line Spacing	Line Course	Speed Knots	Sea State	Wind	Remarks
1	19961007	281	1257	1304	JC	0	90				Velocity cast (19961007_123000.asvp) - Location 45° 53.9896 N, 59° 57.5332 W
2	(Oct 7, 1996)		1306	1309		25m					inner mouth of harbour - depth = 55 ft.
3			1309				270				running lines in and out of Harbour entrance
4											system crash @ 13:13
5											into wharf for system check
6			1511	1520			90				
7			1520	1526			270				
8			1526	1530			90				Screen freeze @ 15:30
9			1532	1534			90				
10			1534	1540			270				
11			1540	1546			90				
12			1546	1551			270				
13			1551	1556			90				
14			1556	1602			270				
15			1603	1610			90				
16			1612	1619			270				
17			1619	1627			90				
18			1627	1633			270				
19			1633	1640			90				
20			1640	1648			270				
21			1648	1654			90				
22			1654	1659			270				
23			1659	1702			90				
24			1702				270				Screen freeze
25			1705	1713							Going to new area
26			1713	1720			35				
27			1723	1730							Lunch break
			1759								SVP cast (19961007_175930.asvp)
			1809								SVP cast redone (19961007_180902.asvp)
28			1816								AGC NAV line 20 south side Harbour running William Head toward Fortress
29				1844							
30			1846	1858			217				1850 over area of ship wreck "Prudent"
31		281									Start AGC line 21 off Careening Point
32											
33			1900	1910							
34											
35			1910	1919		25	217				
36			1919	1924			37				
37			1924	1931			217				
38			1931	1941			37				AGC Line 28 Fortress to Careening Point
39			1941	1948			217				
40			1948	1955							
41			1955	2014							
42			2014	2039							POS/MV error window "POS/MV powered down" - Screen freeze as well
43			2043	2054							EOD

Project:	Louisbourg, N.S.				Data Acquisition Log Book					
Vessel: C.S.L.	Petrel					EM 3000				Page: 1 of 2
Line No.	SVP File Name	Date JD	SOL Time UTC	EOL time UTC	Operator	Line Spacing	Line Course	Speed Knots	Sea State	Wind	Remarks
0	19961008	282	1205	1212	MacG		340	5			SVP cast - (19961008_085621.asvp)
1	(Oct 8, 1996)		1212	1219			160				Lockup - Com error - connection reset by pier
2											
3			1219	1223			340				.5m swell
4			1223	1235							
5			1236	1238							
6			1238	1247							
7			1247	1254							
8			1254	1259							
9			1259	1305							
10			1305	1311	JC						
11			1311	1315							.5>.75m swell
12			1317								Screen freeze
13											
14			1320	1322							Outer coast -Offshore of Fortress Louisbourg southwest of Rochefort Point
15			1323	1333							
16			1333	1345							80m GPS jump. Age of corrections? DGPS bad. Excessive age of corrections.
17			1349	1352							HPC rebooted @ reference station (lighthouse)
18											
19			1412	1421							
20			1421	1425							
21			1425	1426							3 screen freezes.
22											
23											
24			1434	1443							
25			1445	1456							
26			1456	1507	MacG						
27											
28			1508	1523							off Rocky Island and wreck "anvil"
29											

Project: Louisbourg, N.S.

Data Acquisition Log Book

Vessel: C.S.L. Petrel

EM 3000

Line No.	SVP File Name	Date JD	SOL Time UTC	EOL time UTC	Operator	Line Spacing	Line Course	Speed Knots	Sea State	Wind	Remarks
	19961008	282									
	(Oct 8, 1996)		1728								SVP velocity cast: (19961008_142811.asvp) inner harbour entrance 19 m water depth
30											
31											
32			1800	1807							Inner harbour lines.
33			1807	1822							Off Grand Etang between fortress and Battery Island
34			1822	1832							Break in lines system crash
35			1832	1837							
36											
37			1837	1848							
38			1859								Made new project Louisbourg_282_283 to set up for next day but did not use it.
39											lines 38, 39, 40 ,41 have no data in files
40			1912								
41											
42				1917							
43			1923	1936							Freeze.
				1945							EOD

