A MULTI-FACETED ACOUSTIC GROUND-TRUTHING EXPERIMENT IN THE BAY OF FUNDY

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ABSTRACT

The University of New Brunswick Ocean Mapping Group has recently begun a three-year project entitled "Hydrographic Ground Truthing". Prompted by the growing use of sweep and swath-mapping systems for hydrographic surveys, the goal of the project is to establish the spatial transfer function between swath-map data and actual bathymetry, as well as to evaluate the use of sweep and swath-map data for the remote identification and classification of seafloor materials. Because of its large tidal range (up to 16 m), the Bay of Fundy is an ideal area in which to address these questions. By carefully choosing times and survey areas, we were able to map the seafloor with a variety of acoustic systems during high tides and conduct physical surveys and remote sensing measurements during low tides. Our first field season (between June and September) saw 23 organizations (ten companies, four Canadian federal agencies, the U.S. Naval Research Lab, three provincial departments, and three universities participate in surveys of three sites in the Bay of Fundy (Saint John Harbor, Passamaquoddy Bay and Parrsboro approaches). Acoustic systems used included Navitronics Seadig sweep system, Simrad EM-1000 multibeam system, Simrad Mesotech 992 and Klein sidescan sonars, Chirp subbottom profiler, and IKB Seistec subbottom profiler. Low-tide work included: detailed mapping of topographic features and sediment distribution; the placement, at known locations, of specially designed acoustic targets with known acoustic properties; sampling of seafloor materials, aerial photography, airborne multispectral imagery (CASI), and satellite imagery. Sampling in subtidal areas included grab and gravity cores; in Saint John Harbor, Chirp and Seistec data were collected over the site of several boreholes that had been sampled to depths of 18 m below the seafloor. All surveys were precisely navigated with either a PolarFix laser ranging system or differential GPS. More than 8 Gigabytes of acoustic data has been collected to date. We have begun the quantitative analyses of the various acoustic data sets for sediment property information and are devising ways of quantitatively comparing and visualizing such huge multivariate data sets. Most promising is the use of a Geographical Information System capable of handling both vector and raster data for the input of each data set as a separate layer, as well as the use of interactive 3D animation tools that allow the user to interactively explore complex data sets by "flying" through them.

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1. INTRODUCTION

Bathymetric data has been a cornerstone of our exploration and utilization of the oceans. Through its definition of the hypsometry and morphology of the seafloor, bathymetry has provided us with a fundamental understanding of earth and ocean processes; in shallow waters, accurate bathymetry is essential to safe navigation and national security. Despite the importance of bathymetric information, the vastness and remoteness of even shallow seas have presented technological challenges that have severely limited our ability to accurately map the seafloor. Indeed, for the first 350 of the 400 years that systematic bathymetric surveys have been conducted, the major technological achievement in this field was the replacement of the use of hemp leadlines with steel wire (Thompson [1]). With the introduction of the echo-sounder in the late 1920's bathymetric charting took a great leap forward, but despite subsequent refinements in transducer and receiver design, timing circuits and digital acquisition, single channel echo sounders still provide a relatively inaccurate depiction of a limited area of the seafloor.

In the mid-1960's the development of sweep (e.g., Navitronics MCS) and swath (e.g., SeaBeam; Farr[2]) mapping technology began to directly address the issues of bathymetric resolution and areal coverage. In the last few years, advances in beamforming, interferometry, and processing technology have led to the development of "hybrid" multibeam systems capable of simultaneously collecting both high-resolution bathymetric and acoustic backscatter data (e.g., Simrad EM-1000, SeaBeam 2000). These systems are capable of along-track resolution of less than two degrees and vertical resolution on the order of less than one percent of the water depth; swath widths of up to 7.5 times the water depth have been obtained, approaching the theoretical limit of swath size.

As these new systems come into more common use, particularly for hydrographic applications, it is becoming increasingly important to understand their accuracy and limitations. In addition, there is growing awareness of the potential to use these systems to go beyond just measurement of depth, but also to retrieve quantitative information about seafloor properties and characteristics. In order to directly address these issues, the Ocean Mapping Group at the University of New Brunswick, in conjunction with a number of collaborating agencies, recently began a three-year "Hydrographic Ground-Truthing Experiment" designed to study the relationship between acoustic measurements of the seafloor and true seabed characteristics (topography, texture, composition). The specific objectives of the experiment are:

1- To understand the spatial transfer function between seafloor topography and acoustic swathmap data and;
2- To evaluate the potential for extracting seafloor property information from acoustic data.

In order to meet these objectives, the experiment takes advantage of the very large tidal ranges in the Bay of Fundy which allow for acoustic surveys at high tide and direct mapping and sampling at low tide. This paper will describe the first phase of this experiment (HYGRO-92), present some very initial results (the first phase was only completed a few months ago), and discuss plans for future work.

