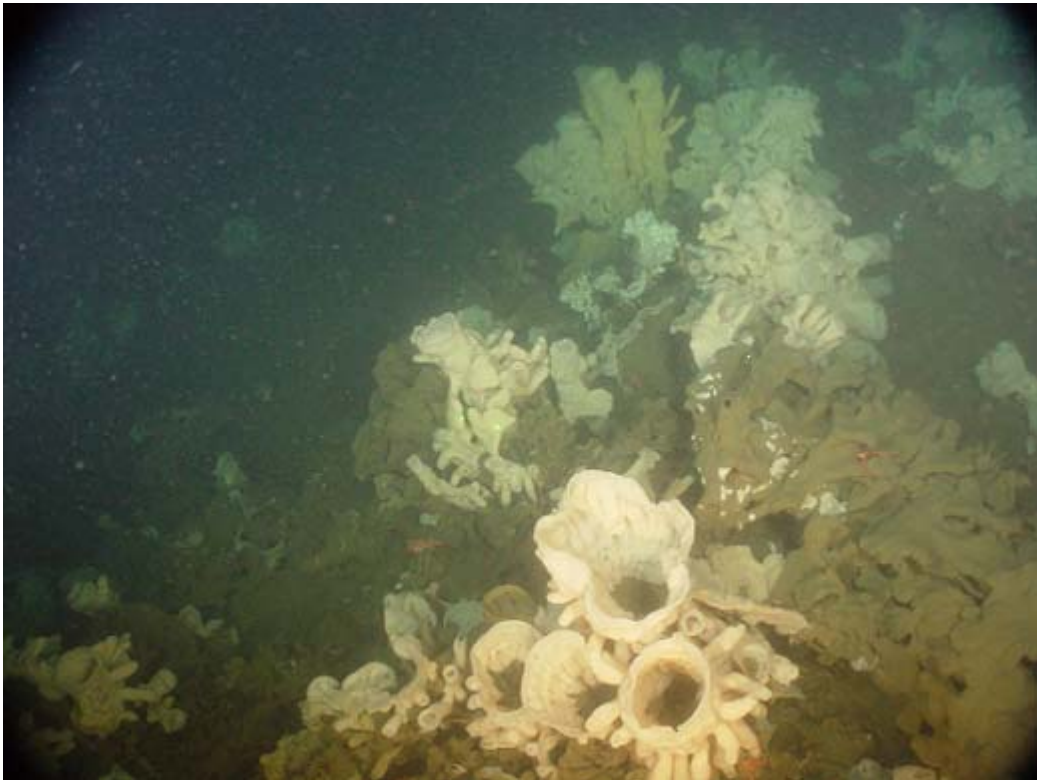


Compendium of Monitoring Activities at Disposal at Sea Sites in 2005-2006

Canadian Edition



Disposal at Sea Program
Environmental Protection and Operations Directorate
Environment Canada

March 2007

Cover: ROPOS submersible image of a cold water Sponge Reef observed at the former Malcolm Island, British Columbia disposal site.

Summary

Canada is a maritime nation whose 243,790 km of coastline is the longest of any nation in the world. The Canadian maritime environment is relatively uncontaminated, but does have some problems. One of the measures in place to protect Canada's marine environment and meet our international obligations under the *London Convention 1972* and its *1996 Protocol*, is the regulation of disposal at sea through a permit system under the *Canadian Environmental Protection Act, 1999* (CEPA).

Each year, as required by CEPA, Environment Canada conducts representative monitoring at disposal at sea sites. This National Compendium of Monitoring Activities provides a technical summary of the monitoring activities conducted in 2005 at a total of 12 disposal sites. This compendium is produced annually to meet national and international reporting obligations.

In the Atlantic Region, the Cheticamp Harbour disposal site was selected for monitoring to investigate the effects of disposal in an exposed coastal area. Approximately 100,000 cubic metres of dredged material and some fish offal have been disposed of at this site since 1979. It was anticipated that materials would remain within the boundaries of the site, however, multibeam bathymetric surveys and seafloor photos have not revealed any dredged material or fish offal accumulation. Benthic analysis of the site has revealed the presence of at least 37 species over 13 stations. The results of further analysis are forthcoming, and decisions about management actions needed will be made upon completion.

Preliminary monitoring data are presented from the Pacific and Yukon Region. Studies were conducted at nine routinely used sites and looked at all or a combination of the following in accordance with National Disposal Site Monitoring Guidelines: sediment dispersal, trace contaminant levels, bioavailability potential, and biological effects. These studies are intended to provide information about the trends at each disposal site, and to verify that use continues to be appropriate and protective of the marine environment. Results and conclusions from these studies are pending analysis of the collected data. Elaborate sponge reefs were observed at the Malcolm Island disposal site, and as a result, the site has been closed.

Potential PAH contamination at a Pointe-Basse Harbour disposal site was investigated in the Quebec region. Sediment samples from within the disposal area, and a nearby reference location, were collected and analysed for chemical contamination and toxicity. Neither sampling site was found to be toxic, nor were measured chemicals above screening levels. It was concluded that disposal of Pointe-Basse Harbour sediments can continue at the site.

A new disposal site in Hudson Bay, near Churchill Manitoba is undergoing a multi-year monitoring study by the Prairie and Northern Region. Sediment sampling was conducted for physical and chemical assessments, and to assess benthic recolonization. Sonar surveys were completed to determine the extent of sediment transport. The results to date indicate that predictions about impacts were correct, and no management actions are required. One further visit to the site is planned before final conclusions about its recovery can be reached.

Comments

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Introduction

Canada is a maritime nation. It possesses 243,790 km of coastline, the longest of any nation in the world, and has a vital interest in preserving a healthy marine environment. Though by world standards the Canadian maritime environment is relatively uncontaminated, Canada's territorial waters do have some problems, especially in harbours, estuaries and near shore areas.

Canada regulates disposal at sea through a permit system under the Canadian Environmental Protection Act, 1999 (CEPA 1999). This is one of the measures in place to protect Canada's marine environment and meet our international obligations under the London Convention 1972 and its 1996 Protocol on preventing marine pollution.

CEPA 1999 requires Environment Canada to monitor representative disposal at sea sites each year. This is conducted in accordance with national monitoring guidelines and is dependant on available resources from the disposal fees collected. In order to respond to Canada's national and international reporting obligations, this National Compendium of Monitoring Activities, based on regional reports, is produced annually.

Role of monitoring

Disposal site monitoring allows permittees continued access to suitable disposal sites by helping to ensure that the permit conditions were met and the use of the site has not caused unacceptable or unpredicted impacts. It verifies that assumptions made during the permit review and site selection process were correct and sufficient to protect the marine environment and human health. Monitoring allows Environment Canada to gather information and take appropriate action to manage the sites in an environmentally sound manner.

Monitoring also plays a critical role in reviewing the overall adequacy of controls. Information compiled nationally and regionally, over time, provides the basis to assess whether the disposal at sea regulatory controls, guidelines and permit conditions are adequate to protect the marine environment and human health.

Experience gained from monitoring may also highlight the need for research to develop better monitoring tools, or to refine the monitoring program, to address specific environmental, health or public concerns. It is also expected that monitoring will uncover gaps in our understanding of impacts, particularly in the area of cause and effect relationships.

To increase the level of stakeholder involvement, annual meetings with clients and other interested parties are organized to gather additional comments on past monitoring and to guide Regional priorities for future assessments. The annual meetings also ensure Environment Canada's decisions concerning monitoring activities are carried out in an open and transparent manner.

Finally, Environment Canada's disposal site monitoring, reporting and stakeholder communication activities are critical to fulfilling its federal and international obligation to apply the Precautionary Principle while administering CEPA.

Conducting monitoring studies

Monitoring at disposal at sea sites is conducted according to national guidelines. Activities carried out in a given year are based on available resources and may involve an assessment of the physical, chemical and biological features of sites under review. Impact hypotheses are generated following permit reviews, and form the basis of this monitoring.

Physical monitoring relates to the collection of geological information that is relevant to determining the area of deposition, delineating the disposal site boundaries, studying the accumulation of dredged material within the area of deposition, and documenting evidence of sediment transport from the disposal site.

Biological and chemical assessments are undertaken concurrently in many cases, and the monitoring design for these parameters takes into account the size and dispersal characteristics of the site. Chemical monitoring is aimed at measuring the levels of chemicals in sediments and comparing them to lower action levels set by the Disposal at Sea Regulations or other national screening levels for additional parameters of concern.

CEPA Lower Action Levels.

Lower Action Levels for chemicals in sediments
(*Disposal at Sea Regulations*)
(mg/kg, dry weight)

Chemical	Current Level
Cadmium	0.6
Mercury	0.75
total PCBs	0.1
total PAHs	2.5

Biological monitoring is primarily centred on biological testing in the laboratory and benthic community surveys. The biological test methods currently used for sediment assessment include:

- an acute toxicity test using marine or estuarine amphipods (the endpoint is lethality);
- a fertilization assay using echinoids (the endpoint is fertilization);
- a toxicity test using a photoluminescent bacteria, the Microtox® solid-phase test (the endpoint is bioluminescence); and
- a bedded sediment bioaccumulation test using bivalves (the endpoint bioaccumulation).

Integrative assessment

If sediments are below the lower action levels or other applicable national screening levels for contaminants, and pass all biological tests, no further action is required. However, if levels of contaminants or biological test results demonstrate a cause for concern then the first step is to verify compliance with the terms of the permits issued since the site was last monitored.

The second step generally involve checking potential sources of pollutants and conducting further site characterization. After considering this information, the following hierarchy of interpretative guidance can be applied to the concurrent chemical and toxicological data:

- if sediments at the disposal site contain substances in excess of national screening levels (including lower action levels), pass the acute toxicity test, but fail one sublethal or bioaccumulation test, then consideration could be given to modifying further use of the site and investigating the long term stability of the material onsite;
- if the sediments contain substances below the national screening levels, yet fail any of the biological tests, then further investigation would be required to determine if this is the result of either a confounding factor such as laboratory anomaly, or the presence of a contaminant not included in the chemical screening; or
- if the sediments contain substances in excess of the national screening levels and either fail the acute test or fail two (or more) additional tests including the sublethal tests and the bioaccumulation test, then further monitoring, site closure or remediation could be considered.

As well, cursory benthic community surveys can be used as a general sediment quality indicator. The overall assessment of the disposal site considers all available information from physical, chemical and biological monitoring.

Intensity of monitoring

Monitoring at every disposal site is not considered necessary, as current knowledge of impacts related to disposal of dredged material from routine dredging allows for good assessments to be drawn from representative disposal sites. Representative sites are selected by attempting to ensure that the major sites (>100,000 m³ of dredged materials/year) are monitored at least once every five years. Monitoring at other sites is triggered by national monitoring guidelines criteria which are based on volume, proximity to sensitive areas, or level of concern. The number of sites monitored in a year and the parameters measured at each site depend on the available resources through the collection of fees from permittees.