Project:	Louisbourg, N.S.					**Data Acquisition Log Book**					
Vessel: C.S.L.	Petrel						**EM 3000**				Page: 1 of 2
Line No.	SVP File Name	Date JD	SOL Time UTC	EOL time UTC	Operator	Line Spacing	Line Course	Speed Knots	Sea State	Wind	Remarks
	19961009	283									
	(Oct 9,1996)										
			1052								SVP cast (19961009_075254.asvp)
2			1053	1114							
3			1114	1130							
4			1130	1135							
5			1135	1144							
6			1144	1204							
7			1206	1225							AGCNAV Line number 9
8											
9			1226	1236							
10			1236	1242							Screen freeze @ 1242 - AGCNAV Line number 18
11			1246	1249							AGCNAV Line number 18
12			1249	1257							AGCNAV Line number 13 - 0.5m chop - DGPS correction age bad. POS/MV is U/S.
13											Positions on last part of this line bad.
14											
15											
16			1325	1332							AGCNAV Line number 13
17			1334	1355			217				AGCNAV Line number 17
18											GPS bad again. Reboot @ lighthouse.
19											
20											
21											
22			1434	1445							AGCNAV Line number 12
23			1445	1453							AGCNAV Line number 16
24			1453	1501							AGCNAV Line number 11
25			1501	1508							AGCNAV Line number 15
26			1509	1520	JC						AGCNAV Line number 10
27			1705	1711							AGCNAV Line number 14 & 13
28			1711	1723							Fill in NE arm.
29			1723	1730							AGCNAV Line number 9

Project: Louisbourg, N.S.

Data Acquisition Log Book

Vessel: C.S.L. Petrel

EM 3000

Line No.	SVP File Name	Date JD	SOL Time UTC	EOL time UTC	Operator	Line Spacing	Line Course	Speed Knots	Sea State	Wind	Remarks
	19961009	283									
30	(Oct 9,1996)		1730	1736							AGCNAV line number 8. Wind has picked up. Very rough now but system still looking good.
31			1736	1751							AGCNAV line number 7 & 6.
32			1751								
33				1809							AGCNAV line number 5 & 4
34				1814							AGCNAV line number 3
35			1814	1823							AGCNAV line number 2
36			1823	1832							AGCNAV line number 1
37			1832	1845							Fill-in lines.
38			1845	1859							Fill-in lines.
39			1859	1908							Fill-in lines.
40			1908	1916							Fill-in lines.
41			1919	1933							Fill-in lines.
											EOD

Project: Louisbourg, N.S. — **Data Acquisition Log Book**

Vessel: C.S.L. Petrel — **EM 3000**

Line No.	SVP File Name	Date JD	SOL Time UTC	EOL time UTC	Operator	Line Spacing	Line Course	Speed Knots	Sea State	Wind	Remarks
	19961010	284									
	(Oct 10,1996)		1208								SVP cast (19961010_090857.asvp)
41			1238	1246	MacG						AGCNAV line number 16 - South end of harbour.
42			1246	1255							Shorelining
43			1255								Shorelining & AGCNAV line number 19
44				1347							
45			1347	1354							AGCNAV line number 12
46			1354	1404							AGCNAV line number 11 - GPS bad data.
47			1414								
48			1559	1602							AGCNAV line number 9 - GPS still bad. Delete data?
49											Bad data @ 1700 to 1721 - Delete.
50			1723	1727							AGCNAV line number 9
51			1729								AGCNAV line number 9 - Screen freezes.
52											
53			1742		JC						AGCNAV line number 8 - Screen freeze.
54				1753							
55			1753								AGCNAV line number 7 - Screen freeze.
56				1806							
57			1806	1813							AGCNAV line number 6
58			1813	1830							AGCNAV line number 5 & 4
59			1830	1844							Fill in.
60											AGCNAV line number 3
61			1949	1955							AGCNAV line number 2
62			1955	2019							AGCNAV line number 1,4 & 3.
63			2019	2025							AGCNAV line number 2
64			2025	2031							Fill in & AGCNAV line number1
65			2034	2045							AGCNAV line number 1 & 0
66			2045	2103							Minus 25 metres from AGCNAV line number 0