2. THE BAY OF FUNDY

The Bay of Fundy is an approximately 300 km long, 50 km wide embayment bounded by the Canadian province of Nova Scotia on its east, and the province of New Brunswick and the U.S. state of Maine on its west (Fig 1). The near resonant response of the Bay of Fundy-Gulf of Maine system results in the world's highest tides with tidal ranges greater than 16 m in the upper reaches of the Bay (Ku et al. [3]). This remarkable tidal range presents the opportunity to acoustically map parts of the Bay of Fundy seafloor with relatively large vessels at high tide, and yet still be able to directly walk upon and sample the same seafloor at low tide, thus directly "ground truthing" the acoustic measurements. Ideally, such an experiment would be carried out in a region that: 1) contained a wide range of sediment types in a relatively constrained area that did not vary through a tidal cycle; 2) permitted easy access for mapping and sampling and; 3) had a maximum tidal range to allow all sonar measurements to be made in the acoustic far field. Unfortunately no one area in the Bay of Fundy meets all of these criteria and thus the Hydrographic Ground-Truthing Experiment was distributed over three regions -- Saint John Harbor, Parrsboro Approaches and Passamaquoddy Bay (Fig.1). After a general description of the experiment, preliminary results from each of these areas will be presented.

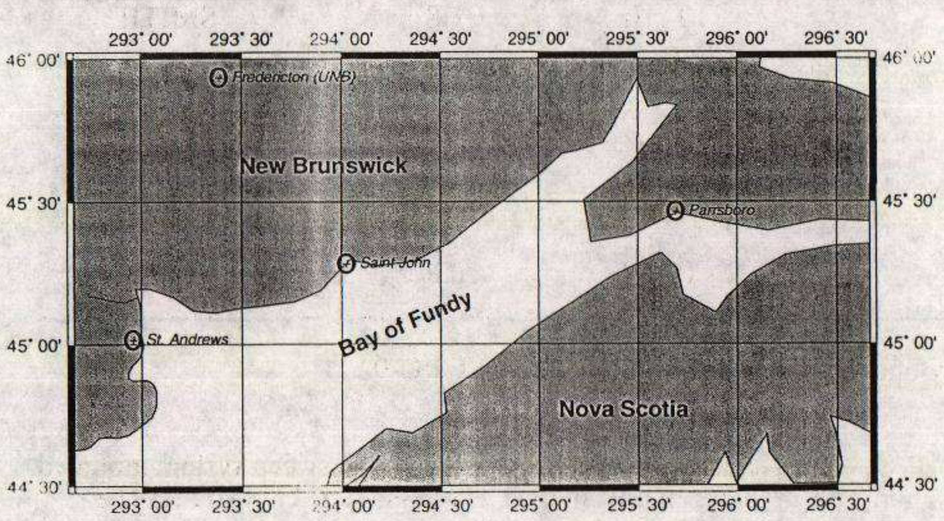

Figure 1. Location map of Hydrographic Ground-Truthing Experiment. Subtract longitudes on map from 360° to get longitude in degrees west

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3. OVERVIEW OF THE EXPERIMENT

Under the guidance of the Ocean Mapping Group, 23 organizations (ten companies, four Canadian federal agencies, the U.S. Naval Research Lab, three provincial departments, and three universities cooperated and collaborated in the first field season of the Hydrographic Ground-Truthing Experiment (HYGRO-92). In particular, the Canadian Hydrographic Service provided two major survey vessels, the F.C.G. SMITH, equipped with a Navitronics sweep system and, the F.G. CREED, equipped with an EM-1000 multibeam system. These vessels also served as platforms for other acoustic systems as did the University of New Brunswick's own research vessel MARY-O. The field program began in June of 1992 and continued well into October. Intensive shipboard operations were focussed around those periods with maximum high tide; groundtruth measurements were made during periods of maximum low tide.

3.1 High-Tide Experiments (Acoustic Surveys):

During periods of high tide, acoustic surveys were carried out using two bathymetric acoustic systems (Navitronics and EM-1000), a new, dual-frequency sidescan sonar (Mesotech 992) and two high-resolution subbottom profiling systems (Chirp Sonar and IKB Seistec) (Table 1). Not all systems were deployed in all regions -- this will be discussed in more detail below.

SYSTEM	FREQUENCY	OWNER	VESSEL
Navitronics	210 kHz	CHS	SMITH
EM-1000	95 kHz	CHS	CREED
Mesotech 992	120/330 kHz	Simrad	SMITH
Chirp Sonar	2 - 10 kHz	FAU	SMITH
IKB Seistec	2 - 10 kHz	AGC	MARY-O

Table 1. Summary of acoustic systems used during HYGRO-92

3.1.1.Navitronics MCS -- The Navitronics MCS is a multichannel sweep system mounted on a specially designed 34.8 m long catamaran, the CHS vessel F.C.G. SMITH. The vessel is fitted with 33 narrow beam (7°) transducers deployed on booms that result in a fixed swath width of approximately 44 m and 100% bottom coverage in water depths greater than about 7 m (Fig 2). The system aboard the SMITH operates at 210 kHz with pulse width and duty cycle selectable by the operator. Depths are digitally logged onto tape (Burke and Forbes[4]).