Reporting

Canada's Disposal at Sea Program is administered through regional offices which are largely responsible for the permit review process, as well as for planning, conducting and reporting on monitoring studies undertaken in their administrative areas. This compendium, based on regional detailed reports, is produced annually to respond to Canada's national and international reporting obligations. Readers may request more detailed information on any of the monitoring activities in this compendium, from the appropriate regional office.

were taken to provide additional information as to the character and composition of the sediments on the seafloor (Figures 2 and 3).

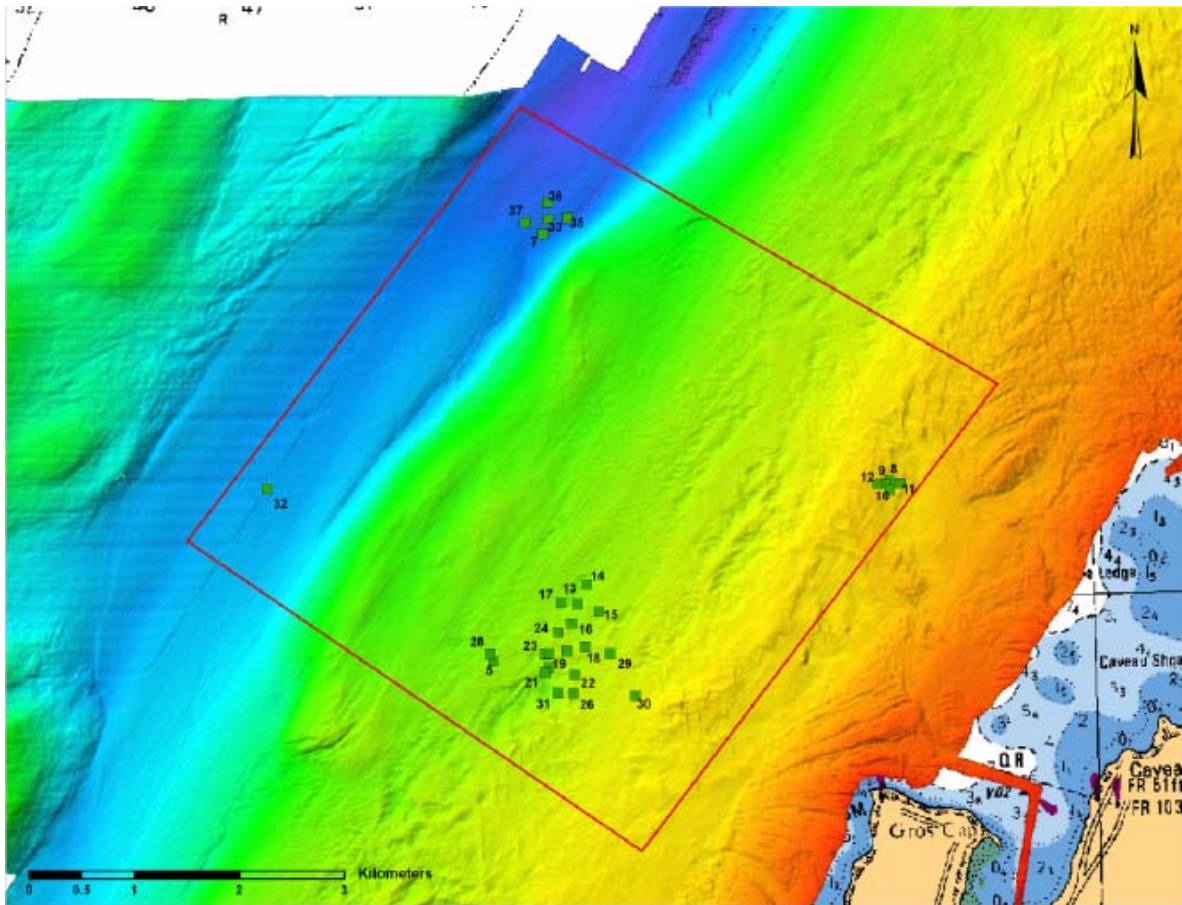


Figure 2. Seafloor grab sample locations taken during survey *Opilio* 2005030, July 2005.

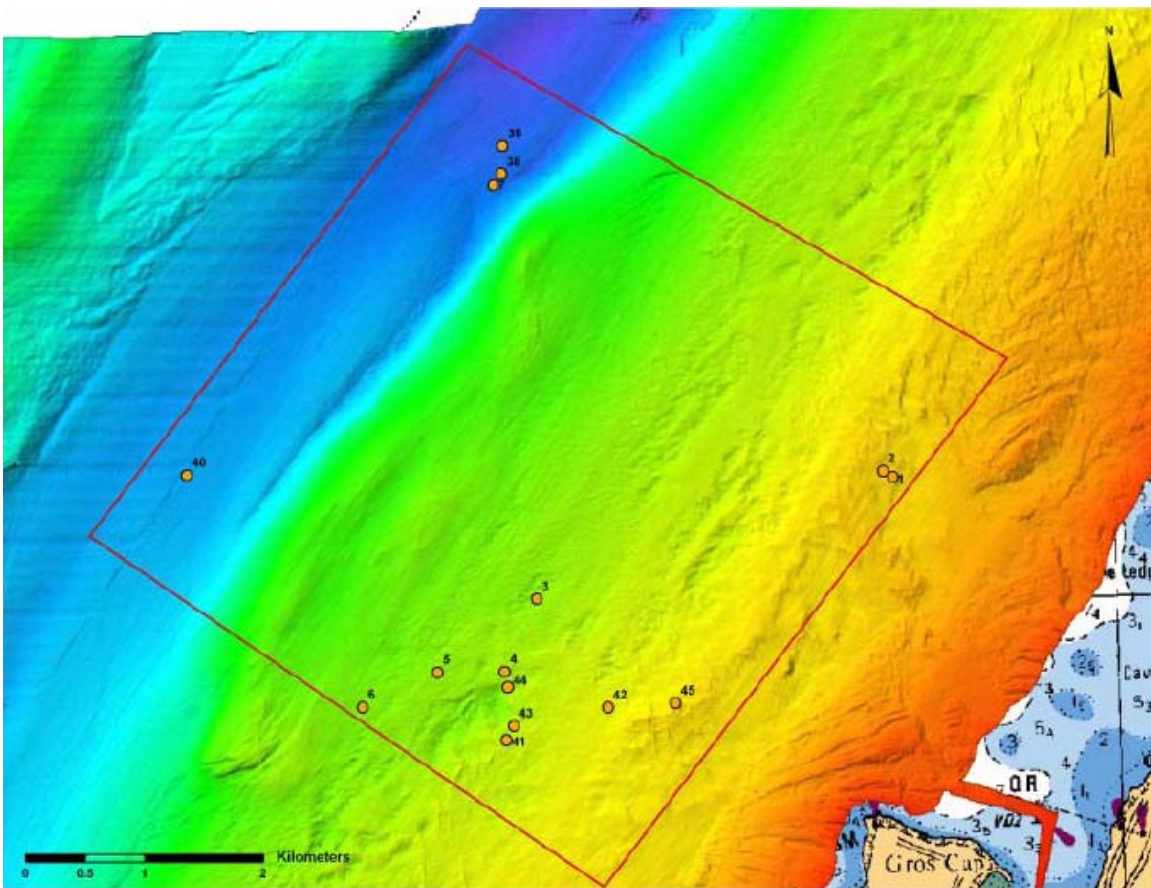


Figure 3. Location of camera stations, survey *Opilio* 2005030, July 2005.

Results and Conclusions

The preliminary multibeam data indicates that the areas where the three disposal sites are located are quite homogeneous with no evidence of dredged material accumulation. Benthic analysis was performed on the photographs and underwater video transects of the sea bottom. All visible benthic flora and fauna were identified to the lowest taxonomic level possible and the presence of each was recorded. To date, 37 different species of benthic flora and fauna have been positively identified over 13 photo stations. The presence of burrows, trails and tracks in the sediment also indicate the existence of an *in fauna* community.

An investigation for fish offal and large accumulations of shell hash has so far revealed nothing significant. An image from one camera station showed many toad crabs (*Hyas* spp.) eating a white object that may have been fish offal. No other signs of offal were seen, and no large accumulations of shell hash were visible from photos or video transects. Scattered shell fragments were visible in most of the video transects and photos but were homogenously scattered on the seafloor.

Further data analysis and a review of results by the Department of Fisheries and Oceans are underway. A final report is anticipated by the end of 2007, at which time decisions about necessary management actions, if any, will be made.

References

Parrott, Russell D. and Patton, E. 2006. *Cruise Opilio 2005030: Nearshore Surveys in Cheticamp, NS, 30 June – 12 July 2005 (Draft)*. Prepared for Environment Canada, Atlantic Region.

Pacific and Yukon Region Preliminary Results

Malcolm Island, British Columbia

Background

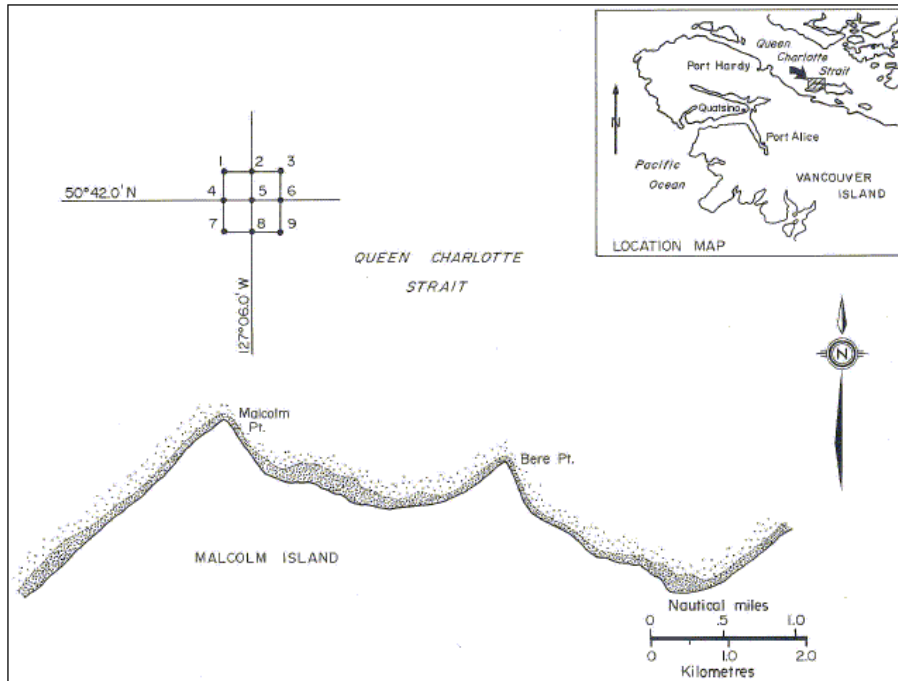


Figure 4. Map showing the location of Malcolm Island, British Columbia

The Malcolm Island ocean disposal site was designated in 1984. To date, the total volume of dredged material disposed of at the site is approximately 103 000 cubic metres. The site is located in 180 metres of water depth. The majority of the material disposed of at the site results from maintenance dredging at log handling facilities on northern Vancouver Island.

