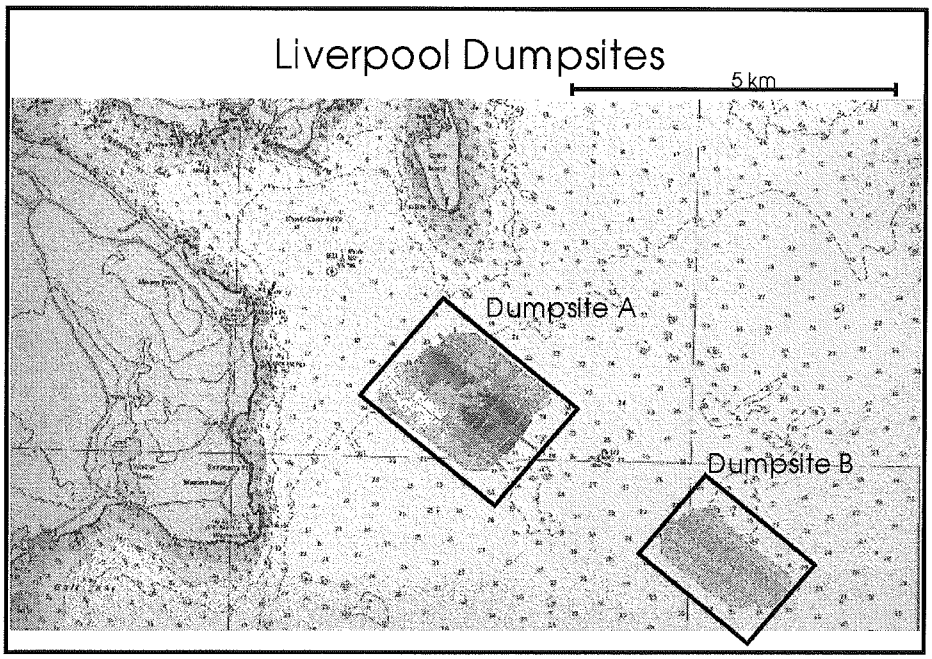
Sidescan Sonar Survey of the Liverpool Offshore Dumpsites

26-28 September 1995

for

Public Works and Government Services Canada
A&ES, Atlantic Region
and
Transport Canada
Marine Navigational Aids



by
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Background

The shipping channel in Liverpool, Nova Scotia has required extensive dredging to allow the passage of vessels into the inner harbour. Much of the dredged material has been disposed of in offshore marine dumping grounds. Public Works and Government Services Canada (PWGSC) and the Geological Survey of Canada (GSC) have undertaken a joint project to determine the effects of offshore dumping on seafloor conditions in the dumpsites located in the approaches to Liverpool Harbour, Nova Scotia (Fig. 1). A geophysical survey DPW94001, (Parrott, 1994) was run in May 1994, to determine seafloor conditions prior to dumping. About 200,000 cmsm (cubic metres scow measure) of materials were then dredged from the inner harbour and dumped in the offshore dumpsites. The geophysical surveys were repeated in September 1995 to determine the effects of dumping of the material.

Survey Summary

Surveys DPW95903 and DPW94001 were jointly performed by the GSC and PWGSC. A Simrad MS992 dual frequency (120 and 330 kHz) sidescan sonar system was used for both the 1994 and 1995 surveys and logged digitally. The 3.5 kHz sub-bottom profiler system was used for the 1994 survey was replaced by a Datasonics BubblePulser system in 1995 to provide increased penetration of the seafloor sediments. Grab samples were taken in Dumpsites A and B to assist with the interpretation of the sidescan sonar and sub-bottom profiler data, and to provide information on the potential for sediment transport in the area. Navigation was provided by PWGSC using a differential GPS system.

Bathymetry data with continuous coverage were collected at the dumpsites by Public Works and Government Services Canada in 1994, using a 14 channel Navitronics sweep bathymetry system mounted on the 10 metre survey vessel Miramichi Surveyor.

Preliminary Results

About 20 km of sidescan sonar, and sub-bottom profiler data were collected during the geophysical survey of Cruise DPW95903. Van Veen grab samples were taken to confirm interpretations made from the acoustic data. Digital mosaics of the sidescan sonar data have been produced to show the distribution of surficial sediments at the seafloor after dredge spoils were dumped in the area.

Examples of the various sidescan sonar mosaics and records have been included in this report to provide a quick overview of the results. High resolution copies have also been produced and provided under a separate cover as a series of large sheets.

Geological Setting

The geological setting was described in the earlier report (Parrott, 1994) and is repeated here for completeness.

Haggis Geophysics and King Associates describe the geological setting of Liverpool Harbour in an 1992 report to PWGSC. Their description of the local geological setting for Liverpool Harbour is applicable to the offshore areas near the harbour and is summarized here. Haggis and King report that Liverpool Harbour is underlain by Meguma Group metamorphic rocks (dominantly quartzose schist) of Cambro-Ordivician age. The bedrock is overlain by surficial sediments that have been reworked by recent glaciations and by changes in sea-level.

Haggis and King describe a patchy cover of glacial till, left by the last glaciation, which is generally composed of sandy or silty gravel with numerous boulders and cobbles. These sediments have been modified during subsequent changes in sea level, which subjected the marine areas to beach-zone reworking of the glacial sediments. The beach-zone reworking produced sandy, gravely and cobbly deposits (basal transgressive lag). The following rise in sea level locally left littoral (sub-marine beach related) sandy and shelly deposits. As sea level rose, the energy level at the seafloor decreased and sediment supply became much lower but steadier, resulting in ponded deposition only in the lower-lying marine areas. These are usually organic and microfossil rich silts and clays.

Deposits within Liverpool Harbour reflect this general history. Borehole data (Maritime Testing, 1992) indicate that in much of the area a very competent unit of variable thickness lies directly on the bedrock. It comprises boulders, cobbles, and often sand and gravel. Haggis and King referred to this unit as the "Cobble Unit". Generally overlying the Cobble Unit is a grey, sorted, usually fine sand with shells, which Haggis and King referred to as the "Sand Unit". Locally overlying the Sand Unit is a green, soft, sandy to silty unit with abundant organic content. This represents the post-glacial to present accumulation, primarily from the Mersey River, which Haggis and King referred to as the "Organics Unit". Much of the dredged material consisted of fine material from the "Organics Unit" with some coarse material fron the "Sand Unit" and the "Cobble Unit".

Haggis and King summarize the local stratigraphy for the Liverpool Harbour as:

Unit	Description
Organics Unit	Sands and silts with abundant organics
Sand Unit	Sorted, sometimes, stratified, grey sand, generally fine sand with shell fragments and some organics
Cobble Unit	Boulders and cobbles, sometimes with sand and gravel
Bedrock	Meguma Group schists

The seafloor in the area of dumpsites A and B appear to be comprised of the same material as those described by Haggis and King for the inner harbour. The seafloor sediments in the area around the dumpsites show signs of modern reworking, possible by wave action during storms.