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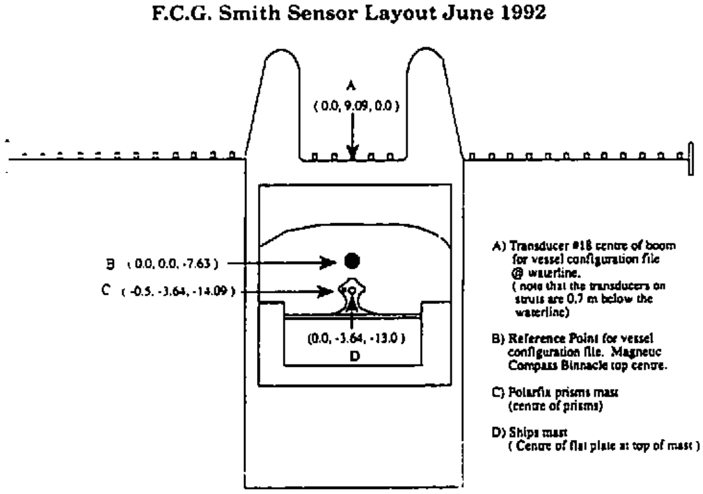

Fig. 2. Diagram of Navitonics transducer configuration on F.C.G. SMITH

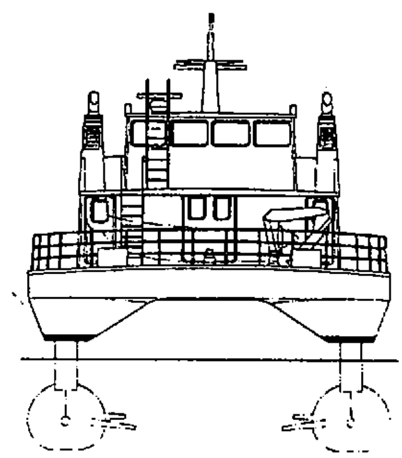

Fig. 3. Diagram of SWATH vessel F.G. CREED.

3.1.2. EM-1000 -- The EM-1000 is a multibeam swath system produced by Simrad. It represents an extension of their EM-100, and in shallow water (< 200 m) forms 60 beams with 2.5° spacing using interferometry to extend effective swath coverage to approximately 7.5 times water depth. In addition to travel time information, the EM-1000 also produces a time-series of echo-amplitude data resulting in co-registered acoustic imagery (see Hughes Clarke [5]). The system used during HYGRO-92 is mounted on the CHS vessel F.G. CREED, a SWATH (Small Water Area Twin Hull) vessel capable of surveying at speeds in excess of 15 knots (Fig 3).

3.1.3. Other Acoustic Systems -- In addition to the systems described above, Simrad/Mesotech provided a EM-992 dual-frequency sidescan sonar for evaluation during the early part of the experiment. This system was operated from the SMITH, and its data logged on a multichannel DAT recorder. Two high-resolution subbottom profiling systems were also deployed in the course of HYGRO-92. The Chirp Sonar (LeBlanc, Mayer, Rufino, Shock, and King[6]) is a quantitative broad-band profiler that uses a swept FM pulse and matched filter processing to produce high-resolution subbottom profiles and quantitative estimates of sediment properties. A new, SPARC-station based processing system developed by workers at Florida Atlantic University was used to capture and process Chirp Sonar data during the experiment. Finally, a second high-resolution subbottom profiler, the IKB Seistec, was also deployed during the experiment. The Seistec, provided by the Atlantic Geoscience Center of the Geological Survey of Canada, is a surface towed profiler that uses a boomer as the seismic source and a line-in-cone array as a receiver. The directionality resulting from the line-in-cone receive array results in relatively noise-free, high-resolution records.

4.2 Low-tide Operations --
During low tide periods a number of ground truthing operations were conducted (Table 2).

LOW-TIDE PROGRAMS
- Detailed topographic surveys
- Feature and sediment distribution mapping
- Sampling of various sediment types
- Deployment of acoustic targets
- Aerial photos
- Multi-spectral imagery (CASI)
- ERS-1 Satellite imagery
- Airborne SAR Imagery

Table 2.

3.2.1 Low-tide Mapping -- In those intertidal areas that are accessible, we have used standard terrestrial survey techniques to begin to accumulate a database of topographic and seafloor material type information that can be precisely compared to our acoustic measurements. We have taken advantage of our association with a Surveying Engineering department to send survey teams into the tidal flats using electronic distance measuring equipment to provide centimeter-accuracy elevation and position information. We have used these same techniques to precisely map out exposed boundaries of various sediment types and to locate the position of samples representative of these seafloor materials.

In addition to looking at the natural variability of the seafloor, we also deployed a series of man-made acoustic targets of various shapes, sizes and known acoustic characteristics. These targets included: two linear arrays of air-filled spheres (15 cm and 30 cm in diameter), some anchored on the seafloor and others anchored above the seafloor (as part of a scattering experiment conducted by Tim Stanton of WHOI); two arrays of PVC pipes of various lengths (one set 15 cm in diameter, the other 30 cm in diameter) standing upright on the seafloor with a cap of ensolite foam on their top ends (creating acoustic "steps"); two large (approximately 250 x 250 cm) ensolite foam covered flat surfaces (one anchored on the bottom, the other floating above) that served as specular reflectors; and a large, cylindrical, mine-like object. The position and elevation of each of these targets was also determined using the electronic measuring system.

3.2.2 Imagery -- In order to provide additional datasets against which to compare our acoustic high-tide measurements, we also imaged the same areas at low-tide using several remote sensing systems. Calibration targets were placed in the intertidal area and low-altitude (300 m) color aerial photographs collected. From photogrammetric analysis of these photos we hope to obtain decimeter-accuracy topographic maps of the intertidal regions. In addition to standard aerial photos, the U.S. Naval Research Lab sponsored flights of CASI (Compact Airborne Spectrographic Imager), a multi-spectral scanner capable of being used as a 288-band spectrometer or of providing any 15 visible and infrared bands with spatial resolution down to 2 m (Borstad[7]). This small, portable system was deployed from a local, unspecialized aircraft and flown over the intertidal areas at low-tide at an altitude of approximately 300 m.