Impact Hypothesis

Disposal activities do not result in a significant dispersal of dredged material at designated sites.

Monitoring Conducted

In October 2005, a Department of Fisheries and Oceans remotely operated submersible ROPOS was used to conduct physical monitoring work at the site. The survey was designed to provide real-time records of the benthic conditions at the disposal site. The transect lines are geo-referenced to allow future surveys to be carried out for comparative purposes. The video records were used to record conditions, including biological and geophysical changes and any currents related effects, at the disposal site and in the surrounding area. These video images, as well as still digital camera images and Interactive-Realtime-Logging images that were collected are currently being processed.

During the ROV survey, a significant sponge reef formation was encountered on both transects of the disposal site. Due to the sensitive nature of the sponge reefs, which provide a complex deep water habitat for invertebrates and fishes, the disposal site has been closed, and a potential relocation site is under consideration.

Pacific and Yukon Region Preliminary Results

Malaspina Strait, British Columbia

Background

The Malaspina Strait ocean disposal site has been in active use since 1980 (Ward and Sullivan, 1980), and approximately 600,000 cubic metres of dredged and excavated material have been disposed of there. Elevated cadmium levels were detected at the disposal site prior to designation and during past surveys. However, monitoring data have not indicated any increase in the levels, nor does there appear to be any relationship between these levels and the results of the acute toxicity tests conducted.

The disposal site is located in 390 metres of water and was selected to avoid interference with marine navigation, fisheries habitat and marine resources. The site has been monitored by Environment Canada since 1980.

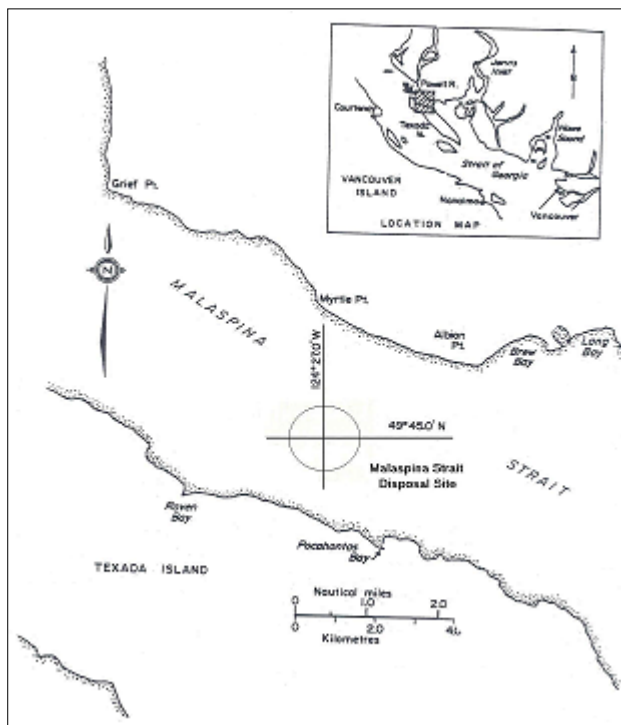


Figure 5. Map showing the location of Malaspina Strait, British Columbia

Impact Hypotheses

- i. *Disposal of dredged material does not result in a significant increase in trace contaminant levels in the sediments at designated sites.*
- ii. *The bioavailability of contaminants at designated sites is low.*
- iii. *The disposed dredged material does not cause biological responses in sensitive marine organisms as determined by toxicity testing.*

Monitoring Conducted

In May 2005, sediment chemistry samples were collected with a Smith-McIntyre grab sampler at pre-determined station locations and analyzed for trace metals, organics, particle size distribution, TOC and AVS/SEM. The sediment chemistry data will be added to the monitoring database and compared with survey results from May 2000. Sediment chemistry, particle size and TOC will also be used to monitor the distribution of material disposed of at the site and the surrounding areas. AVS/SEM will be used to evaluate the potential for bioavailability of trace metal contaminants in the sediment at the disposal site.

Composite sediment samples were collected at pre-determined station locations and prepared for biological testing. Bioassays using the amphipods *Eohaustorius estuarius*, the Microtox® solid phase test, and the echinoid fertilization test were conducted. Results will be evaluated against current pass/fail criteria.

Pacific and Yukon Region Preliminary Results

Johnstone Strait – Hickey Point, British Columbia

Background

The Johnstone Strait ocean disposal site was designated in 1980. To date, the total volume of dredged material disposed of at the site is approximately 186,000 cubic metres. The site is located in 270 metres of water. The majority of the material disposed of at the site results from maintenance dredging at forest industry sites and is comprised of wood waste, silt, clay, sand, and gravel.

Impact Hypothesis

Disposal activities do not result in a significant dispersal of dredged material at designated sites.

Monitoring Conducted

In October 2005, a Department of Fisheries and Oceans remotely operated submersible ROPOS was used to conduct physical monitoring work at the site. The survey was designed to provide real-time records of the benthic conditions at the disposal site. The transect lines are geo-referenced to allow the comparison of future surveys. The video records were used to document conditions at the site and in the surrounding area. The footage will be processed to observe biological and geophysical changes, and any current-related effects. Still digital camera images and Interactive-Realtime-Logging images were also collected, and are currently being processed as well.

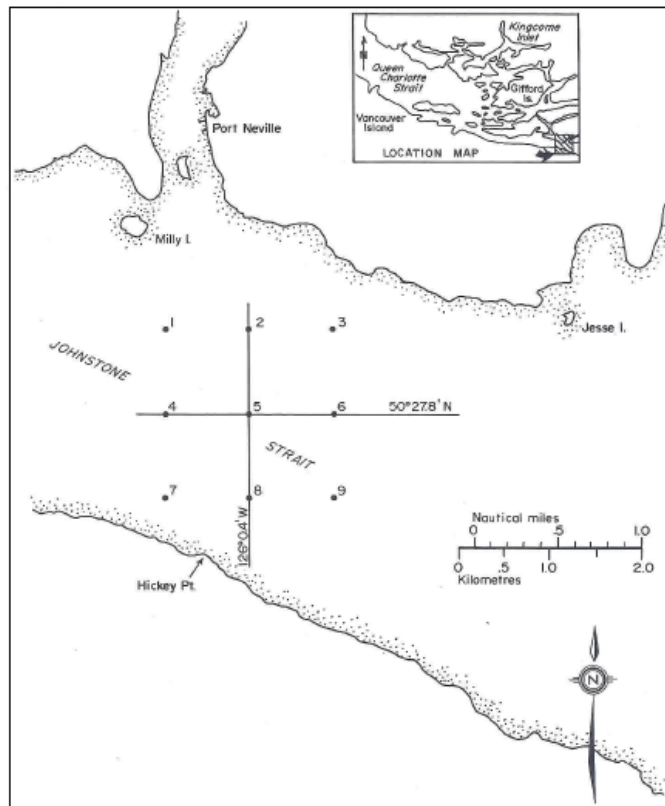


Figure 6. Map showing the location of Johnstone Strait, Hickey Point, British Columbia

Pacific and Yukon Region Preliminary Results

Queen Charlotte Strait, British Columbia

Background

The Queen Charlotte Strait ocean disposal site was designated in 1984. To date, the total volume of dredged material disposed of at the site is approximately 20,613 cubic metres. The site is located in 390 metres of water depth. The majority of the material disposed of at the site results from maintenance dredging at log handling facilities on northern Vancouver Island.

Impact Hypothesis

Disposal activities do not result in a significant dispersal of dredged material at designated sites.

Monitoring Conducted

In October 2005, a Department of Fisheries and Oceans remotely operated submersible ROPOS was used to conduct physical monitoring work at the site. The survey was designed to provide real-time records of the benthic conditions at the disposal site. The transect lines are geo-referenced to allow future surveys to be carried out for comparative purposes. The video records were used to record conditions, including biological and geophysical changes and any currents related effects at the disposal site and in the surrounding area. This video footage, as well as still digital camera images and Interactive-Realtime-Logging images that were collected at the same time are currently being processed.

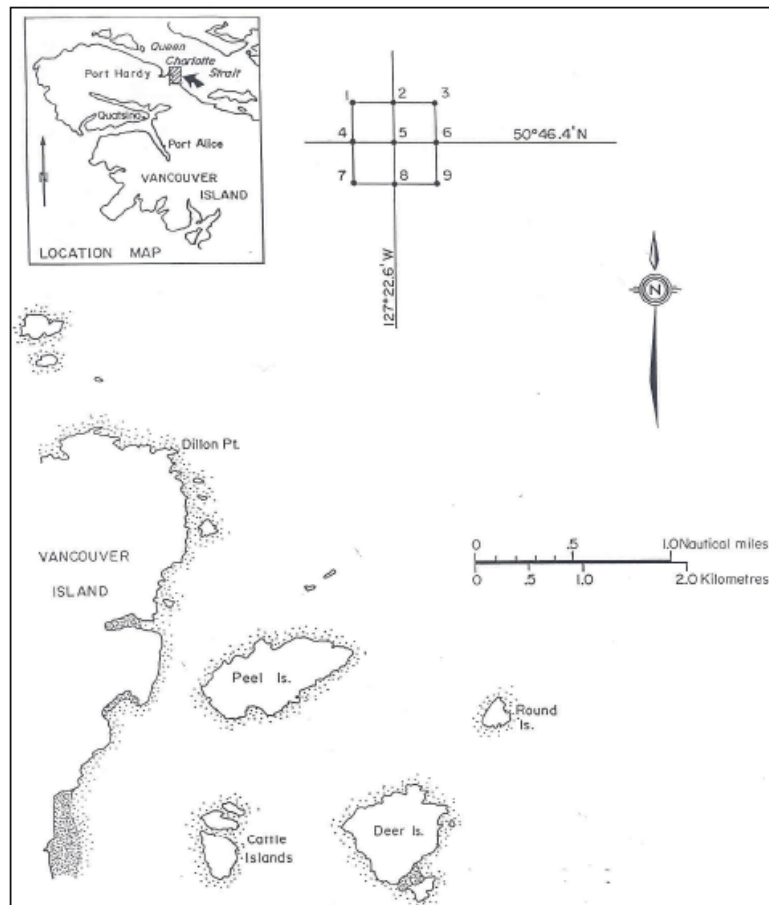


Figure 7. Map showing the location of Queen Charlotte Strait, British Columbia

Pacific and Yukon Region Preliminary Results

Cape Mudge, British Columbia

Background

The Cape Mudge disposal site was designated in 1981. To date, the total volume of dredged material disposed of at the site is approximately 170,000 cubic metres. The site is located in 200 metres of water. The majority of the material disposed of at the site results from maintenance dredging at log handling facilities in the Campbell River area.