APPENDIX 2

OBSERVED TIDES

Louisbourg, Nova Scotia
October 6-12, 1996

COMPARISON FORM

FORM No. 105A

LOCALITY: LOUISBOURG N.S. GAUGE TYPE: SOCOMAR YEAR 19: 1996

CHIEF OF PARTY: B. MacGOWAN GAUGE NO.: S000666I TIME USED: (UTC)

MONTH: OCTOBER

MONTH OCTOBER			TIME COMPARISON			HEIGHT COMPARISON					WIND AND SEA			
1 DIAGRAM NO.	2 WEEK DAY	3 DATE	4 DIAGRAM TIME	5 TRUE TIME	6 TIME ERROR	7 TRUE TIME	8 TAPE GAUGE	9 STAFF GAUGE	10 DIAGRAM	11 DIFF.*	12 WIND DIRECTION	13 WIND FORCE	14 STATE OF SEA	15 REA[illegible] BY
1	SAT	05		2022			1.29	1.28		0.01				
1	SUN	06		1241			0.79	0.75		0.04				
1	MON	07		1004			1.29	1.26		0.03				
1		07		2115			1.48	1.47		0.02				
1	TUES	08		1054			1.54	1.52		0.02				
1		08		1958			1.55	1.54		0.01	SW	10kn	2	
1	WED	09		1018			1.71	1.71		0.00	S	1	1	
1		09		1955			1.55	1.56		0.01		25 kn	2	
1	THURS	10		1038			1.86	1.87		0.01	SW	10	1	
	THURS	10		2129			1.50	1.49		0.01	SW	—	—	

I HEREBY CERTIFY that the information given on this sheet and on the Automatic Gauge record, is correct and that I personally attended to the duties with the exception of the dates stated on the back of this report.

Signed ....
Gauge Attendant

* NOTE TO HYDROGRAPHERS. The average difference in column (11) is entered as (+) in section 1A or (−) in section 1B of Form TWL−502 if the reading on the staff gauge, column (9), is greater than on the diagram, column (10) and vice versa.

LOUISBOURG, NOVA SCOTIA				STATION
OBSERVED TIDES				600
OCTOBER 6 TO 12, 1996				
(Water Level (WLvl) is used to plot observed tides)				
Date	Hour	Days	WCol(cm)	WLvl(cm)
yyyy mm dd	hh mm ss	Decimal	Group1	Group1
1996/10/06	0:00:00	6.00	91.42	84.2
1996/10/06	0:15:00	6.01	93.46	86.23
1996/10/06	0:30:00	6.02	91.82	84.59
1996/10/06	0:45:00	6.03	90.42	83.19
1996/10/06	1:00:00	6.04	91.44	84.22
1996/10/06	1:15:00	6.05	90.42	83.19
1996/10/06	1:30:00	6.06	92.12	84.89
1996/10/06	1:45:00	6.07	96.44	89.21
1996/10/06	2:00:00	6.08	95.73	88.51
1996/10/06	2:15:00	6.09	100.43	93.2
1996/10/06	2:30:00	6.10	104.23	97.01
1996/10/06	2:45:00	6.11	106.21	98.99
1996/10/06	3:00:00	6.12	115.2	107.97
1996/10/06	3:15:00	6.14	117.03	109.81
1996/10/06	3:30:00	6.15	120.51	113.28
1996/10/06	3:45:00	6.16	123.41	116.18
1996/10/06	4:00:00	6.17	126.04	118.81
1996/10/06	4:15:00	6.18	133.37	126.14
1996/10/06	4:30:00	6.19	136.93	129.71
1996/10/06	4:45:00	6.20	140.34	133.11
1996/10/06	5:00:00	6.21	141.64	134.41
1996/10/06	5:15:00	6.22	149.17	141.95
1996/10/06	5:30:00	6.23	146.17	138.94
1996/10/06	5:45:00	6.24	151.02	143.79
1996/10/06	6:00:00	6.25	148.11	140.88
1996/10/06	6:15:00	6.26	150.44	143.21
1996/10/06	6:30:00	6.27	153.79	146.57
1996/10/06	6:45:00	6.28	149.26	142.03
1996/10/06	7:00:00	6.29	152.86	145.63
1996/10/06	7:15:00	6.30	150.08	142.85
1996/10/06	7:30:00	6.31	152.92	145.69
1996/10/06	7:45:00	6.32	147.98	140.75
1996/10/06	8:00:00	6.33	146.89	139.66
1996/10/06	8:15:00	6.34	144.48	137.25
1996/10/06	8:30:00	6.35	142.32	135.09
1996/10/06	8:45:00	6.36	139.77	132.54
1996/10/06	9:00:00	6.37	133.63	126.4
1996/10/06	9:15:00	6.38	132.13	124.9