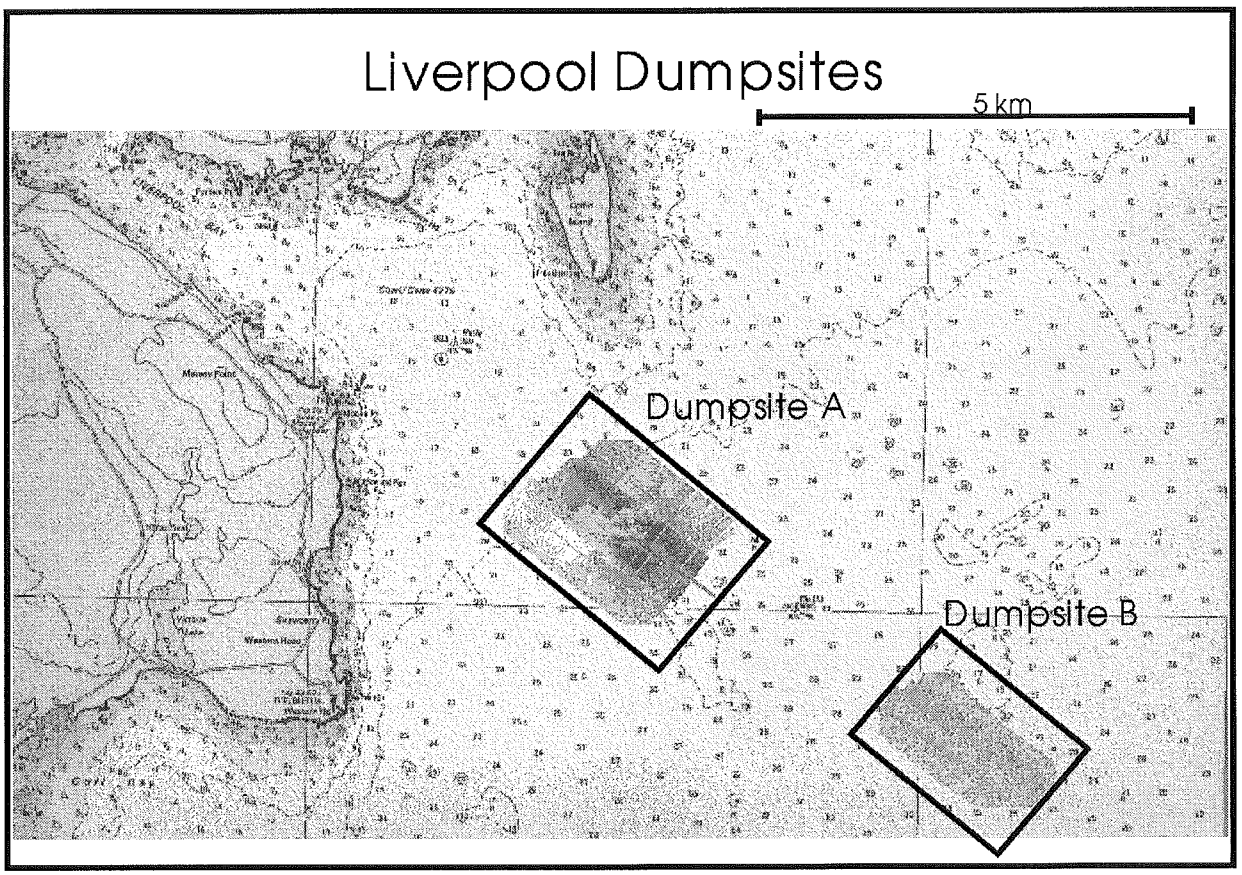

Figure 1 Approaches to Liverpool NS showing locations of dumpsite surveys.

Dumpsite A

Overview

Dumpsite A, shown in the location map in Figure 1, is situated in the approach to Liverpool Harbour, NS, at location 44° 00.2'N 64° 38'W. Water depths in the area range from about 30 to 45 metres. Sidescan sonar and subbottom profiler data were collected over the dumpsite in 1994 and 1995, and a series of grab samples were taken to assist with the interpretation of the acoustic data.

Survey Procedure

The 1995 geophysical survey was run with similar equipment and procedures as used in 1994. Survey lines run in the 1994 survey were repeated in the 1995 survey. These lines were run at a 100 metre range on the sidescan sonar system (each side) with a spacing of 75 metres to provide overlapping data for use in building a digital sidescan sonar mosaic. Subbottom profiler data were collected concurrently with the sidescan sonar data. A problem with the digital data logger resulted in only the port channel of sidescan sonar data being recorded. About 60 percent data coverage was achieved for the digital data in the area. Note that the data was correctly displayed on the hardcopy record, and this information has been integrated into the interpretation of the data.

Seafloor conditions

Interpretation of the sidescan sonar data from the 1994 survey of Dumpsite A (shown below in Figure 2) confirmed the presence of the same units as described by Haggis and King for the inner harbour, and provides the basis for interpreting the effects of offshore dumping in the area. Separate sidescan sonar mosaics have been produced using the data from the 1994 and 1995 surveys and provide a convenient method to visualize the location of features on the seafloor (Figures 3 and 4). The distribution of fine and coarse sediments, interpreted from the mosaics, have been summarized in the maps shown in Figures 5 and 6. The details of these features can be seen in the individual sidescan sonar graphic records on file at the Geological Survey of Canada - Atlantic in Dartmouth, NS.

Bedrock outcrops are predominately located in the southeast and northeast corners of the survey area. The outcrops are surrounded by large areas of high backscatter (dark tone on records) with many discrete reflectors on the sidescan sonar data which have been interpreted as the coarse sand, gravel, cobbles and boulders of the Cobble Unit of Haggis and King. Overlying the Cobble Unit are areas with more uniform, high backscatter. These areas generally show the presence of 1-2 metre wavelength ripples on the seafloor and have been interpreted as a deposit of coarse sand with a thickness of up to 2-3 metres - the Sand Unit of Haggis and King.

An area of low backscatter (light tone on records) occur in the centre of the surveyed area and was interpreted as fine sand - and is probably a fine sand sub-unit of the Sand Unit. The fine sand appears to occur as a thin veneer overlaying the coarse sand of the Sand Unit and the Cobble Unit. In some areas the coarser sediments are seen to protrude through the finer sediments. This

area in the centre of the Dumpsite appears to have received the majority of the dredge spoils from the 1994/95 dredging program.

A large area of low backscatter (light records) in the western portion of the mosaic is associated with a wedge of material seen on the sub-bottom profiler records. This unit overlies both the Cobble Unit and the Sand Unit in this area. Two of the grab samples (#10 from the 1994 survey and #13 from the 1995 survey) in this unit showed abundant fines and woodchips, indicating that this deposit is related to the Organics Unit of Haggis and King.