Impact Hypotheses

- i. *Disposal of dredged material does not result in a significant increase in trace contaminant levels in the sediments at designated sites.*
- ii. *The bioavailability of contaminants at designated sites is low.*
- iii. *The disposed dredged material does not cause biological responses in sensitive marine organisms as determined by toxicity testing.*

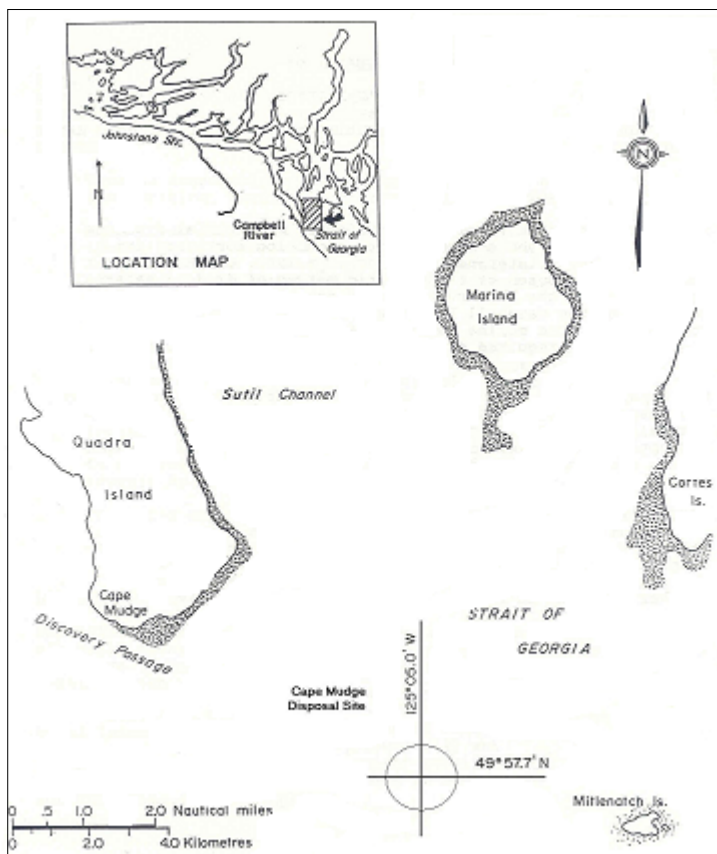


Figure 8. Map showing the location of Cape Mudge, British Columbia

Monitoring Conducted

In May 2005, sediment chemistry samples were collected with a Smith-McIntyre grab sampler at pre-determined station locations and analyzed for trace metals, organics, particle size distribution, TOC and AVS/SEM. The sediment chemistry data will be added to the monitoring database and compared with survey results from May 2000. Sediment chemistry, particle size and TOC will also be used to monitor the distribution of material disposed of at the site and the surrounding areas. AVS/SEM will be used to evaluate the potential for bioavailability of trace metal contaminants in the sediment at the disposal site.

Composite sediment samples were collected at pre-determined station locations and prepared for biological testing. Bioassays using the amphipods *Eohaustorius estuarius*, the Microtox® solid phase test, and the echinoid fertilization test were conducted. Results will be evaluated against current pass/fail criteria.

Pacific and Yukon Region Preliminary Results

Watts Point, British Columbia

Background

The Watts Point ocean disposal site has been in active use since 1976 (Ward and Sullivan, 1980). Approximately 520,000 cubic metres of dredged material has been disposed of since that time. The site is located in 230 metres of water and was selected to avoid interference with marine navigation, fisheries habitat and marine resources. The site has been monitored by Environment Canada since 1980.

Impact Hypotheses

- i. *Disposal of dredged material does not result in a significant increase in trace contaminant levels in the sediments at designated sites.*
- ii. *The bioavailability of contaminants at designated sites is low.*
- iii. *The disposed dredged material does not cause biological responses in sensitive marine organisms as determined by toxicity testing.*

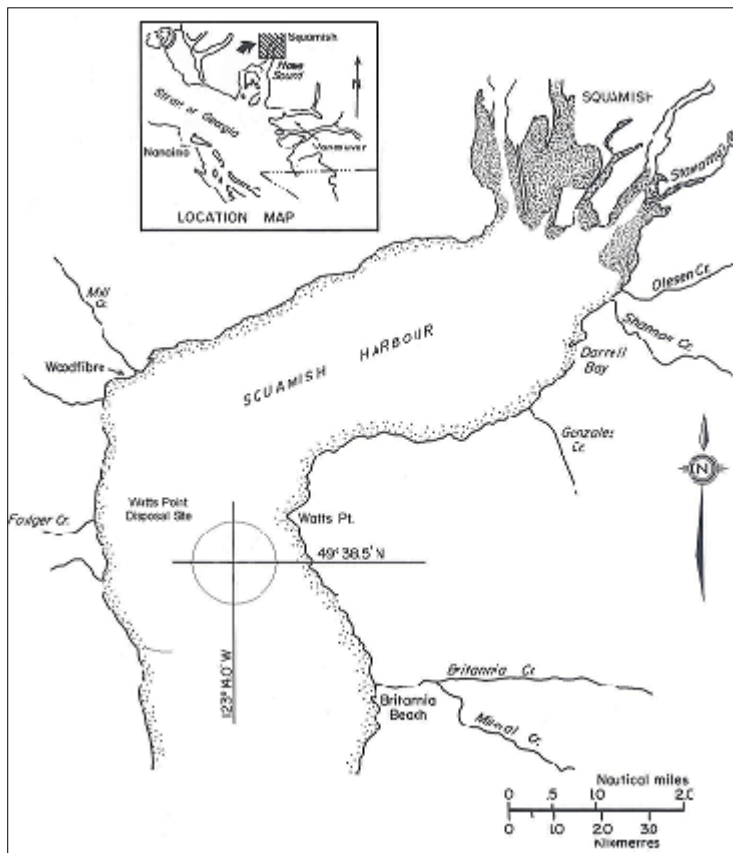


Figure 9. Map showing the location of Watts Point, British Columbia

Monitoring Conducted

In May 2005, sediment chemistry samples were collected with a Smith-McIntyre grab sampler at pre-determined station locations and analysed for trace metals, organics, particle size distribution, TOC and AVS/SEM. The sediment chemistry data will be added to the monitoring database and compared with survey results from September 1999. Sediment chemistry, particle size and TOC will also be used to monitor the distribution of material disposed of at the site and the surrounding areas. AVS/SEM analysis will be used to evaluate the potential for bioavailability of trace metal contaminants in the sediment at the disposal site.

Composite sediment samples were collected at pre-determined station locations and prepared for biological testing. Bioassays using the amphipods *Eohaustorius estuarius*, the Microtox® solid phase test and the echinoid fertilization test were conducted. Results will be evaluated against current pass/fail criteria.

Pacific and Yukon Region Preliminary Results

Thornborough Channel, British Columbia

Background

The Thornborough Channel disposal site has received approximately 114,000 cubic metres of dredged material since its designation in 1975. The site is located in 220 metres of water. The majority of the material disposed of at the site results from maintenance dredging at log handling facilities and gravel operations in the immediate area.

Impact Hypotheses

- i. *Disposal of dredged material does not result in a significant increase in trace contaminant levels in the sediments at designated sites.*
- ii. *The bioavailability of contaminants at designated sites is low.*
- iii. *The disposed dredged material does not cause biological responses in sensitive marine organisms as determined by toxicity testing.*

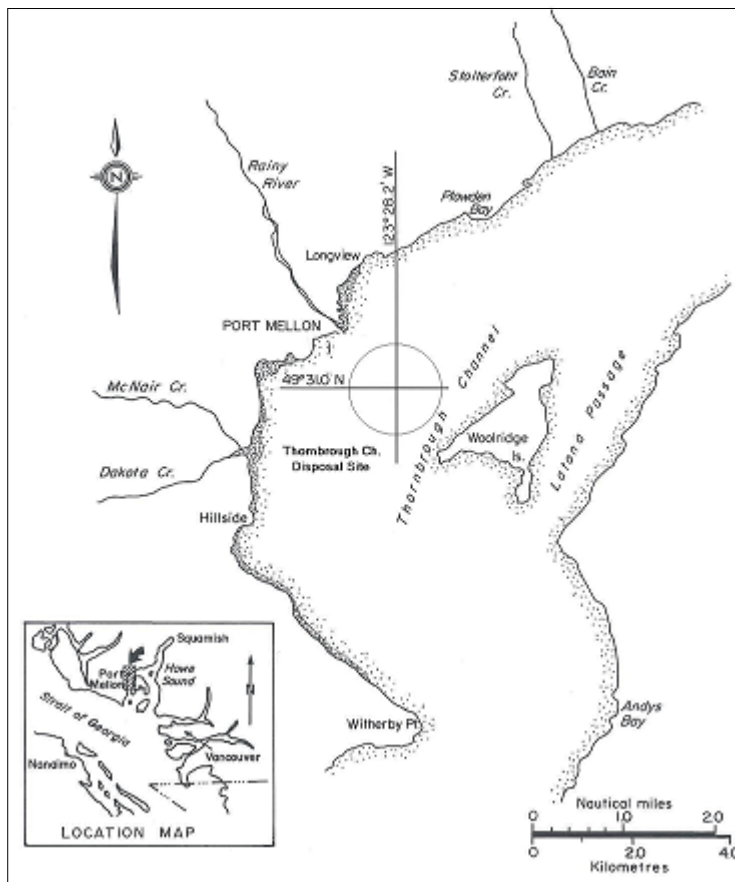


Figure 10. Map showing the location of Thornborough Channel, British Columbia

Monitoring Conducted

In May 2005, sediment chemistry samples were collected with a Smith-McIntyre grab sampler at pre-determined station locations and analysed for trace metals, organics, particle size distribution, TOC and AVS/SEM. The sediment chemistry data will be added to the monitoring database and compared with survey results from September 1999. Sediment chemistry, particle size and TOC will also be used to monitor the distribution of material disposed of at the site and the surrounding areas. AVS/SEM analysis will be used to evaluate the potential for bioavailability of trace metal contaminants in the sediment at the disposal site.

Composite sediment samples were collected at pre-determined station locations and prepared for biological testing. Bioassays using the amphipods *Eohaustorius estuarius*, the Microtox® solid phase test and the echinoid fertilization test were conducted. Results will be evaluated against current pass/fail criteria.

Pacific and Yukon Region Preliminary Results

Haro Island, British Columbia

Background

The Haro Strait ocean disposal site was designated in 1976. To date, the total volume of dredged material disposed of at the site is approximately 190,000 cubic metres. The site is located at a water depth of 200 metres. The majority of the material disposed of at the site results from maintenance dredging at local marinas or log handling facilities on southern Vancouver Island.

Impact Hypotheses

Disposal of dredged material does not result in a significant increase in trace contaminant levels in the sediments at designated sites.

Monitoring Conducted

In October 2005, due to scheduling conflicts at the start of the scheduled fall survey, an unplanned sediment sampling survey was undertaken at the Haro Strait location. Conditions at the disposal site are known to be moderately dispersive. Several samples were collected with a Smith McIntyre grab sampler and will be analyzed for trace metals, organics, particle size distribution and TOC.