Date	Hour	Days	WCol(cm)	WLvl(cm)
yyyy mm dd	hh mm ss	Decimal	Group1	Group1
1996/10/06	9:30:00	6.40	130.27	123.04
1996/10/06	9:45:00	6.41	124.87	117.64
1996/10/06	10:00:00	6.42	122.95	115.73
1996/10/06	10:15:00	6.43	119.29	112.06
1996/10/06	10:30:00	6.44	115.21	107.98
1996/10/06	10:45:00	6.45	112.1	104.88
1996/10/06	11:00:00	6.46	104.34	97.11
1996/10/06	11:15:00	6.47	104.99	97.76
1996/10/06	11:30:00	6.48	98.28	91.05
1996/10/06	11:45:00	6.49	97.55	90.32
1996/10/06	12:00:00	6.50	95.79	88.57
1996/10/06	12:15:00	6.51	93.44	86.21
1996/10/06	12:30:00	6.52	90.05	82.82
1996/10/06	12:45:00	6.53	86.15	78.93
1996/10/06	13:00:00	6.54	84.15	76.93
1996/10/06	13:15:00	6.55	86.39	79.17
1996/10/06	13:30:00	6.56	84.73	77.5
1996/10/06	13:45:00	6.57	84.97	77.74
1996/10/06	14:00:00	6.58	85.46	78.23
1996/10/06	14:15:00	6.59	90.04	82.81
1996/10/06	14:30:00	6.60	90.47	83.24
1996/10/06	14:45:00	6.61	91.9	84.68
1996/10/06	15:00:00	6.62	93.57	86.34
1996/10/06	15:15:00	6.63	96.2	88.97
1996/10/06	15:30:00	6.64	98.7	91.47
1996/10/06	15:45:00	6.66	102.72	95.49
1996/10/06	16:00:00	6.67	105.79	98.56
1996/10/06	16:15:00	6.68	107.32	100.09
1996/10/06	16:30:00	6.69	111.84	104.61
1996/10/06	16:45:00	6.70	117.08	109.85
1996/10/06	17:00:00	6.71	119.04	111.81
1996/10/06	17:15:00	6.72	122.72	115.49
1996/10/06	17:30:00	6.73	127.34	120.12
1996/10/06	17:45:00	6.74	126.81	119.58
1996/10/06	18:00:00	6.75	128.79	121.57
1996/10/06	18:15:00	6.76	130.65	123.42
1996/10/06	18:30:00	6.77	135.44	128.21
1996/10/06	18:45:00	6.78	137.16	129.94
1996/10/06	19:00:00	6.79	133.84	126.61
1996/10/06	19:15:00	6.80	136.45	129.22
1996/10/06	19:30:00	6.81	134.28	127.06
1996/10/06	19:45:00	6.82	134.9	127.68
1996/10/06	20:00:00	6.83	132.94	125.71
1996/10/06	20:15:00	6.84	130.19	122.97