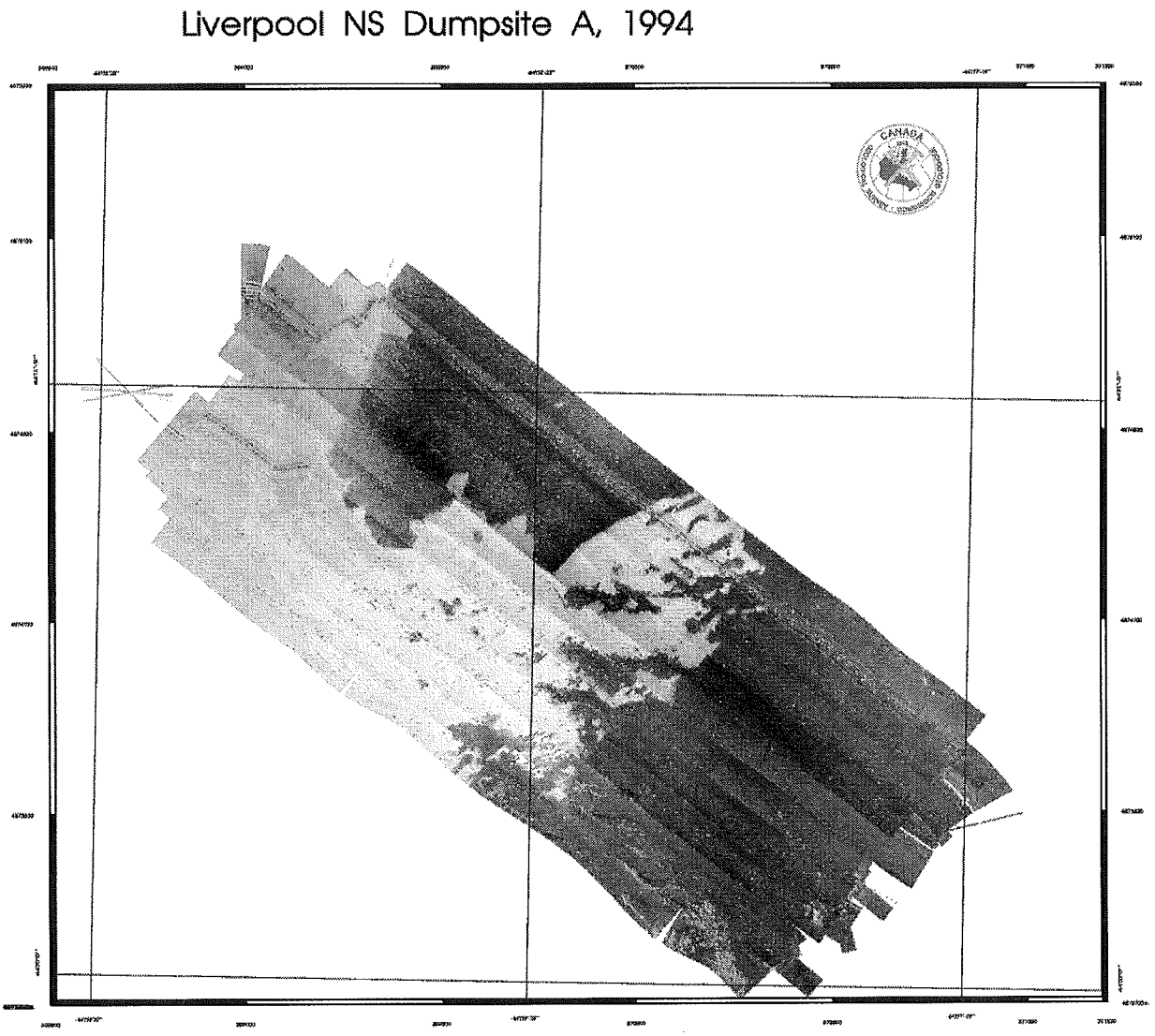

Figure 2 Digitally processed sidescan sonar mosaic from the 1994 survey of Dumpsite A showing data collected at a swath of 200 metres (100 metres each side). The light colour indicates the presence of fine sediment such as clay and fine sands. The darker coloured areas indicate coarse sediments such as bedrock, gravels, and coarse sands.