Figure 11. Map showing the location of Haro Strait, British Columbia

Pacific and Yukon Region Preliminary Results

Five Finger Island, British Columbia

Background

The Five Finger Island disposal site was designated in 1978. To date, the total volume of dredged material disposed of at the site is approximately 260,000 cubic metres. The site is located in 271 metres of water in the Strait of Georgia. The majority of the material disposed of at the site results from maintenance dredging sawmills and log handling facilities in the Nanaimo area.

Monitoring work conducted at the Five Finger Island disposal site in 2004-2005 produced varied responses in bioassays. As a result, further study was recommended to understand the effects of disposal activities at the site.

Impact Hypothesis

- i. *Disposal of dredged material does not result in a significant increase in trace contaminant levels in the sediments at designated sites.*
- ii. *The bioavailability of contaminants at designated sites is low.*
- iii. *The disposed dredged material does not cause biological responses in sensitive marine organisms as determined by toxicity testing.*

Monitoring Conducted

In October 2005, sampling was undertaken at the Five Finger Island site. Sediment chemistry samples were collected with a Smith-McIntyre grab sampler at pre-determined station locations and analyzed for trace metals, organics, particle size distribution, TOC and AVS/SEM. Composite sediment samples were collected at pre-determined station locations and prepared for biological testing. Bioassays using the amphipods *Eohaustorius estuarius*, the Microtox® solid phase test, and the echinoid fertilization test were conducted. The results will be evaluated against current pass/fail criteria. Management action may be required if varied biological responses are again observed.

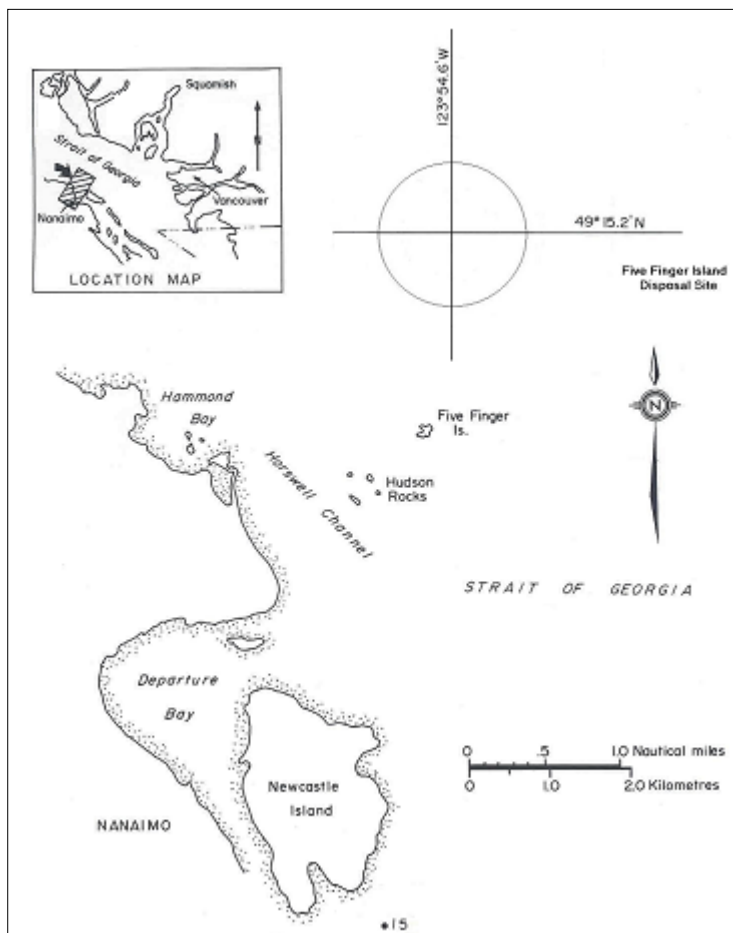


Figure 12. Map showing the location of Five Finger Island, British Columbia

Quebec Region: *Pointe-Basse Harbour, Disposal Site PB-8*

Background

The PB-8 disposal site for dredged sediment is located in 13 m of water, 2.4 km south of Pointe-Basse Harbour in the Magdalen Islands (Figures 13 and 14). Since its designation as a disposal site in 1985, this site has received mainly dredged sediment from Pointe-Basse Harbour. In total, 124,912 m³ of sediment was dumped here between 1985 and 2003 inclusively. These numbers include 41,447 m³ of sediment from Cap-aux-Meules Harbour, which was

dumped in 1985.

There is some concern over the possibility of PAH contamination from past disposal activities. In 1995, the harbour sediments were sampled and assessed using the criteria in effect at the time, and deemed suitable for ocean disposal. However, subsequent sampling in 1999 and 2000 revealed PAH levels above the 2.5 mg/kg lower action level (Figure 15). Based on these results, a zone of exclusion was established such that dredged materials originating within its boundaries were prohibited from ocean disposal. Other disposal means, such as disposal on land, could be considered.



Figure 13. Map showing the location of disposal site PB-8 in Pointe-Basse Harbour, Magdalen islands, Quebec

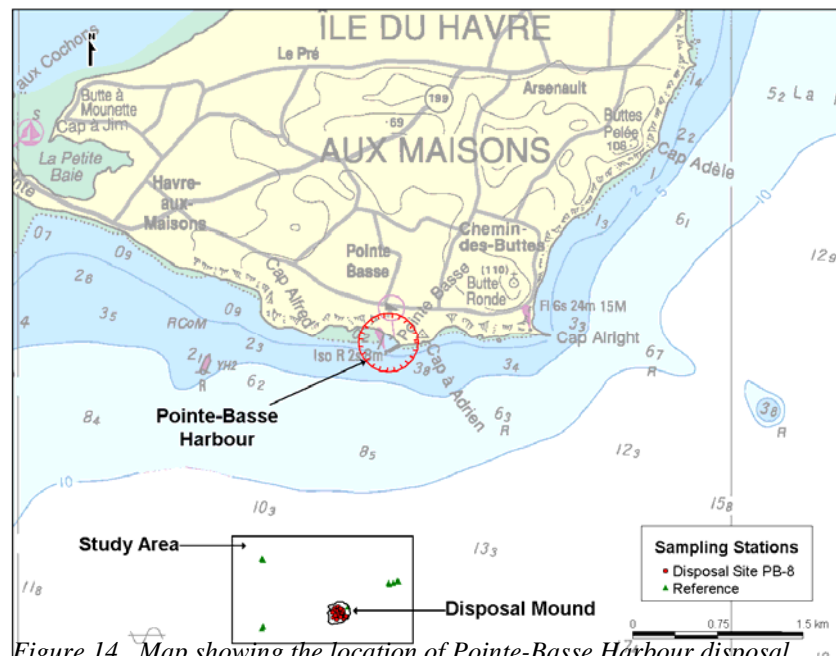


Figure 14. Map showing the location of Pointe-Basse Harbour disposal site and sampling stations within the harbour.

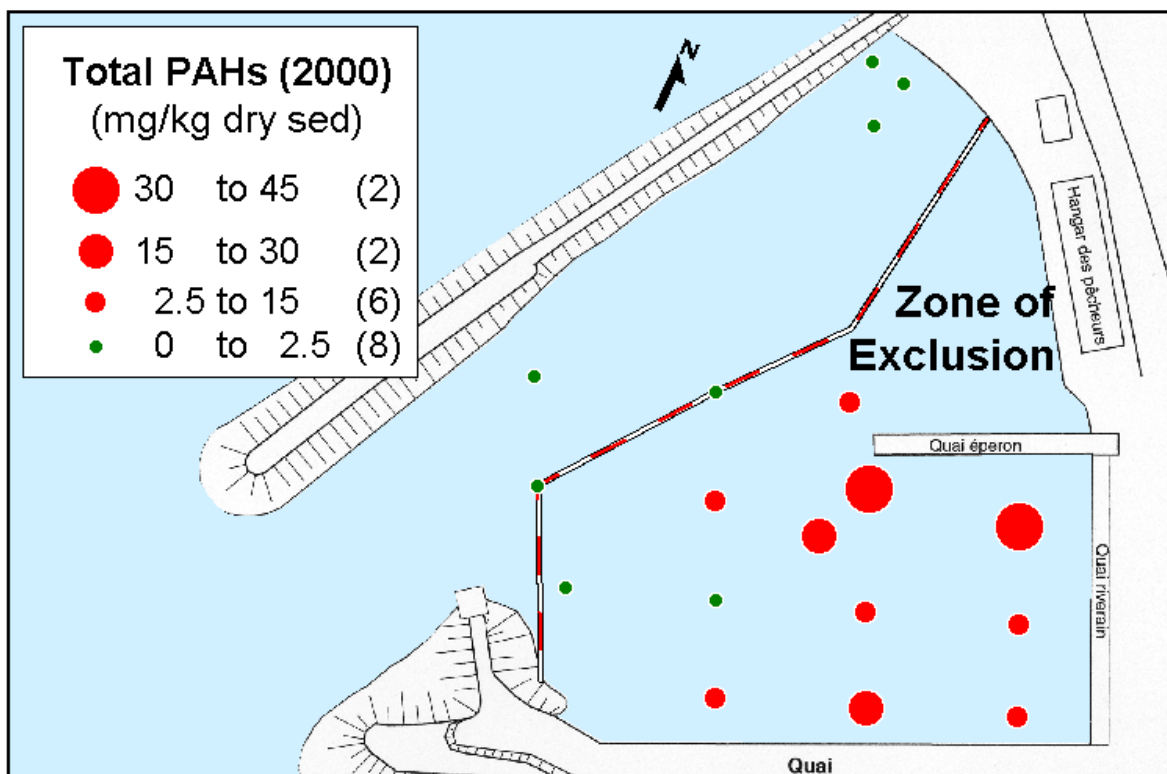


Figure 15. Total PAH content in the Pointe-Basse Harbour sediments as measured in 2000. The red line represents the zone of exclusion boundaries. Sediments originating within this zone cannot be disposed of at sea.

Between 1995 and 1999, and prior to the establishment of the zone of exclusion, it is possible that dredged materials with elevated PAH levels were disposed of at the PB-8 site, resulting in PAH contamination. This possibility, and the fact that the PB-8 site is representative of other disposal sites in the area, triggered monitoring at the PB-8 site.

Impact Hypothesis

Disposal at sea activities have not resulted in increased levels of PAH and other contaminants in disposal site sediments, nor does the dredged material disposed of cause biological responses in sensitive marine organisms as determined by toxicity testing..

Monitoring Conducted

Bathymetric readings of the PB-8 disposal site were taken in August of 2001 from a Canadian Hydrographic Service vessel that was equipped with a SIMRAD EM-3000 multibeam sonar system connected to a differential global positioning system. This system was also used to produce a map image of sea roughness. The combination of both these pieces of information made it possible to collect and establish the limits of the heaped sediment at PB-8 disposal site (Figures 14 and 16).