Date	Hour	Days	WCol(cm)	WLvl(cm)
yyyy mm dd	hh mm ss	Decimal	Group1	Group1
1996/10/06	20:30:00	6.85	127.09	119.86
1996/10/06	20:45:00	6.86	126.75	119.52
1996/10/06	21:00:00	6.87	122.35	115.12
1996/10/06	21:15:00	6.88	123.97	116.74
1996/10/06	21:30:00	6.89	116.22	108.99
1996/10/06	21:45:00	6.90	116.49	109.26
1996/10/06	22:00:00	6.92	110.85	103.62
1996/10/06	22:15:00	6.93	109.5	102.27
1996/10/06	22:30:00	6.94	102.54	95.31
1996/10/06	22:45:00	6.95	100.34	93.12
1996/10/06	23:00:00	6.96	98.21	90.99
1996/10/06	23:15:00	6.97	93.51	86.28
1996/10/06	23:30:00	6.98	91.53	84.3
1996/10/06	23:45:00	6.99	88.01	80.78
1996/10/07	0:00:00	7.00	84.47	77.25
1996/10/07	0:15:00	7.01	82.91	75.68
1996/10/07	0:30:00	7.02	80.46	73.23
1996/10/07	0:45:00	7.03	79.22	72
1996/10/07	1:00:00	7.04	76.37	69.14
1996/10/07	1:15:00	7.05	78.75	71.53
1996/10/07	1:30:00	7.06	76.04	68.82
1996/10/07	1:45:00	7.07	80.72	73.49
1996/10/07	2:00:00	7.08	77.81	70.58
1996/10/07	2:15:00	7.09	79.15	71.93
1996/10/07	2:30:00	7.10	81.54	74.32
1996/10/07	2:45:00	7.11	82.87	75.64
1996/10/07	3:00:00	7.12	89.5	82.27
1996/10/07	3:15:00	7.14	87.83	80.6
1996/10/07	3:30:00	7.15	96.01	88.78
1996/10/07	3:45:00	7.16	100.14	92.91
1996/10/07	4:00:00	7.17	103.7	96.47
1996/10/07	4:15:00	7.18	104.01	96.78
1996/10/07	4:30:00	7.19	110.16	102.93
1996/10/07	4:45:00	7.20	115.52	108.29
1996/10/07	5:00:00	7.21	117.73	110.5
1996/10/07	5:15:00	7.22	123.53	116.3
1996/10/07	5:30:00	7.23	128.85	121.62
1996/10/07	5:45:00	7.24	130.25	123.02
1996/10/07	6:00:00	7.25	138.57	131.34
1996/10/07	6:15:00	7.26	135.74	128.51
1996/10/07	6:30:00	7.27	142.59	135.37
1996/10/07	6:45:00	7.28	141.43	134.2
1996/10/07	7:00:00	7.29	145.73	138.5
1996/10/07	7:15:00	7.30	149.33	142.1

Date	Hour	Days	WCol(cm)	WLvl(cm)
yyyy mm dd	hh mm ss	Decimal	Group1	Group1
1996/10/07	7:30:00	7.31	150.54	143.32
1996/10/07	7:45:00	7.32	153.16	145.94
1996/10/07	8:00:00	7.33	149.18	141.95
1996/10/07	8:15:00	7.34	152.1	144.87
1996/10/07	8:30:00	7.35	149.47	142.24
1996/10/07	8:45:00	7.36	151.41	144.18
1996/10/07	9:00:00	7.37	146.42	139.19
1996/10/07	9:15:00	7.38	148.14	140.91
1996/10/07	9:30:00	7.40	138.72	131.5
1996/10/07	9:45:00	7.41	144.04	136.81
1996/10/07	10:00:00	7.42	135.83	128.6
1996/10/07	10:15:00	7.43	135.69	128.47
1996/10/07	10:30:00	7.44	132.93	125.7
1996/10/07	10:45:00	7.45	126.83	119.6
1996/10/07	11:00:00	7.46	125.15	117.92
1996/10/07	11:15:00	7.47	118.8	111.57
1996/10/07	11:30:00	7.48	118.86	111.63
1996/10/07	11:45:00	7.49	115.75	108.52
1996/10/07	12:00:00	7.50	112.27	105.04
1996/10/07	12:15:00	7.51	107.94	100.72
1996/10/07	12:30:00	7.52	105.05	97.82
1996/10/07	12:45:00	7.53	106.43	99.21
1996/10/07	13:00:00	7.54	105.46	98.24
1996/10/07	13:15:00	7.55	97.52	90.3
1996/10/07	13:30:00	7.56	95.23	88
1996/10/07	13:45:00	7.57	95.87	88.64
1996/10/07	14:00:00	7.58	97.12	89.9
1996/10/07	14:15:00	7.59	96.02	88.8
1996/10/07	14:30:00	7.60	96.03	88.8
1996/10/07	14:45:00	7.61	95.96	88.73
1996/10/07	15:00:00	7.62	96.62	89.39
1996/10/07	15:15:00	7.63	101.9	94.67
1996/10/07	15:30:00	7.64	103.15	95.93
1996/10/07	15:45:00	7.66	108.23	101
1996/10/07	16:00:00	7.67	102.27	95.04
1996/10/07	16:15:00	7.68	114.01	106.78
1996/10/07	16:30:00	7.69	109.83	102.6
1996/10/07	16:45:00	7.70	124.02	116.8
1996/10/07	17:00:00	7.71	124.8	117.57
1996/10/07	17:15:00	7.72	127.25	120.02
1996/10/07	17:30:00	7.73	130.55	123.32
1996/10/07	17:45:00	7.74	138.85	131.62
1996/10/07	18:00:00	7.75	142.78	135.55
1996/10/07	18:15:00	7.76	143.97	136.74