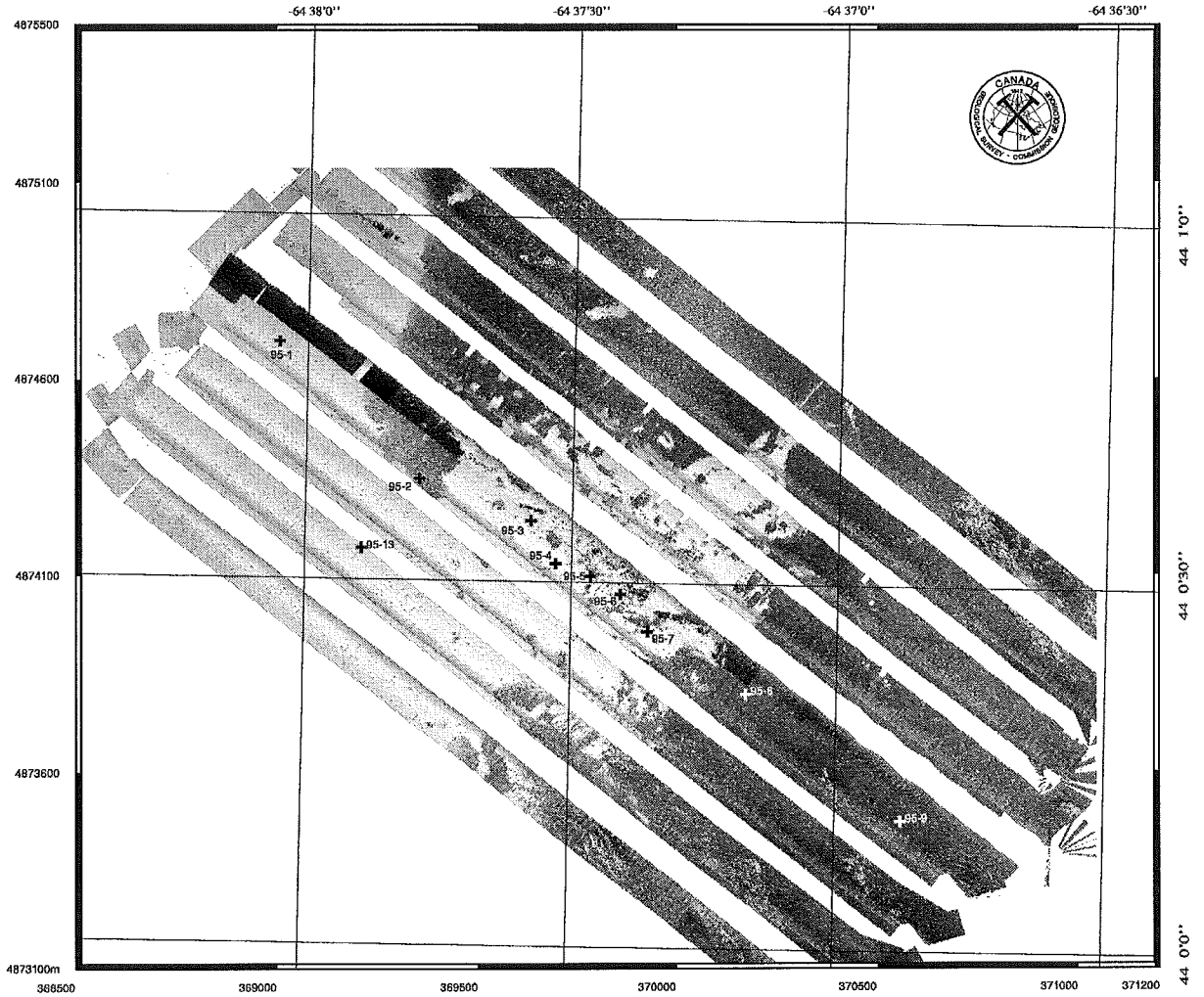

Figure 3 Digitally processed sidescan sonar mosaic from the 1995 survey of Dumpsite A showing data collected at a swath of 200 metres (100 metres each side). The light colours indicate the presence of fine sediment such as clay and fine sands. The darker colours indicate coarse sediments such as bedrock, gravels, and coarse sands. The central portion of the image shows considerable change from the 1994 mosaic. It appears that the fine material in the dredge spoils has covered areas of coarse sediments near the centre of the dump site. Areas with a considerable content of coarse sediment can also be seen in the centre of the dump site. Grab sample locations are indication by a "+" and labelled.

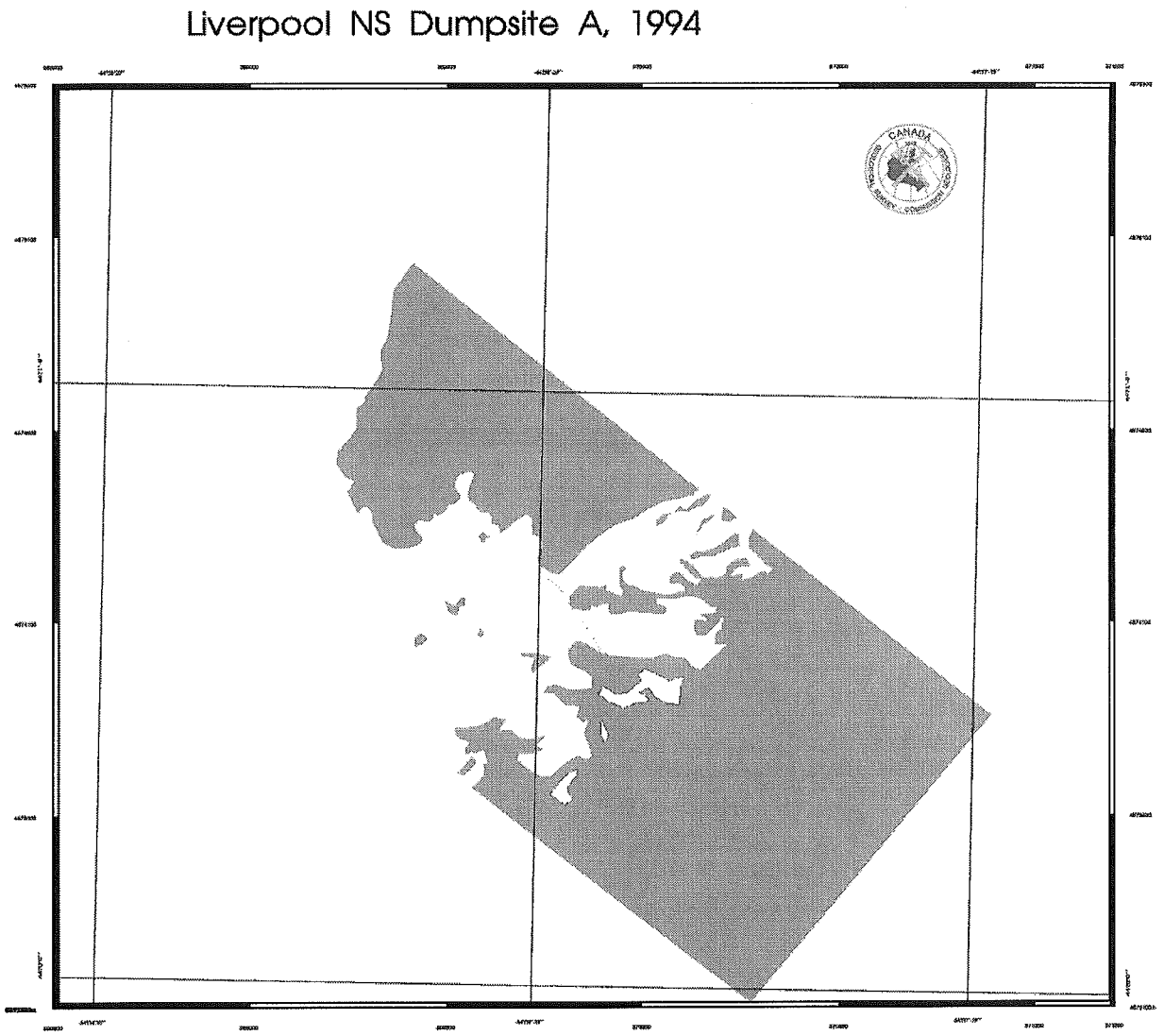

Figure 4 Distribution of sediments as interpreted from the 1994 sidescan sonar mosaic shown in Figure 2. The dark coloured areas show the distribution of coarse sediments such as gravels, rock and coarse sands. The light coloured areas indicate the presence of fine sediments such as muds and fine sands.