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At approximately the same time that the CASI was being flown, the ERS-1 satellite flew above some of our intertidal areas. While the resolution of the ERS-1 imagery may be more than an order of magnitude less than that of the CASI, and certainly many times less than that of our acoustic measurements, it can provide a general overview of the distribution of material type in the intertidal region (Tittley[8]). Finally, we have identified historical Airborne C-band Narrow Mode SAR imagery (collected by the Canadian Center for Remote Sensing) that has been flown over some of our areas. These data have been requested from CCRS.

3.3 Sub-tidal Programs

At those sites that have limited intertidal areas, we have provided ground truth through the sampling of seafloor materials by grab or gravity cores. Recovered cores will be analyzed for a full suite of physical and acoustic properties. We have also sponsored the development of an underwater camera system that collects overlapping stereo photographs in a 30 m spiral around a central location. If this system proves feasible, it should provide the photographic base upon which to build a centimeter-accuracy DTM that can be used to understand several scales of acoustic roughness in subtidal regions.

3.4 Navigation and Co-registration of Datasets

Our ability to draw meaningful conclusions from the comparison of the acoustic measurements to the ground truth measurements will be determined, to a large degree, by our ability to precisely determine the relative positions of these measurements. For this reason, great care was taken to insure the best possible navigation for each of our surveys. All work conducted on the SMITH (Navitronics, Chirp Sonar, Mesotech-992) was positioned by a POLARFIX laser ranging system with decimeter accuracy. Work from the CREED (EM-1000) and from the MARY-O (Seistec, coring) was positioned with Differential GPS (one to five m accuracy). Field mapping and sampling was positioned with an Electronic Distance Measurement system, also with centimeter accuracy. Common control points were used for all surveys.

The aerial photographs (which have precisely positioned calibration targets in them) as well as airborne and satellite imagery will be co-registered with the aid of a sophisticated Geographical Information System (CARIS; Smart[9]) that permits the input of both raster and vector datasets and has a series of tools that facilitate co-registration (e.g. Fig 4). The GIS will become an essential component in the analyses of these massive and complex data sets, allowing us to create a series of layers, each representing a particular type of measurement (e.g., a layer of digital acoustic backscatter measurements, a layer of acoustically derived bathymetry, another of measured sediment type, another of measured topography, etc). With the GIS we can quantitatively compare similarities and differences amongst these layers and begin to address the primary objectives of the Hydrographic Ground-Truthing Experiment.

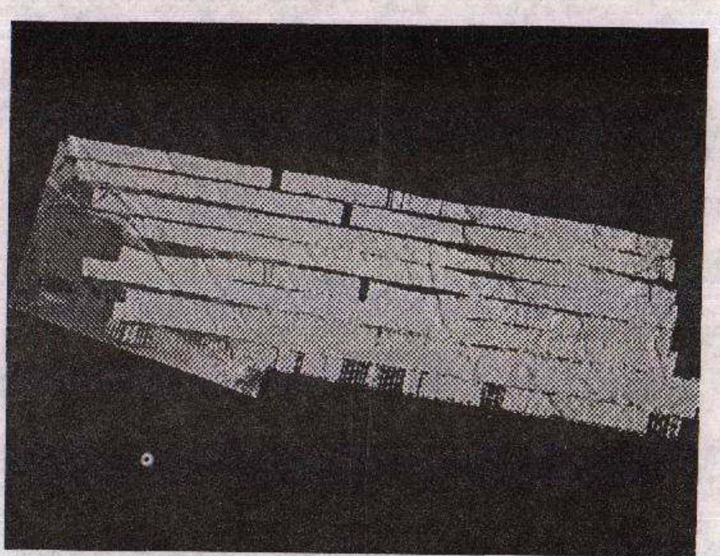

Figure 4. Selected EM-1000 sonar imagery lines co-registered with digitized aerial photo from intertidal area of Parrsboro. Co-registration was done with CARIS/CRIS.

4. PRELIMINARY RESULTS

In presenting initial results of HYGRO-92 we must emphasize that these are very preliminary. Between June and October we collected over 8 Gigabytes of acoustic data alone and are only now beginning to come to grips with the massive data handling and processing tasks facing us. Nonetheless we have processed some of these data and will present several examples of these results here.

4.1 Saint John Harbor

The Saint John Harbor study area is closest to what we would consider an ideal natural laboratory for ground-truth studies. It has a large (2 x 2 km), easily accessible, very stable intertidal region that contains a range of sediment types as well as a number of natural and man-made rock piles (some covered by weeds and others bare - Fig 5). The major problem with Saint John Harbor is that at maximum high tide, the deepest intertidal regions are covered by no more than about 9 m of water. While this provides enough water for most of our acoustic systems, it proved marginal for the EM-1000 system on board the CREED. On the CREED, the EM-1000 transducers are located on one of the hull's deep pontoons, approximately 2.8 m below the waterline (Fig 3). Thus in 9 m of water there is only about 6.2 m of water beneath the transducer. While this is within the claimed specifications of the EM-1000, our experience during HYGRO-92 indicated that the system's performance greatly degraded in water depths less than 10 m over soft sediment (Fig. 6). Recent modifications to the software control of amplifier gains should rectify this problem and we hope to bring the CREED further into the intertidal region of Saint John Harbor next summer. Nonetheless, the existing imagery from Saint John Harbor clearly depicts (qualitatively for now) clear contrasts between sediment types that