APPENDIX 3

COASTAL GPS SURVEYS

Louisbourg, Nova Scotia

REFERENCE STATION	PT#	INFORMATION	Northing	Easting	Elevation(m)	NO SATS	PDOP	TIME SPN	S DEV	SIG HT	PCODE
REF STN=CONTROL MARKER 1675 LOUISBOURG LIGHT			(Corrected)	(Corrected)	(Corrected)						
DATE=10-20-1996											
TIME=09:25:39 (AST)	1	LOUISBOURG LIGHT	5088169.99	735916.717	18.563	7	2.01	2	0.012	2.000	TEST SE SIDE OF LIGHTHOUSE
UNITS=0013	2	W EDGE RK OUTCROP BY ROAD	5088157.41	735832.083	8.451	7	2.27	2	0.009	2.000	LOUISBG LIGHTHOUSE
WGS84-X=2225788.831											
WGS84-Y=-3848521.739	5	W EDGE RK OUTCROP BY SEA	5088088.41	735871.926	6.384	8	1.59	2	0.007	2.000	LOUISBG LIGHTHOUSE
WGS84-Z=4557981.045	6	PHOTO 93300132-RK OUTCROP OFFSHORE (PT	5088112.19	735489.136	3.239	8	1.97	2	0.01	2.000	LIGHTHOUSE PICNIC AREA
NORTH N83=5088116.976	7	RK OUTCROP BY RD INTERSECTION	5088392.17	735369.713	11.405	7	2.34	2	0.01	2.000	LIGHTHOUSE PICNIC AREA
EAST N83=736013.706	8	N EDGE RD INTERSECTION TO PICNIC AREA	5088403.73	735355.187	10.346	7	2.46	2	0.013	2.000	LIGHTHOUSE PICNIC AREA
ELEV=-13.347	9	EDGE VEG AND RK OUTCROP	5088770.2	735201.283	4.389	8	2.11	2	0.009	2.000	OLD RAILWAY POINT
IH=0.920	10	NE CORNER OF WHARF	5089094.13	735402.405	2.542	7	2.87	2	0.012	2.000	WHARF1
CONROL MARKER 1675 CAP	11	Y JUNCTION OF TWO ROADS	5089051.23	735589.704	16.466	5	3.19	6	0.013	2.000	ROAD1
Corr Elev=16.565m											
Correct UTMS	13	N EDGE CONCRETE WALL	5089975.45	735638.868	2.665	9	2.21	2	0.009	2.000	RIVER OUTLET AT BRIDGE
North N83=5088146.370	14	EDGE SIDEWALK AT ROAD /HWY JUNC	5090031.12	735388.507	8.246	6	4.57	2	0.019	2.000	LOUISBOURG TOWN
East N83=736023.090	15	GOVT WHARF INNER T-JUNC OF WHARF	5089256.64	734914.003	2.944	6	4.27	2	0.017	2.000	LOUISBOURG TOWN
ZONE 20											
TIME=10:06:46 TO 11:44:22 (AST)											