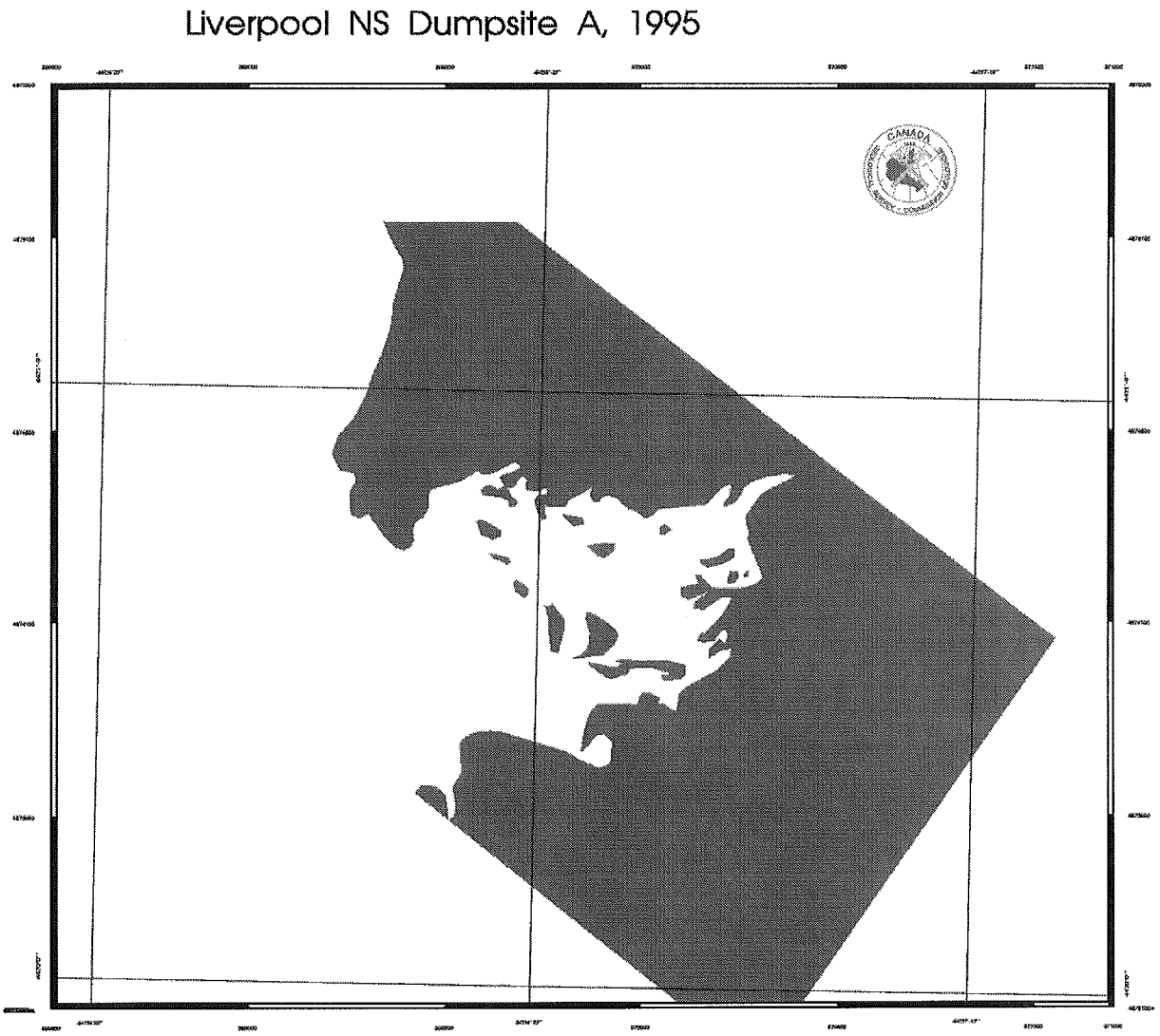

Figure 5 Distribution of sediments as interpreted from the 1995 sidescan sonar mosaic shown in Figure 3. The dark coloured areas show the distribution of coarse sediments such as gravels, rock and coarse sands. The light coloured areas indicate the presence of fine sediments such as muds and fine sands.

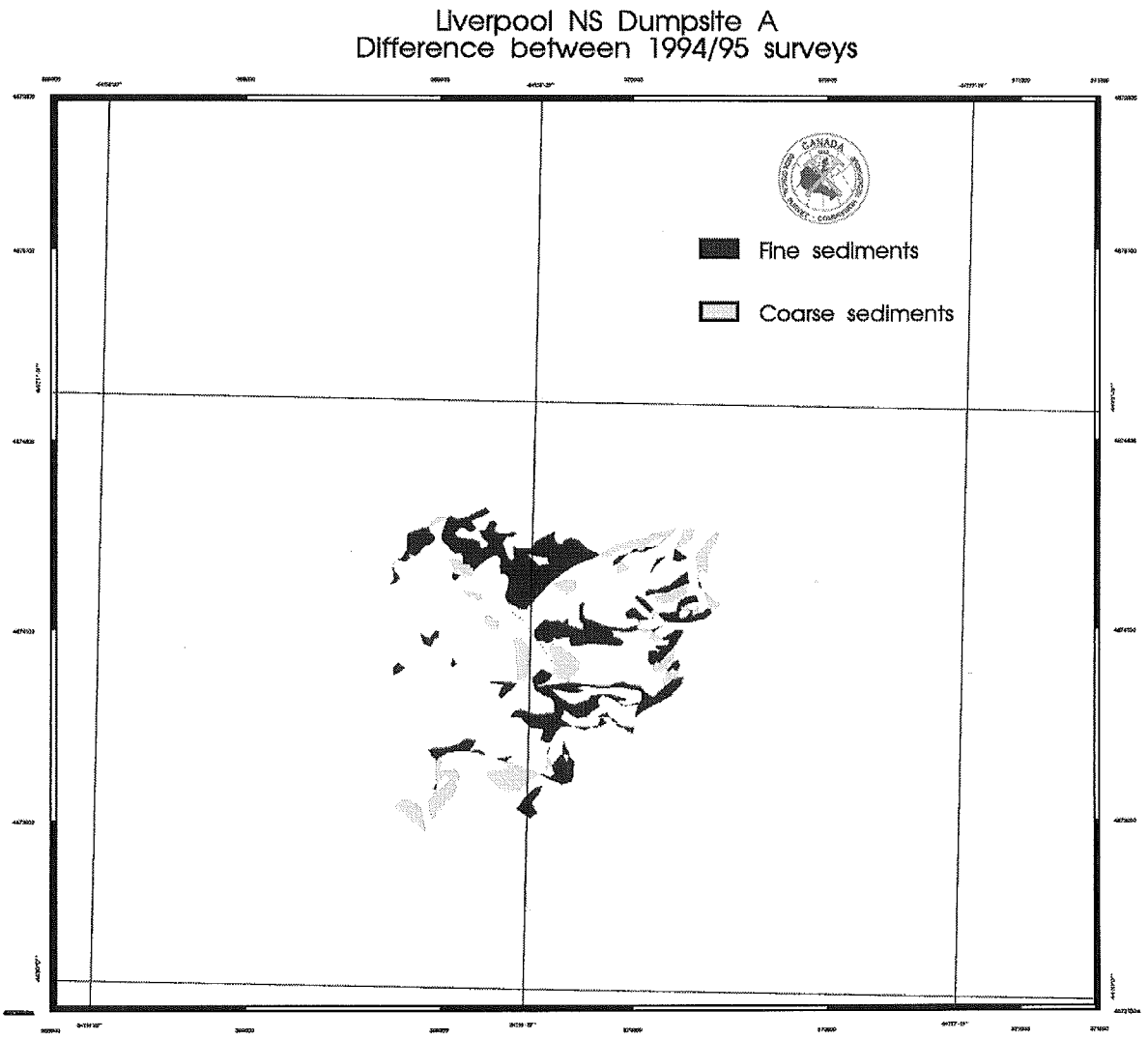

Figure 6 Difference in the distribution of sediments in Dumpsite A as interpreted from sidescan sonar surveys in 1994 and 1995. The dark colour shows areas where fine sediments have accumulated and overlay the coarse sediments. The lighter colour shows areas where coarse sediments have accumulated or have been exposed by erosion.