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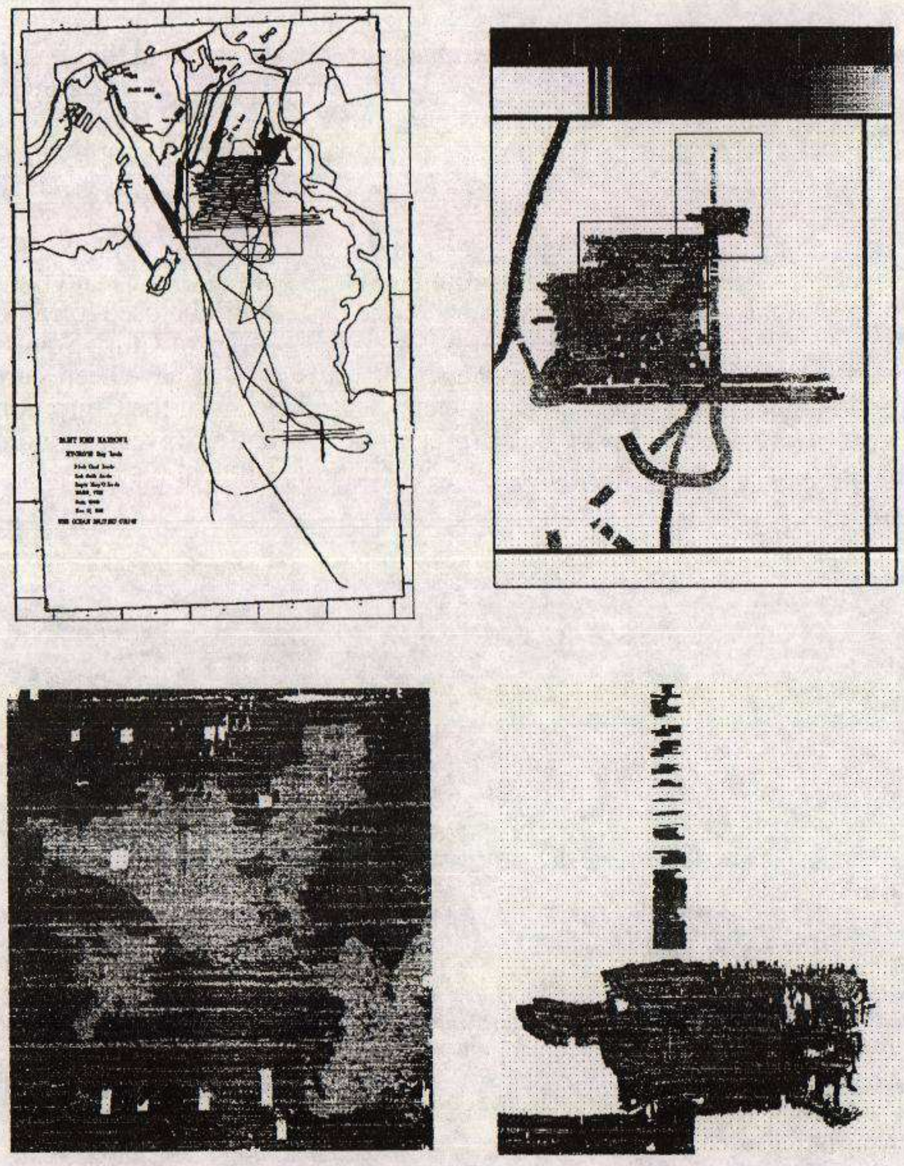

Figs. 5 & 6. Track plot and selected sections of EM-1000 sonar imagery from Saint John Harbor. Rectangles show selected subareas. Light regions represent high amplitude acoustic return. Note degredation of signal in shallower regions. Area of very dense track coverage is site of target deployment.

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can be tested by cores and grabs. It also appears that a gravel - silt transition that was mapped at low tide shows gravel-like backscatter characteristic well beyond the surficial transition (Fig 6). We know that the gravel is present beneath the surficial fine-grained cover and thus it appears that we are getting some penetration even at 95 kHz similar to that found by Mitchell[10]. This transition will be the subject of much closer scrutiny in the future.

Saint John Harbor was also the area in which our man-made targets were deployed (Fig. 6). The targets were clearly imaged on the Navitronics sweep system (Fig 7) and the Chirp Sonar (Fig 8). Analyses of the response from these targets will be used to calibrate the acoustic systems. Also in Saint John Harbor we collected a series of Chirp Sonar and Seistec lines over the site of 54 boreholes (the deepest being 18 m) that have been sampled and analyzed for a number of geotechnical parameters. Comparisons of the Chirp Sonar profiles in this area (being done by Lester LeBlanc at Florida Atlantic University) indicate significant differences in scattering parameters as a function of sediment type.

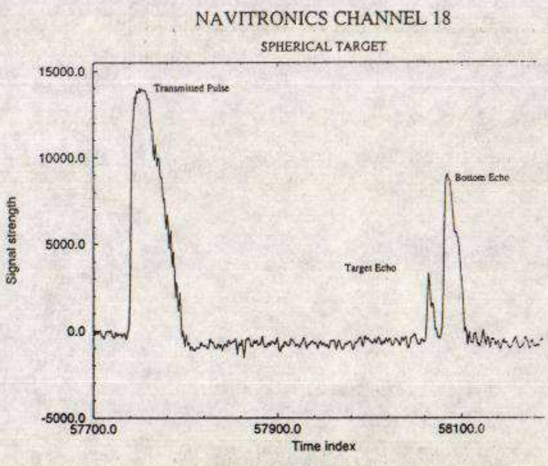

Fig. 7. Digitized rectified waveform of Navitronics return over spherical target anchored just above seafloor.