A sampling survey plan including 20 stations and five reference stations (Figures 14 and 16) was designed to reflect the extent of the dumping location, the nature of the surrounding sea bottom and the direction of possible sediment transport. The samples were submitted for physical, chemical, and biological assessments. Whole sediment analyses included particle size, moisture content, metals, total organic carbon (TOC) and the PAH. Due to a lack of PAH observed in all samples taken, a smaller subset of samples was submitted for toxicity testing and an analysis of the

associated support parameters. Toxicity tests included an amphipod survival test, fertilization inhibition using sea urchins, and luminescent bacteria solid-phase test.

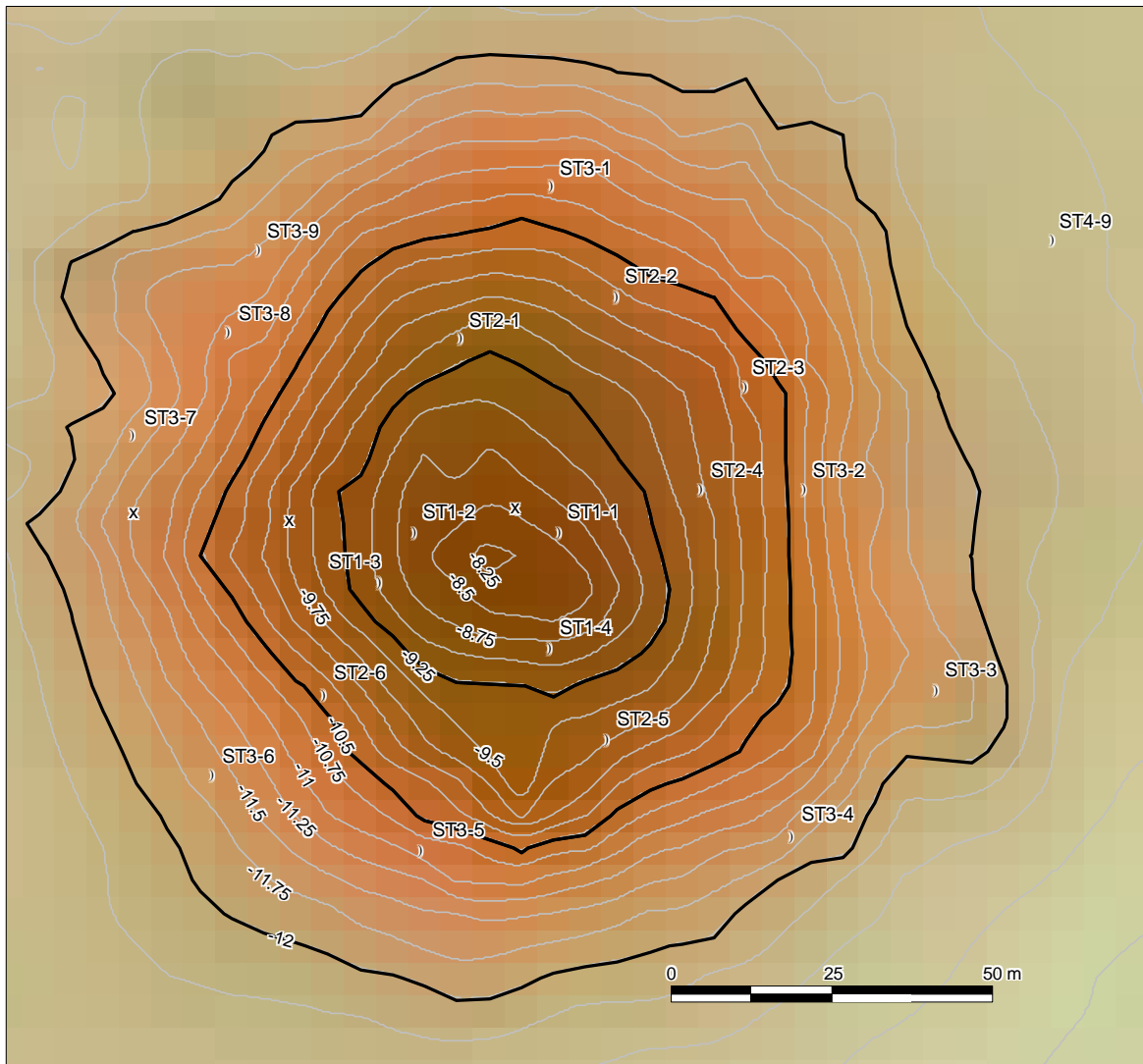


Figure 16. Positions of the sampling stations at the PB-8 disposal site.

Observations and Results

The interpretation of the chemical analyses and the biological tests was based primarily on the criteria established to evaluate dredged materials proposed for ocean disposal. Comparisons of results from disposal and reference sites were also used for interpretive purposes.

Physicochemical Properties of the Sediments

No PAH exceedances were observed in the sediment samples collected at the PB-8 disposal site, and the total PAH concentrations measured were consistently below the current 2.5 mg/kg standard. Three hypotheses were proposed to explain these observations:

- The dredged sediment disposed of at disposal site PB-8 was not contaminated with PAH;
- The portion of PAH-contaminated dredged sediments was diluted by the much larger volumes of clean sediment located outside the exclusion zone (Figure 15) to the point that measured PAH levels were lower than the detection limits; or
- The sediment particles to which the PAH were attached were disposed of outside the limits of the disposal site due to the prevailing currents during the disposal operations.

All metal concentration measurements were lower than the standards or guidelines defined in the Disposal at Sea Program. However, observations suggested that the reference sediment was not identical to the disposal site sediments. Reference sediment was composed of finer particles than the disposal area sediment, and cobalt, nickel, vanadium, and zinc concentrations in reference sediments, although lower than Interim Sediment Quality Guidelines, were significantly higher than in the disposal site sediments. The difference in these metal concentrations is likely attributable to the different percentages of fines noted at the two sites (Table 2).

Parameter	Reference Area		PB-8 Site		PB-8 Site = Reference Probability ^A	Number of Failures ^B
	Average	N	Average	N		
<i>Biological Tests</i>						
Amphipod % Death (10 days)	2.3	3	0.7	3	0.1429	0
Sea Urchin Fertilization Decrease (%)	25	3	3	3	<.0001	1 ^C
Luminescent Bacteria IC ₂₅ (mg dry sediment/L)	4,487	5	15,556	12	0.0003	0 ^D
<i>Support Parameters for Biological Tests</i>						
NH ₃ -N at t = 0 in Amphipod overlying water (mg/L)	0.1	3	0.0	3	0.0132	NA ^E
NH ₃ -N in Sediment (µg NH ₃ -N/g dry sediment / L)	26.3	3	9.8	3	0.0086	NA
Redox in Sediment (mV)	-153	3	255	3	<.0001	NA
Sulphide in Sediment (µg S/g dry sediment)	44	3	15	3	0.0138	NA
Moisture prior to Luminescent Bacteria Test (%)	31	5	23	12	<.0001	NA
<i>PAHs</i>						
Total PAHs (mg/kg dry sediment) ^F	0.007	6	0.005	23	NA	0
<i>Metals (mg/kg dry sediment)</i>						
As	ND ^G	6	ND	23	NA	0
Cd	ND	6	ND	23	NA	0
Co	2.87	6	1.26	23	<.0001	NA
Cr	10.83	6	11.49	23	0.3948	0
Cu	4.20	6	2.90	23	0.1455	0
Hg	ND	6	ND	23	NA	0
Ni	10.08	6	7.28	23	<.0001	0
Pb	ND	6	ND	23	NA	0
V	8.68	6	5.76	23	<.0001	NA
Zn	18.5	6	11.9	23	<.0001	0
<i>Sediment Characteristics</i>						
Depth (m)	12.7	10	10.6	29	<.0001	NA
Fine Sediment Fraction (%)	12.0	6	0.2	23	<.0001	NA
Sediment Moisture (%)	22	6	17	23	<.0001	NA
Organic Matter (%)	0.4	6	0.2	23	0.0007	NA

Table 2. Summary of analytical results.

^A Values in bold indicate a statistically significant difference between the disposal site and the reference area.

^B When compared to Interim Pass-Fail criteria for Biological Testing or to National Screening Levels for Sediment Chemistry.

^C Failure was observed at reference station REF-3.

^D For the Solid-Phase Luminescent Bacteria Test, the pass-fail criterion is based on the IC₅₀.

^E NA = Not applicable.

^F Very few individual PAH compounds were detected.

^G ND = Not detected.

Toxicological Properties of the Sediment

Based on the pass/fail criteria associated with each biological test, neither the disposal nor the reference site sediments were toxic (Figures 17, 18, and 19). A single sample, taken from the REF-3 reference station, was toxic to sea urchin gametes.

There is no significant difference between the disposal site and reference sediments in terms of amphipod mortality. However, fertilization inhibition in sea urchins and photoluminescence inhibition in marine bacteria are significantly higher in reference sediments than in disposal site sediments. The interpretation of the support parameters measured in the biological tests revealed the following:

- Ammonia levels in the sediment ranged from 6.0 µg/g (station ST2-1 of the disposal site) to 30.4 µg/g (REF-3 reference station)
- Sulphide concentrations ranged from 8.5 µg/g (station ST2-1 of the disposal site) to 50.6 µg/g (REF-3 reference station)
- The redox potential varied from -166 mV (REF-3 sample) to 259 mV in the (ST1-3 disposal site sample)
- Also, levels of ammonia and sulphur were significantly higher in the samples from the reference area than from the disposal site, and the reference zone is significantly more anaerobic than the disposal site.

Thus, the higher toxicity observed in the reference sediments would be attributable to naturally present ammonia and sulphide, and the anaerobic conditions, rather than to anthropogenic contamination. It should be noted that the same conclusion was reached following similar studies conducted previously in two other disposal sites also located in the Magdalen Islands.