Effects of dumping

Dredge spoils in this area consist of a combination of fine material from the "Organics Unit" with some coarse material fron the "Sand Unit" and the "Cobble Unit". The nature of the dumped material provides some challenges in determining the extent of the dredge spoil in Dumpsite A. The fine material in the dredge spoils has a similar acoustic character to the fine sediments found in the centre of the dumpsite. It has not been possible to map changes in the seafloor in the areas where fine material has overlain fine material. The detection of the spoils in areas where the fine material has accumulated on coarse material is quite straight forward due to the difference in the acoustic character of the materials. Some of the dredge spoils appear to have contained some coarse material, and these can be detected where they overlay fine material. The mosaics produced from the 1994 and 1995 surveys have been compared to determine changes in the distribution of sediments.

Several effects of the marine dumping program have been interpreted from the sidescan sonar data.

1. Much of the dredged material was dumped near the centre of the site. The central portion of the image shows considerable change from the 1994 mosaic. It appears that the fine material in the dredge spoils have accumulated and overlay areas of coarse sediments near the centre of the dump site.

2. Areas with a considerable content of coarse sediment can also be seen in the centre of the dump site. This probably results from accumulation of coarse material from the dredge spoils.

3. Isolated zones of fine sediment (shown as light coloured areas on the mosaics) can be seen in the coarse sediment and may also be related to the dumping program.

Dumpsite B

Overview

Dumpsite B, shown in the location map in Figure 1, is situated in the approach to Liverpool Harbour, NS, at location 43° 59.5'N 64° 34.5'W. Water depths in the area range from about 30 to 45 metres. Sidescan sonar and sweep bathymetry data were collected over the dumpsite. Grab samples were taken to assist with the interpretation of the sidescan sonar data.

Survey Procedure

A series of lines with a spacing of 250 metres were run at a 300 metres range (each side) to provide information on the distribution of surficial sediments and seafloor conditions in Dumpsite B. Subbottom profiler and sweep bathymetry data were collected concurrently with the sidescan sonar data.

Seafloor Conditions

Most of the sidescan sonar data of the 1994 survey at Dumpsite B is characterized by areas of high backscatter (dark records) with many discrete reflectors on the sidescan sonar data, as shown in Figure 7. These areas have been interpreted as the coarse sand, gravel, cobbles and boulders of the Cobble Unit of Haggis and King. This may occur as a thin veneer over the bedrock surface.

Overlying the Cobble Unit are areas with more uniform, high backscatter. These have been interpreted as being a coarse sand, the Sand Unit of Haggis and King. In places it appears to reach a thickness of several metres. An area of low backscatter (light records) in the centre of the surveyed area has been interpreted as mainly a fine sand - and is probably a fine sand sub-unit of the Sand Unit. It occurs in small isolated deposits as a veneer which overlays the coarse sand of the Sand Unit.

The central portion of the sidescan sonar mosaic from the 1995 survey (Figure 8) shows numerous areas of low backscatter (light records) in the mosaic. This represents a considerable change from the 1994 mosaic (Figure 7), and has been interpreted as an accumulation of fine sediments from the dredge spoils.

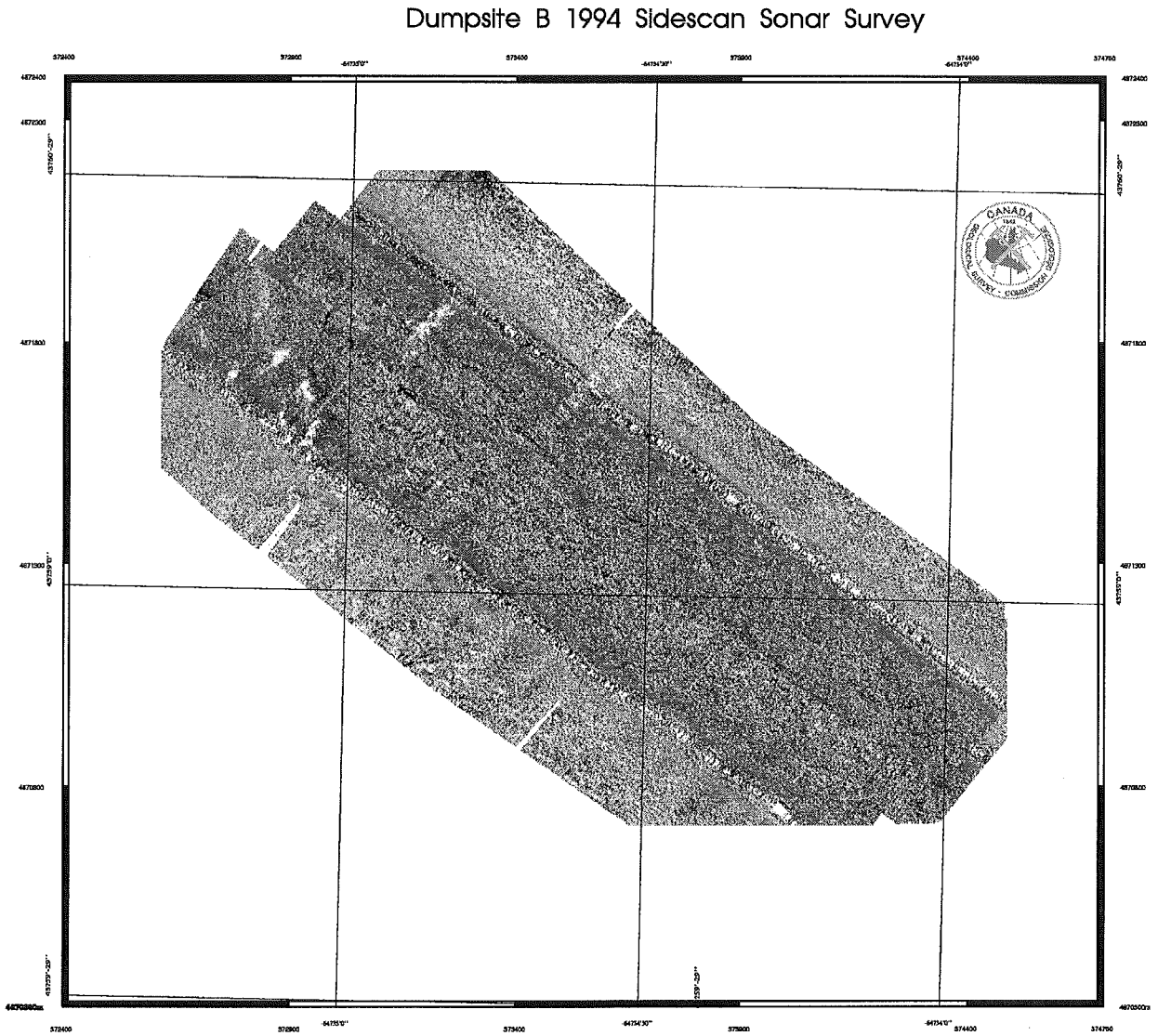

Figure 7 Digitally processed sidescan sonar mosaic from the 1994 survey of Dumpsite B showing data collected at a swath of 200 metres (100 metres each side). The light colours indicate the presence of fine sediment such as clay and fine sands. The darker colours indicate coarse sediments such as bedrock, gravels, and coarse sands. Small deposits of the fine material appear as light tones on the record in the western portion of the survey area.