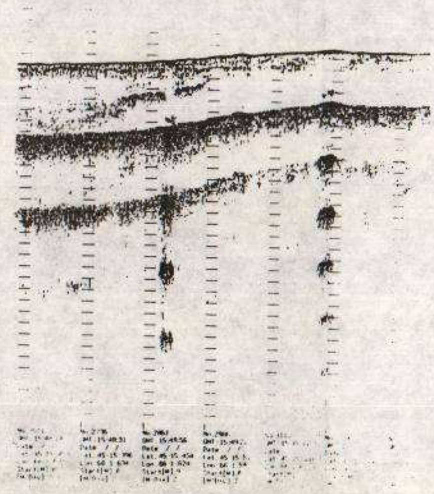

Fig. 8. Analog record as Chirp Sonar passes over two planar reflectors on seafloor.

4.2 Parrsboro Approaches

Unlike Saint John Harbor, the tidal range in the Parrsboro area (>15 m) allows plenty of water under the EM-1000 transducers and thus we have been able to collect spectacular EM-1000 data in this region (Fig 9). Unfortunately the Parrsboro area is difficult to get to and to work in (there are often 8 knot tidal currents in region) and thus we were unable to bring the man-made targets or the SMITH (with the Navitronics) to Parrsboro. We can however, still directly map and sample the intertidal area, and we have aerial photos and CASI imagery of the region. We have begun the process of comparing these datasets, producing what are probably the first direct inter-comparisons of sonar and airborne

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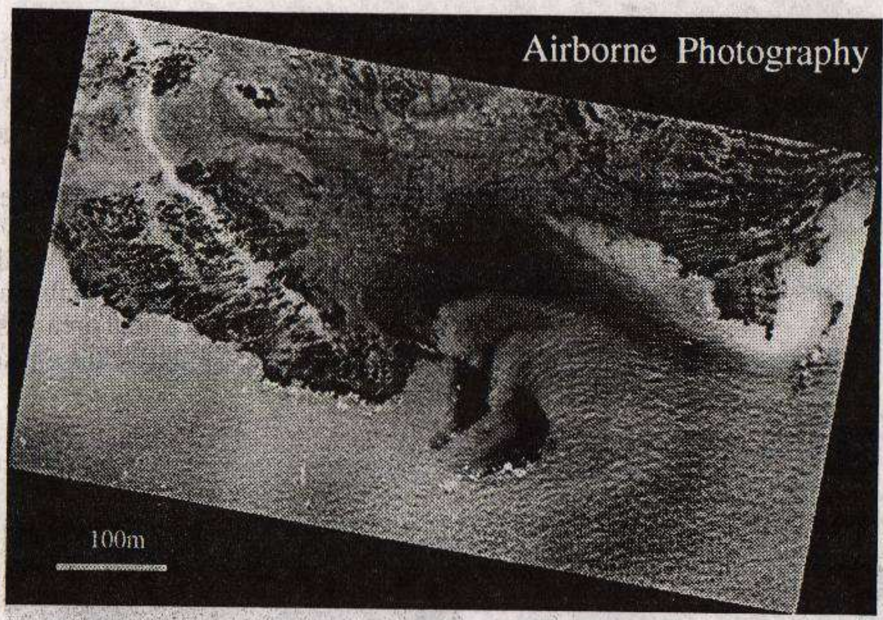

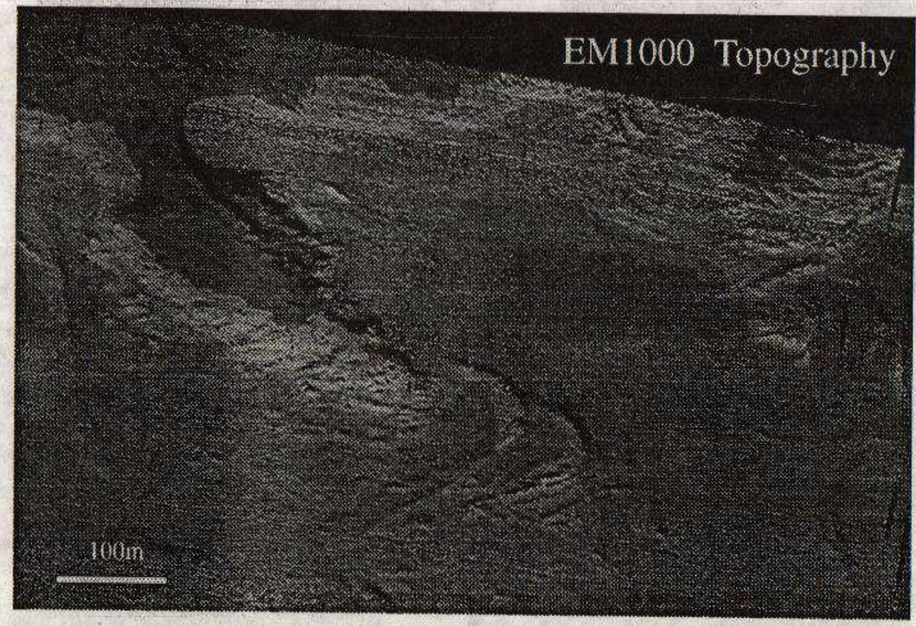

Fig. 9. Aerial photograph taken of Parrsboro intertidal area at low tide and EM-1000 bathymetry of same area collected at high tide.