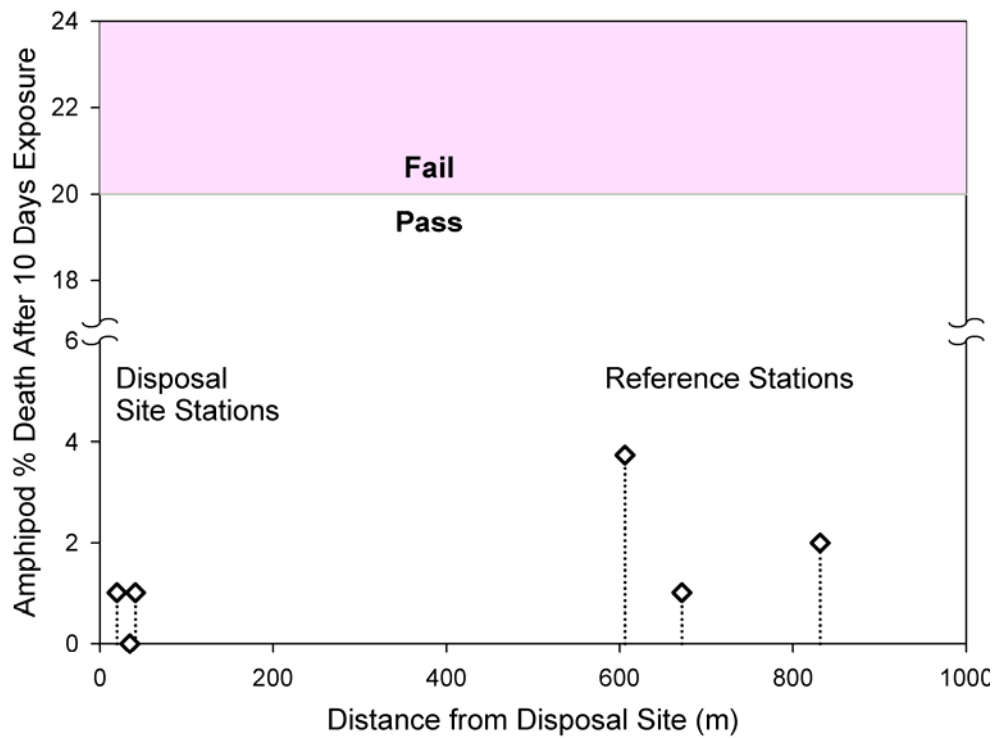


Figure 17. Amphipod mortality percentage after 10 days of sediment exposure.

Note: The points to the left of the chart represent the results for stations located at the disposal site. Those on the right are the results from the reference stations.

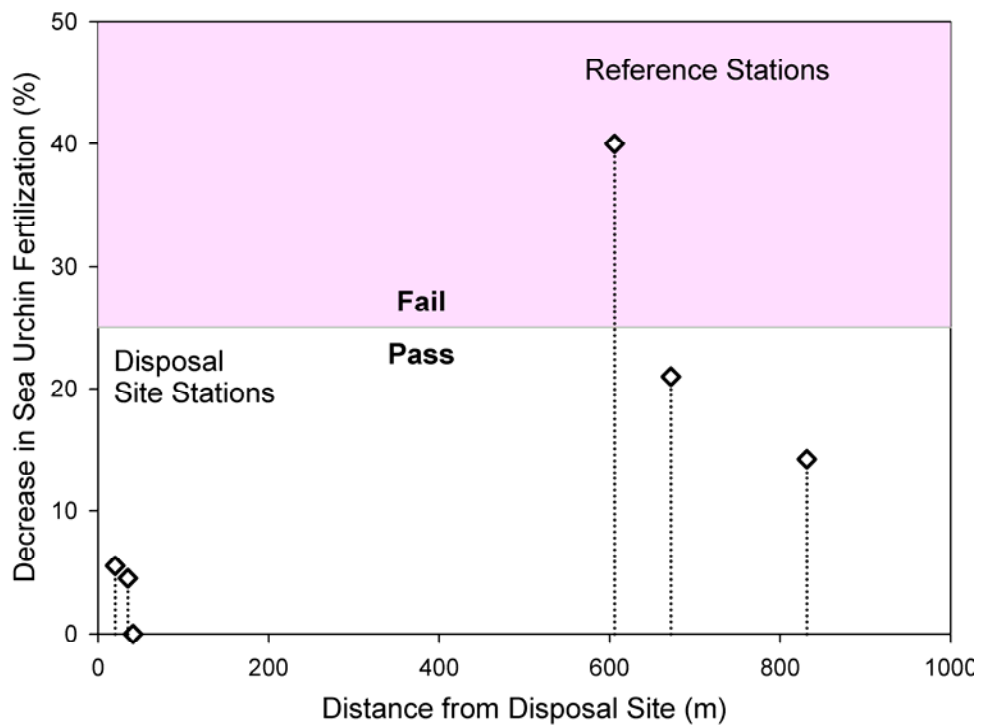


Figure 18. Percent inhibition of sea urchin fertilisation.

Note: The points to the left of the chart represent the results for stations located at the disposal site. Those on the right are the results from the reference stations.

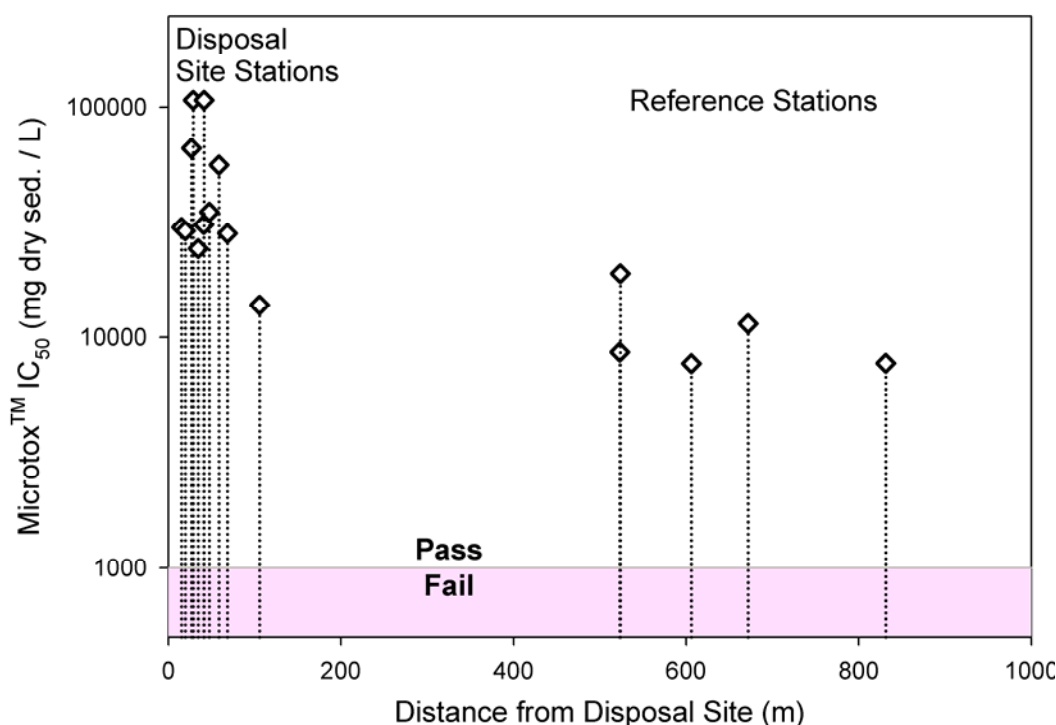


Figure 19. IC₅₀ obtained through biological tests for acute toxicity on the photoluminescent marine bacteria *Vibrio fischeri* in the solid phase

Note: The points to the left of the chart represent the results for stations located at the disposal site. Those on the right are the results from the reference stations.

Potential Factors to Explain Photoluminescent Marine Bacteria Test Responses

Although the photoluminescent marine bacteria biological test results suggested that none of the sediment samples were toxic, the inhibition of photoluminescence was higher in the reference zone than in the disposal area (Table 2 and Figure 19). To determine which factors had the greatest impact on the results of this biological test, a meta-analysis was conducted using the results from the PB-8 reference stations, combined with the results from the reference stations used in two other studies on disposal sites CM-7 and D, also located on the Magdalen Islands. The results of this meta-analysis revealed that zinc had the greatest influence on the toxicity results observed in this biological test. However, the sparse existing data and the use of results from other studies call for great caution in the interpretation of the relationship between the inhibition of photoluminescence and the presence of zinc.

Conclusions

The monitoring results obtained from the PB-8 disposal site showed that the disposal of dredged sediments did not create adverse effects in the receiving environment. The sediment contaminant load was lower than the screening levels for all substances analysed including PAHs.

Sediments at disposal site PB-8 were no more toxic than at nearby reference stations. None of the samples were toxic to amphipods, photoluminescent marine bacteria, or sea urchins, except for one reference sample. The toxicity of this sample was related to the presence of ammonia and sulphide and to anaerobic sediment conditions, and not to anthropogenic contamination. Sea urchin fertilisation and bacterial photoluminescence bioassays seemed sensitive to the higher levels of ammonia, and possibly sulphide, present in the undisturbed anaerobic reference station sediments.

In light of these results, it would appear that the PB-8 disposal site can continue to receive dredged sediments from the Pointe-Basse Harbour. Moreover, the current framework provided by legislation, guidance documents, and permit requirements for disposal at sea seem to be adequate to protect the marine environment and human health.

Prairie and Northern Region: *Churchill, Manitoba*

Background

The Churchill River flows east across Northern Saskatchewan, emptying into Hudson Bay at Churchill, Manitoba (Figure 20). A Manitoba Hydro diversion of approximately 80% of the Churchill River's volume in the early seventies reduced water flow in the river, and caused silt accumulation in the harbour and river mouth.

The province of Manitoba sold the near-derelict Churchill port facility to a private company hoping that they would revitalize it. In 2000 and 2001, the company applied for and was granted a permit for the disposal at sea of dredge spoil from a large Churchill, Manitoba harbour redevelopment project. The project proposal estimated that 1.2 million m³ of material would be dredged and disposed of at a Hudson Bay disposal site.

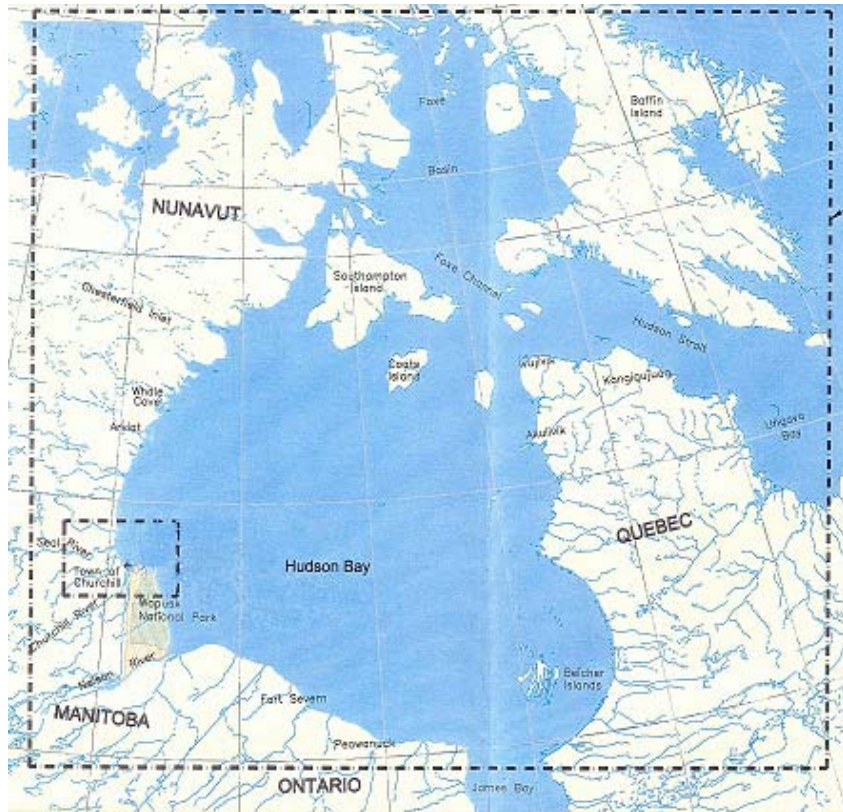


Figure 20. Map showing the location of Churchill, Manitoba.