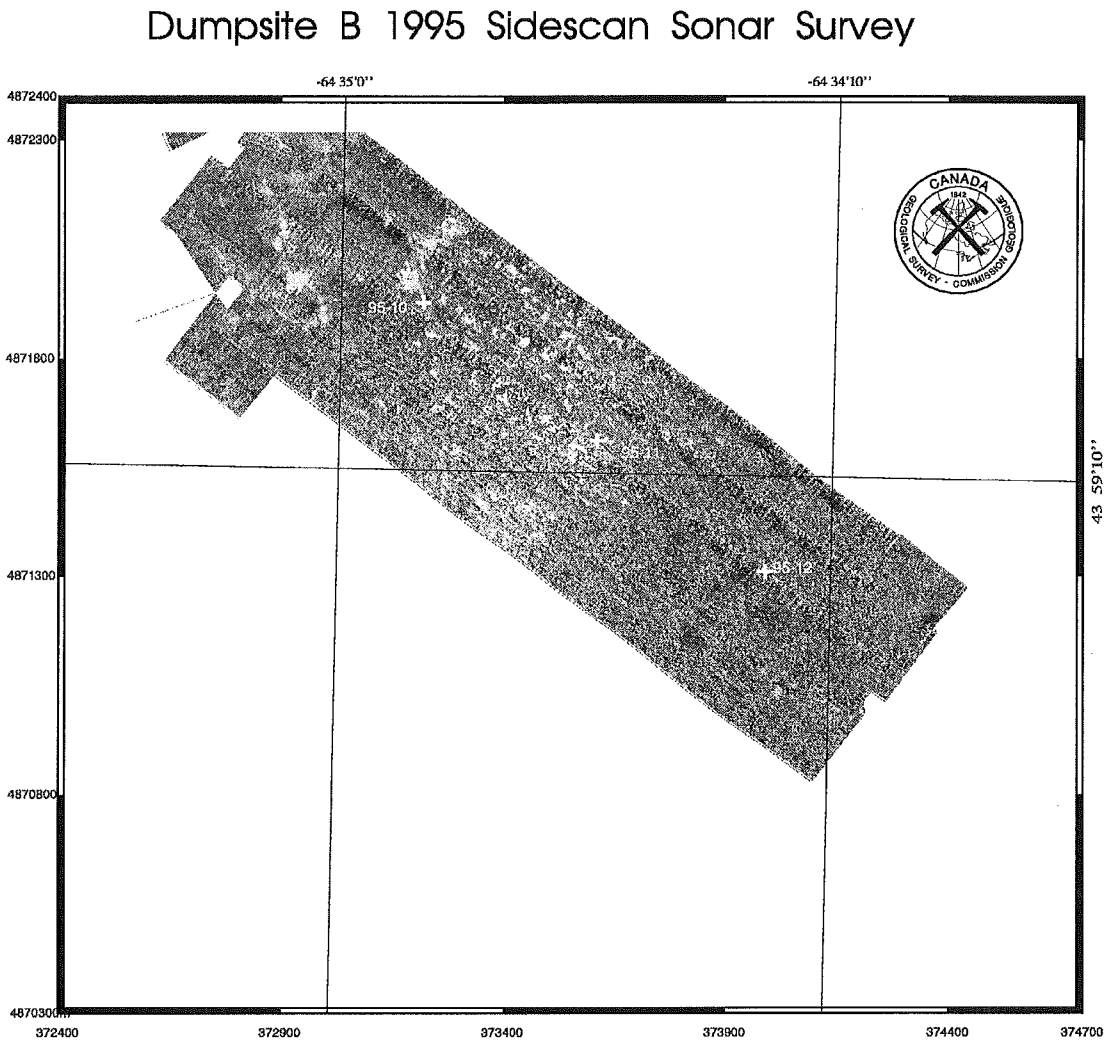

Figure 8 Digitally processed sidescan sonar mosaic from the 1995 survey of Dumpsite B showing data collected at a swath of 400 metres (200 metres each side). The light colours indicate the presence of fine sediment such as clay and fine sands. The darker colours indicate coarse sediments such as bedrock, gravels, and coarse sands. The central portion of the image shows considerable change from the 1994 mosaic indicating an accumulation of fine material from the 1995 dredge spoils. Grab sample locations are indicated by a "+" and labelled.

Samples

Sediment samples were taken with a van Veen sampler to provide groundtruth for the interpretation of the sidescan sonar and sub-bottom profiler data. The sample positions and a brief description are provided in Table 1 below and shown on Figures 3 and 8.

Sample #	UTM easting	UTM northing	Description
GSC 95-903-1	369001	4874702	fine grained grey sand
GSC 95-903-2	369349	4874348	coarse sand + fines
GSC 95-903-3	369633	4874238	angular gravel + fine sand
GSC 95-903-4	369694	4874127	fine silt + sand
GSC 95-903-5	369783	4874094	silty sand, gas odour
GSC 95-903-6	369859	4874048	fine silty sand
GSC 95-903-7	369927	4873952	silty sand
GSC 95-903-8	370175	4873789	boulders, cobbles, gravel,
GSC 95-903-9	370564	4873462	pebbles
GSC 95-903-10	373216	4871935	gravel
GSC 95-903-11	373613	4871614	fine sand
GSC 95-903-12	373996	4871310	cobbles
GSC 95-903-13	369204	4874170	silty sand with wood chips

Access to Geophysical Data

The sidescan sonar, subbottom profiler and grab samples collected during this survey are archived at the Geological Survey of Canada, in Dartmouth Nova Scotia. For access to the geophysical data and samples contact the senior scientist for the survey, Russell Parrott (902-426-7059) or Susan Merchant of the GSC Curation group (902-426-3410). Available data consist of the field collected graphical records for the sidescan sonar and subbottom profiler, digitally processed sidescan sonar mosaics, ExaByte tapes containing the sidescan sonar data in SEG-Y format, and a CD-ROM containing the (compressed) sidescan sonar data in SEG-Y format.

Proposed Future Work

Seafloor conditions at Dumpsite A and B have been surveyed before and immediately after a large scale offshore marine dumping program. The presence of several sediment types were interpreted, and the effects of dumping seen. Indications of reworking of the seafloor sediments by modern seafloor processes have been found - probably by wave action during storms. Evidence of previous dumping of dredged material at site A has been found.

Repetitive sidescan sonar and subbottom profiler surveys should be performed on the dumpsites to determine the net effect of dumping and modern reworking of the sediments in this area. A survey should be performed during 1996 to determine the effect of winter storms and then additional surveys at intervals of 1-2 years to determine the effect of present day seafloor processes on the dumped materials. Surveys should also be performed before and after any major dumping at a site to establish seafloor conditions and determine the effects of dumping.