REFERENCE STATION	PT#	INFORMATION	Northing	Easting	Elevation(m)	NO SATS	PDOP	TIME SPN	S DEV	SIG HT	PCODE
REF STN=CONTROL MARKER 2094, BLACK ROCK											
DATE=10-25-1996	500	GSC 500 CAP	5085902.73	734445.428	7.564	7	2.23	2	0.009	2.000	SHORE MONIT. SITE 1532
TIME=11:42:09 (AST)	501	TOP CLIFF EDGE	5085893.18	734445.326	7.393	7	2.2	2	0.009	2.000	SHORE MONIT. SITE 1532
UNITS=0013	502	SW CORNER OF STONE WALL	5086530.53	734183.671	3.238	6	2.98	2	0.012	2.000	LOUISBG FORTRESS, RD INTERSECT
WGS84-X=2225162.244	503	W END OLD CAUSEWAY IN WATER	5086597.29	734299.957	0.498	8	1.81	2	0.007	2.000	MAUREPAS BASTION
WGS84-Y=-3850650.063	504	E END OLD CAUSEWAY IN WATER	5086661.23	734320.83	0.459	8	1.77	4	0.008	2.000	MAUREPAS BASTION
WGS84-Z=4556537.134	505	SITE 1541 TOP IRON ROD	5086708.42	734347.78	3.802	8	1.75	2	0.012	2.000	SW CONTROL MKER, GRAND ETANG
NORTH N83=5085953.941	506	NE CORNER	5086719.88	734586.103	3.071	7	2.11	2	0.009	2.000	OLD RANGE LIGHT FOUNDATION
EAST N83=734486.709	507	BM SITE 1540 CRN CONCRETE	5086719.74	734589.35	3.784	7	2.08	2	0.008	2.000	OLD RANGE LIGHT FOUNDATION
ELEV=13.900	508	SE CORN BALL MONUMENT	5086586.67	734555.196	3.916	8	1.79	2	0.007	2.000	SITE 1536
IH=1.010	509	TOP S CORN	5086492	734409.757	4.486	8	1.71	3	0.007	2.000	POWDER MAGAZINE
BLACK ROCK, 1100 (AST); DAY 299	510	TOP SE CORN	5086502.72	734406.72	4.617	8	1.71	2	0.007	2.000	POWDER MAGAZINE
CONTROL SURV MARKER 2094	511	TOP NE CORN	5086497.6	734389.304	4.508	8	1.71	2	0.014	2.000	POWDER MAGAZINE
CORRECTIONS	512	TOP NW CORN	5086486.93	734392.693	4.62	8	1.71	2	0.007	2.000	POWDER MAGAZINE
ELEV=13.0	513	TOP INNER CORN	5086443.34	734363.392	5.247	8	1.69	3	0.007	2.000	SITE 1535 BROULLION BASTION
NORTHN83= 5085932.243	514	NE END NEWTON MON	5086593.99	734526.415	4.677	8	1.66	2	0.013	2.000	SITE 1536 MONUMENTS
EAST N83=734481.365	515	E END SOC OF COL WARS 1936 MON (ON W SI	5086604.22	734520.387	4.925	7	2.65	2	0.011	2.000	SITE 1536 MONUMENTS
ZONE 20	516	S END OF FRENCH CROSS MON E SIDE OF RC	5086649.68	734525.792	4.226	8	1.62	2	0.007	2.000	SITE 1536 MONUMENTS
	517	WD STICK EDGE OF POND	5086782.54	734821.071	4.322	7	1.78	2	0.011	2.000	SHORE MONIT SITE 1539
	518	GSC CAP 497	5086717.01	734745.573	4.434	6	2.19	2	0.009	2.000	SHORE MONIT SITE 1538
	519	INNER CORNER T-JUNCTION	5089256.53	734914.019	2.957	6	2.27	2	0.009	2.000	GOVT WHARF
	520	CONROL MARKER 1675 CAP	5088146.42	736023.104	16.566	6	2.38	4	0.05	2.000	LOUISBOURG LIGHTHOUSE AREA

APPENDIX 4

LIST OF CHARTS AND AIR PHOTOS

Topographic maps:

1: 50,000 National Topographic Series, Map 11 G/13 (edition 5) 1991.