imagery (Fig 9 and 10). Our initial analysis indicates that while the topographic features can be precisely matched between the photographic and acoustic data, changes in the sonar imagery do not directly match those seen optically (Fig 10). Based on our knowledge of the distribution of sediment types in the area we once again suspect that the 95 kHz sidescan is responding to material that is not necessarily surficial. Finally, we can begin to get a feel for the bathymetric resolution of the EM-1000 by looking at the topography collected over a 50 cm high wooden wreck that is exposed at low tide (Fig. 11). While the feature cannot be recognized as a wreck in the bathymetry, it is certainly discernible as a bathymetric anomaly. The high quality of the EM-1000 data in this intertidal area has made this region the focus of a detailed study on the applicability of backscatter data for seabed classification (Hughes Clarke[5]).

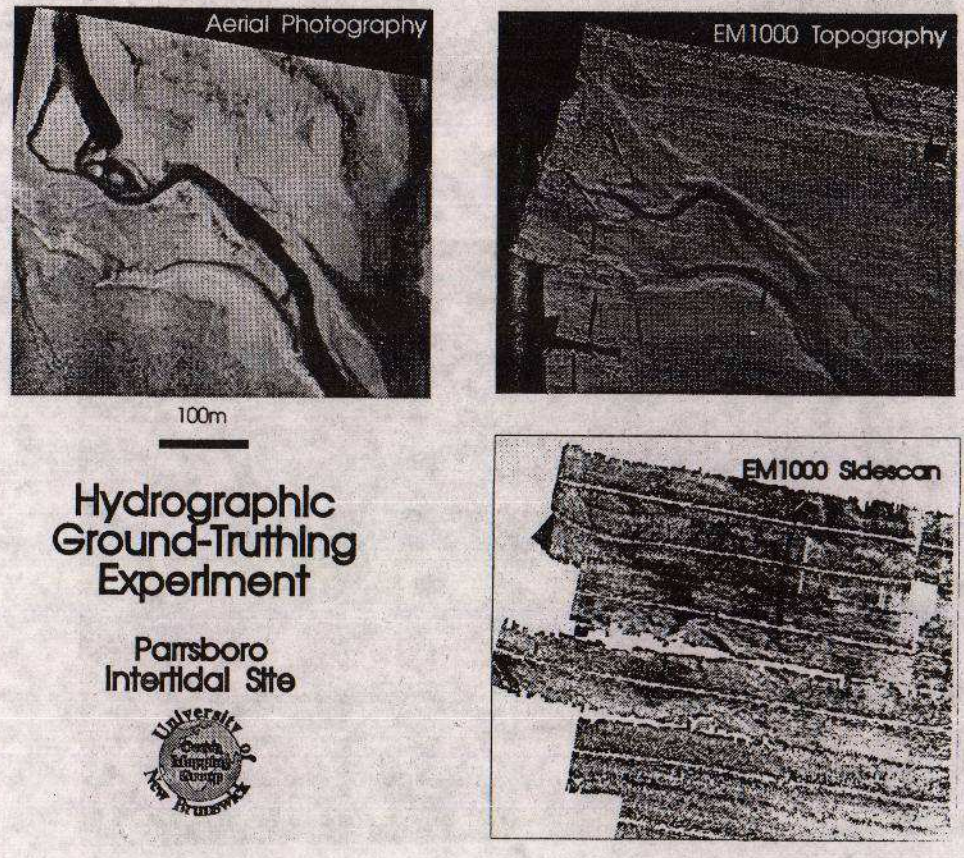

Fig. 10. Comparison of low tide aerial photography with EM-1000 bathymetry and imagery from same region at high tide (Parrsboro Approaches).

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Fig. 11 EM-1000 bathymetry over 50 cm high wooden wreck in Parrsboro intertidal area.

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4.3 Passamaquoddy Bay
Located between Maine and New Brunswick, Passamaquoddy Bay does not have the large intertidal areas that exist in either Parrsboro or Saint John Harbor. It is, however, the site of a number of existing and proposed aquaculture sites and thus an environmentally sensitive region that is in need of bottom characterization. Thus, we brought both the CREED and the SMITH to Passamaquoddy Bay, with the hope that the ground truth studies conducted in Saint John and Parrsboro could be applied to classifying seabed characteristics in the Bay. In the large and open area of Passamaquoddy Bay, the CREED was able to run at full survey speed (17 knots) and thus in less than 30 hours of surveying we were able to map an approximately 150 km^2 area (Fig 12).

The survey of Passamaquoddy Bay revealed a complex bottom structure with a number of "pockmarks" or circular depressions, the largest of which are about 30 m in diameter and about 30 m deep. These features, which appear to be restricted to Holocene sediments, are lineated along the direction of regional faulting. While their origin is unknown, we suspect that they are related to the escape of gas or fresh water along recent faults. In order to explore the complex topographic relationships of Passamaquoddy Bay, we are using an innovative six-dimensional mouse (the Bat; Ware and Jessome[11]) that allows interactive flight through three-dimensional datasets (Fig. 13).