The techniques used in this project, such as sidescan sonar and subbottom profiler surveys, provide a quick, non-intrusive technique for determining the distribution of seafloor sediments; repetitive surveys with these techniques will allow interpretation of reworking of the dumped materials by modern day oceanographic processes. Unfortunately they will not allow accurate prediction of the conditions for sediment reworking or for the direction of sediment transport. Site specific techniques should be considered to determine the sediment properties at the dumpsites, and the oceanographic conditions. These techniques would include monitoring of tides, currents and waves with concurrent time-lapse photography of the seafloor in the dumpsites. The response of the dumped material to the effects of dynamic loading, as caused by waves and ship passages, should be determined. The Sea Carousel, available at the Geological Survey of Canada (Atlantic), uses a small annular flume to determine the shear strength of the seafloor sediments, by accelerating the water in the flume until the critical velocity is reached and sediments within the flume are suspended in the water. The combination of direct measurement of the parameters required for suspension of the sediments at the dumpsite, and determination of the oceanographic conditions at the site, would greatly enhance the understanding of the stability of the dumpsite, and allow prediction of the most likely direction(s) of sediment transport.

References

Haggis Geophysics and Edward L. King and Associates, Investigation for Liverpool Harbour Dredging: Surficial Geological Conditions as Mapped from Seismic Data, 29 July 1992.

Maritime Testing (1985) Limited, Geotechnical Drilling/Sampling/Testing Liverpool Channel Dredging and Containment Ponds Liverpool, Nova Scotia, Service Contract No. 2106316, July 1992.

Parrott, D.R., Sidescan Sonar and Bathymetry Survey of Offshore Marine Dumpsites in Liverpool, Nova Scotia May 1994. Unpublished report to Public Works and Government Services Canada A&ES, Atlantic Region and Transport Canada Marine Navigational Aids. May 1994.

Appendix A

Survey Particulars

Name of Vessel:	Sable Arrow
Vessel Owner/Operator:	Andrew Bushen
Dates of Survey:	26-28 September 1995
Area of Operation:	Liverpool, Nova Scotia
Senior Scientist:	Russell Parrott, GSC

Personnel

Geological Survey of Canada	Public Works	Geoforce Associates
Russell Parrott	Darryl Green	Donald Locke

Equipment Specifications and Performance

The Liverpool offshore dumpsites were surveyed with sidescan sonar and sub-bottom profiler equipment between 26-29 September 1995 using the charter vessel Sable Arrow, a 9.5 metre fiberglass fishing boat owned and operated by Andrew Bushen of Cherry Hill, NS. The sidescan sonar and sub-bottom profiler survey equipment were positioned on the afterdeck of the vessel. The survey and navigation electronics were placed in the deckhouse on a plywood bench installed for the survey.

SIMRAD MS992 SIDESCAN SONAR

The Simrad MS992 digitally controlled Sidescan Sonar was used to generate high resolution acoustic images of the seabed at 100 and 200 metre ranges each side of the survey track (200 and 400 metre swaths). Lines run at the 100 m range were typically 75 metres apart for dumpsite A. A 200 metre range with 125 metre spacing was used for the sidescan sonar survey of Dumpsite B. About 75 metres of towcable were deployed for Dumpsite A and 80 metres for Dumpsite B. Data (both 120 and 330 kHz) were digitized and stored on an AGCDig digital data recorder developed at the Geological Survey of Canada (Atlantic). A hardcopy graphic record of the sidescan sonar data was produced on an Alden 9315CTP thermal recorder. The sidescan sonar system was capable of resolving objects down to a size of about 25 cm. The digital gain settings for the system were logged on field sheets. The Simrad sidescan sonar was deployed from the port side of the vessel.

DIGITAL DATA ACQUISITION

The sidescan sonar data were digitized and logged on an AGCDig digital data recorder developed at the Geological Survey of Canada (Atlantic). The clock in the AGCDig was synchronized to the DPW navigation data logger. Sidescan sonar were acquired at a sample interval of 100 microseconds. No gains or geometric corrections were applied to the raw lagged data. Channel configurations for the logged data were:

Channel	Use
0	120 kHz port
1	120 kHz starboard

BATHYMETRY

Bathymetry data were collected by PWGSC using a single channel Raytheon echosounder attached to a pole on the starboard side of the vessel. Data were processed by PWGSC and provided to GSC as a file with positions and water depths.

SAMPLING EQUIPMENT

Samples of the surficial sediment in the area were obtained using a small van Veen grab sampler deployed from the starboard side of the Sable Arrow and recovered with the vessel's line hauler.

SUB-BOTTOM PROFILER

A Datasonics BubblePulser sub-bottom profiler system was used to determine the thickness of the sediments in the survey area. The system was capable of penetrating to the base of these sediments and showing the location of the underlying harder material, typically glacial deposits and bedrock. The subbottom profiler was deployed on a surfboard from the starboard side of the afterdeck. A NSRF single channel streamer was deployed from a boom on the starboard side of the vessel. Resolution of the sub-bottom profiler system was about 1 metre.

NAVIGATION

Navigation was by a differential Global Positioning System owned and operated by PWGSC, This system utilized a shore station placed on Moose Pt. Accuracy of the navigation was about 4 m.

Data processing

The sidescan sonar and sub-bottom profiler records were interpreted in the field to provide an overview of the surficial geology of the survey area, and sites were selected for sample coverage. Proposed positions for grab samples were identified in terms of offset from the position of the dumpsite.

Digital sidescan sonar data were recovered from the ExaByte tapes recorded on the AGCDig recorder and processed to remove geometric distortions present in sidescan sonar data. (These distortions are caused by the need to tow the sensor above the sea floor.) The geometrically corrected data were then integrated with navigation and processed to remove the effects of varying sensor gain with angle. The sidescan sonar data from adjacent survey lines were then integrated to produce a sidescan sonar mosaic of the harbour using software developed by the Geological Survey of Canada.

The sub-bottom profiler and processed sidescan sonar data collected during the survey were used to prepare a geological interpretation of the dumpsites.

Summary of Activities

Tuesday 26 September - Mobilization and field test of Gear
GSC personnel drove to Liverpool. Weather conditions were too rough to allow surveying at the offshore dumpsites. Electrical connections were completed for all gear, and a test line was run in harbour with sidescan, sub-bottom profiler and the digital recorder to confirm that all equipment was operational.

Wednesday 27 September 1995 - Survey Dumpsites A and B
Detailed lines were then run at 100 m range (200 m swath) and an offset of 75 metres between lines for Dumpsite A. Dumpsite B was surveyed at 200 m range (400 m swath) and an offset of 125 metres. The vessel then returned to Liverpool.

Thursday 28 September 1995 - Sampling Dumpsites A and B
The geophysical survey gear was removed from the vessel. A series of van Veen samples were taken at Dumpsites A and B for use in groundtruthing the geophysical data. Weather conditions deteriorated throughout the day, making sampling of offshore Dumpsite B quite difficult. The vessel returned to the dock at the completion of the sampling program, all remaining gear was removed, and GSC personnel returned to Dartmouth.