Air photos:

1993 (colour) 1:10,000 scale (June 13, 1993):

Flight line 93300 - colour photos	76 to 79
	130 to 133
	153 to 154
	and 207.

Charts:

Canadian Hydrographic Chart 4376, 1987 edition reprinted in 1995. Scale 1:9600 Polyconic projection, NAD 27.

APPENDIX 5

PROCESSING INFORMATION EM3000 SONAR DATA

C.S.L. *PETREL* 96-001

Louisbourg, Nova Scotia

Multibeam Bathymetry Processing Information for C.S.L. Petrel 96-001, Louisbourg Harbour

Prepared by TekMap Consulting, November 1996

- Survey lines from day 280 to 284 were processed (October 6 to October 10).
- Due to software and / or hardware limitations the dataset was broken into two sections for processing.
- The first section, the Inner Harbour, consisted of the following days / lines:
  - ⇒ *Day 280 - Line 5*
  - ⇒ *Day 281 - Lines 25 to 40*
  - ⇒ *Day 283 - All Lines*
  - ⇒ *Day 284 - All Lines*
- This section makes up in excess of 76 million data points and requires approx. 2.2 GB of temporary storage for processing.
- The second section, the Harbour Entrance and Approaches, consisted of the following days / lines:
  - ⇒ *Day 281 - Lines 0 to 24*
  - ⇒ *Day 281 - Lines 41 to 42*
  - ⇒ *Day 282 - All Lines*
- This section makes up in excess of 32 million data points.
- A number of lines with bad navigation were eliminated from the dataset. These lines are:
  - ⇒ Day 283 - Lines: 12,13, 14, 19, and 20.
- Line 46 on Day 284 possesses bad data (navigation), however most of the line was good. To eliminate the bad portion the entire line was processed individually, and the bad portion was masked out.
- A line from the second section which overlaps the first section makes a poor match and is masked out. This line is the cause of the rectangular depression visible on the first dataset (2 meter resolution). This difference between data sections is probably attributable to tidal errors.
- Due to software limitations Lines 65 and 66 were not processed in the first section. The software appears to stop processing at approx. 76 million points ?? These two lines were gridded separately and later merged with the final dataset.
- All data sections were merged using a simple average between coincident data points.
- No data exists for Lines 38, 39, 40, and 41 on Day 282.
- The data was gridded at a 1x1 meter horizontal resolution using predicted tide data.
- Data was gridded in a UTM projection, zone number 20, using a horizontal datum of WGS84 (NAD83).
- Illumination was added using a sun altitude of 45° and a sun azimuth of 250°.

APPENDIX 6

LIST OF ARCHIVAL DATA AT GEOLOGICAL SURVEY OF CANADA (ATLANTIC)

C.S.L. *PETREL* 96-001
Louisbourg, Nova Scotia

Data Archived at:
Geological Survey of Canada (Atlantic)
Bedford Institute of Oceanography,
PO. Box 1006, Dartmouth,
Nova Scotia, B2Y 4A2

Contact Person: Susan Merchant tel: 902-426-3410,
e-mail: merchant@agc.bio.ns.ca

List of Material

Exabyte Tapes

	Day	Information
1	280	TAR of all data Louisbourg test runs EM3000
2	281	Louisbourg Harbour Survey
3	281	Louisbourg Harbour Survey
4	282	Louisbourg Harbour Survey
5	283	Louisbourg Harbour Survey
6	283/284	Louisbourg Harbour Survey, Lines 63-66
7	283/284	Louisbourg Harbour Survey

Computer 3.5" Diskettes

1	Observed Tides Louisbourg, Nova Scotia	Station 600	October 6,7, 1996
2	Observed Tides Louisbourg, Nova Scotia	Station 600	October 8, 1996
3	Observed Tides Louisbourg, Nova Scotia	Station 600	October 9, 1996
4	Observed Tides Louisbourg, Nova Scotia	Station 600	October 10, 1996
5	Predicted Tides Louisbourg, Nova Scotia	Station 600	October 1996
6	EM 3000 survey planning lines for AGC Nav, CSL *Petrel* 96-001, Oct. 6-12 Louisbourg, Nova Scotia		