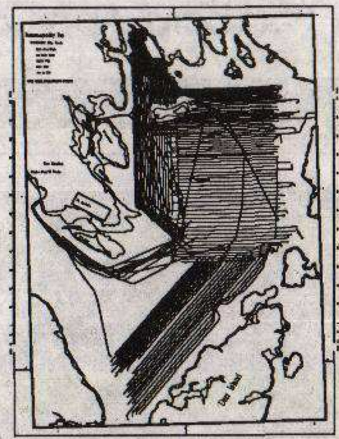

Fig. 12. Track chart of F.G. CREED survey lines in Passamaquoddy Bay
Fig. 13. Two three-dimensional views of pockmarks found in Passamaquoddy Bay.

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5. SEAFLOOR CLASSIFICATION USING THE NAVITRONICS

As discussed earlier, one of the primary objectives of the Hydrographic Ground-Truthing Experiment is to evaluate the usefulness of hydrographic sonars for seafloor classification. While Hughes Clarke[5] is looking at shallow-water multibeam sonars in this context, we are also evaluating the applicability of the vertical incidence sweep systems for this task. As configured on the SMITH, the Navitronics system records only a highly processed digital depth value. In order to explore the potential of using this system for seabed classification we calibrated the initial filter and amplifier stage of the system and then captured the rectified output of the central transducer before it entered the Navitronics processing stages. While we eventually were able to digitize three channels, it became clear from even a single channel that the rectified waveforms appear to robustly change shape as a function of seafloor type, and that a relatively simple statistical analysis may, in certain circumstances, provide a robust seafloor classifier (Fig. 14).

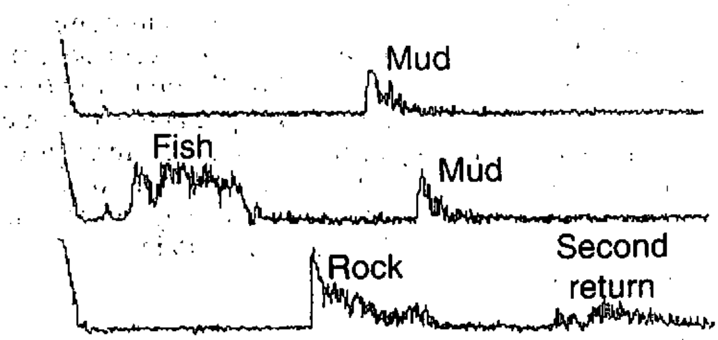

Fig. 14. Characteristic Navitronics echo returns from different bottom types.

6. PLANS FOR THE NEXT FIELD SEASON

Though still buried in the deluge of data collected in HYGRO-92, we must continue to plan our next field season (HYGRO-93). Present plans call for bringing the CREED back to Saint John Harbor to test the software modifications that will permit the EM-1000 to work further into the intertidal zone and for returning with the CREED to Parrsboro to begin to look at questions of angular dependence of backscatter. We also hope to bring the CREED to the approaches of Halifax Harbor where we already have a large EM-100 dataset. We would like to use a launch-deployed Navitronics system to survey well into the intertidal region of Saint John Harbor and to collect sweep data in the Parrsboro intertidal region (where the SMITH was unable to work). For next year's work a dedicated multi-channel acquisition and display system for the Navitronics is being built by Quester Tangent of Sydney, British Columbia. We will also use the results of our first year's analyses to focus our low-tide and subtidal sampling and mapping programs on areas of particular acoustic interest and will explore the feasibility of collecting LIDAR data in some of the ground truth areas. As usual, collaborators are welcome.

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7.CONCLUSIONS

The first phase of the Hydrographic Ground-Truthing Experiment (HYGRO-92) has provided a wealth of data that will enable us to more fully understand the capabilities of modern sweep and swath mapping systems in terms of resolution as well as seafloor characterization. By collecting acoustic data sets at high tide and then mapping, sampling and imaging (photographically and with airborne and satellite radar and spectral scanners) the same piece of seafloor at low tide, we can unambiguously relate reflectivity and backscatter measurements to seafloor type. In order to handle the massive raster and vector datasets collected during this experiment we have taken advantage of the capabilities of a Geographic Information System (GIS) that allows for the co-registration of the datasets as well as the quantitative comparison of their similarities and differences. Initial results indicate that both a 210 kHz sweep system and a 95 kHz multibeam system presented accurate topographic representations of the seafloor (though the multibeam system degraded in water depths less than 10 m). Sonar imagery from the swath system clearly shows changes in seafloor type and has great potential for classification work (see Hughes Clarke[5]) but offsets between the position of boundaries mapped at low tide and their position on sonar imagery imply that the system may be responding to features just below the surface (Mitchell[10]). Our initial analyses of rectified waveforms from the vertical incidence sweep profilers indicates that they appear to robustly change shape as a function of seafloor characteristics and that a statistical analysis may, in certain circumstances, provide a straightforward seafloor classifier.

HYGRO-92 represents the beginning of at least a three-year program aimed at addressing the issues of establishing the limits of resolution of swath and sweep systems as well as exploring the potential of these systems for seafloor classification. We are now in the process of planning next summer's field work which will return to many of the same areas and try to fill in gaps in last summer's surveys as well as to address new questions like the angular component of backscatter as a means of seafloor classification. We welcome input from and collaboration with those interested in participating in these upcoming programs.

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