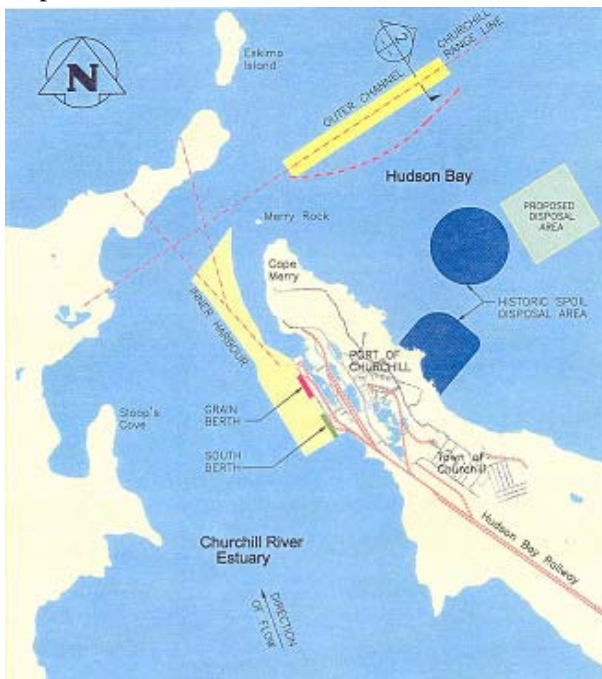


Figure 21. Map showing the location of the proposed disposal site in Hudson Bay.

Historically, harbour spoil disposal had taken place at a shallow site located approximately 1 km offshore in about 10 m of water. However, disposing the anticipated 1.2 million cubic metres of dredge spoil there would create a navigation hazard, and so a new site was needed. The selection criteria for the new site included similar sediment and biotic composition to dredge areas, sufficient size and depth to accommodate sediment generated during harbour redevelopment and future maintenance dredging.

A suitable disposal site was located 3 km from the mouth of Churchill harbour under 14 - 17 metres of water (Figure 21). The Environmental Assessment Report that accompanied the permit application described the new site as a 700 by 700 metre square, the western half of which had been heavily

influenced by sediment disposal activities during the late 1970s. The sediment in the western half of the disposal area is similar to the dredge spoil (60-95% sand), gradually becoming finer and more uniform towards the eastern half. The proponent subdivided the site into 21 sectors that were each to receive a predetermined amount of spoil. This even distribution of dredge spoil would maintain a minimum water depth of 9 metres and reduce the potential for off-site spoil transport, and was considered crucial to prevent the disposal site from becoming a navigation hazard.

Financial and logistical constraints caused the proponent to reduce the amount of material it planned to dredge. A total of 134,390 m³ of material was deposited at the disposal site, with the majority being placed in sectors 2, 12, and 20.

A Fisheries Authorization was issued for the harbour redevelopment project and required the company to compensate for the habitat destruction that dredging and disposal activities would cause by constructing a reef-like structure from larger material (gravel, rocks, etc.) within the disposal area. This placement of coarse material was expected to increase habitat diversity, encourage recolonization, and contribute to site stabilization.

The monitoring program outlined here is ongoing, and is designed to assess the accuracy of the predictions made in the Environmental Assessment Report (EAR) submitted by the proponent in support of their Disposal at Sea permit application. Specifically the EAR stated that sediment transport would be limited, and that sediment would remain in place except under severe storm conditions. The EAR also predicted that benthic organisms would begin to recolonize the site soon after disposal activity ceased, but that species diversity would be affected. The EAR further predicted that recolonization would be more rapid in areas with harder substrates.

Impact Hypotheses

- i. *Dredge spoil deposited at the disposal site is stable and there is minimal transport outside the disposal site boundaries.*
- ii. *A new benthic community is recolonizing the disposal site.*
- iii. *Disposal activities have not resulted in metal contamination at the disposal site.*

Monitoring Conducted

Sediment transport and benthic recolonization are generally slow processes in cold northern waters so a one year monitoring program would be inadequate to assess the accuracy of EAR predictions. Therefore, a multi-year monitoring plan was developed. The first of 3 planned monitoring visits took place in August of 2002; the second visit took place in 2003 but was unsuccessful and was rescheduled for 2004. The third visit is being planned to coincide with a Public Works and Government Services of Canada (PWGSC) multibeam sonar survey of the area, potentially scheduled for the summer of 2008. This monitoring schedule will result in Environment Canada gathering data in the first, fourth and potentially the eighth year after disposal operations ceased.

The sediment transport modeling predictions made in the EAR were based on the particle size of the spoil and the water current profile of the disposal site area. The sampling plan employed was based on the assumption (as indicated in the EAR) that the particle size characteristics of the spoil were different from the particle size characteristics of the sediments found in the disposal area.

Sediment samples were collected at a total of 20 stations laid out in lines to cross sectors 12 and 20 where the majority of the sediment was deposited (see Figure 22). The axes of the sampling lines were oriented to ensure that they began and ended in undisturbed ocean sediment. The “vertical” (North by NW) axis is 350 m and was sampled at six points, while the horizontal (East by SE) axis is 200 m long and was sampled at four points. The axes parallel the sides of the sector and extend at least 100 metres beyond the top and bottom of the sector and 50 metres each side. Differential

GPS coordinates of the sampling stations were recorded to allow collection of samples from the same site during subsequent monitoring visits. Two sediment samples were collected from each sampling location. The original intent was to use a sampler such as an Ekman dredge, but dredges proved ineffective so ultimately divers were required. The 6.35 cm (2.5 inch) diameter sediment cores will be subdivided into the following sections 0-1cm 1cm - 2cm and 3cm - 4cm. The sections will be analyzed for particle size distribution and metals. Ten percent of the samples will be reanalyzed for analytical quality assurance and control.

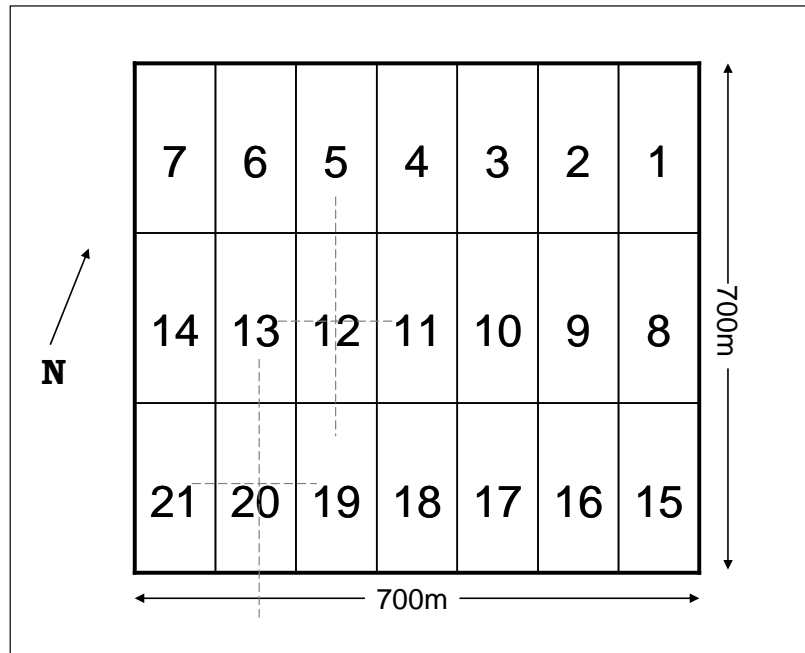


Figure 22. Schematic showing disposal site sectors and sampling lines at the new disposal site .

To test the assertion that benthic re-colonization is occurring, a second sediment sample was collected in conjunction with the particle size samples. Benthic organisms in the top 10 cm of these samples were identified and their densities measured. Invertebrate density and diversity data collected over time will indicate whether re-colonization is occurring.

In 2002 a detailed bathymetric survey was conducted and the data generated was compared to a similar 2001 survey. Comparisons were made by overlaying recent data onto earlier surveys. The overlay technique shows any morphological changes that have taken place within the disposal site.

A remotely operated vehicle (ROV) was employed to give an overview of the disposal site and aid in assessing benthic recolonization. The ROV will be particularly valuable in the assessment of benthic recolonization of the hard surfaced reef-like structure created in the disposal site.

Monitoring activities commenced in September of 2002 with an assessment of topographical changes at the site during the winter following the cessation of disposal. The assessment was carried out by comparing detailed sonar surveys from fall of 2001 to mid summer of 2002. A remotely operated camera was used to obtain images of both the disposal site and of virgin seabed. A comparison of the images will allow an assessment of changes in the character of the seabed caused by disposal activities. The images of the bed forms will also provide information regarding the effects of wave action and currents and will help to characterize the epifaunal community both within the disposal area and at the control site. Video reconnaissance of the site also provided baseline imagery for a qualitative assessment of the effectiveness of the coarse capping material to encourage recolonization and to reduce off-site transport of fines. Prolonged severe weather led to the cancellation efforts to collect sediment samples for the assessment of sediment transport, benthic recolonization and disposal impacts on species diversity in 2002.

In 2004, video footage of the disposal and control sites was obtained, and sediment samples were collected by SCUBA divers. Of the two sediment samples collected at each site, one was analysed for metals and the other was sieved for benthic organisms.

Future site visit

It is expected that sediment sampling collection will be conducted by divers again during the next monitoring visit. Sufficient cores will be collected to allow the benthic community and site particle distribution to be analyzed. Video footage of the disposal site, control area and “reef” will also be obtained for comparison to earlier footage.

Observations and Results

Sonar surveys

Graphic depictions of the sonar survey data collected in 2001 and 2002 are presented in Figures 23 and 24. The sounding equipment performed well, but inclement weather in 2002 introduced the “wave noise” evident in Figure 24. Figure 25 was generated by subtracting the 2001 survey from the 2002 survey and demonstrates that some changes have taken place in the topography of the site. Qualitatively it is obvious that the contours of the three spoil piles have softened but they can still be clearly seen in the survey. Analysis indicated that the maximum change at any given spot in the survey area was approximately 2.1 m of loss and 1.3 m of deposition. High transport and deposition totals were not typical of the site, and further analysis indicated that these peak numbers could likely be attributed to the ice scour that is evident on the 2002 survey near the northernmost disposal pile. The ice scour is 2.1 m deep and the shoulders of the scour are 1.3 m high which correlates well with the maximum transport and deposition amounts noted above. More typical results indicate that the height of the material on the site has declined by less than 10 cm which is consistent with minor off site transport combined with settling and ice scour.

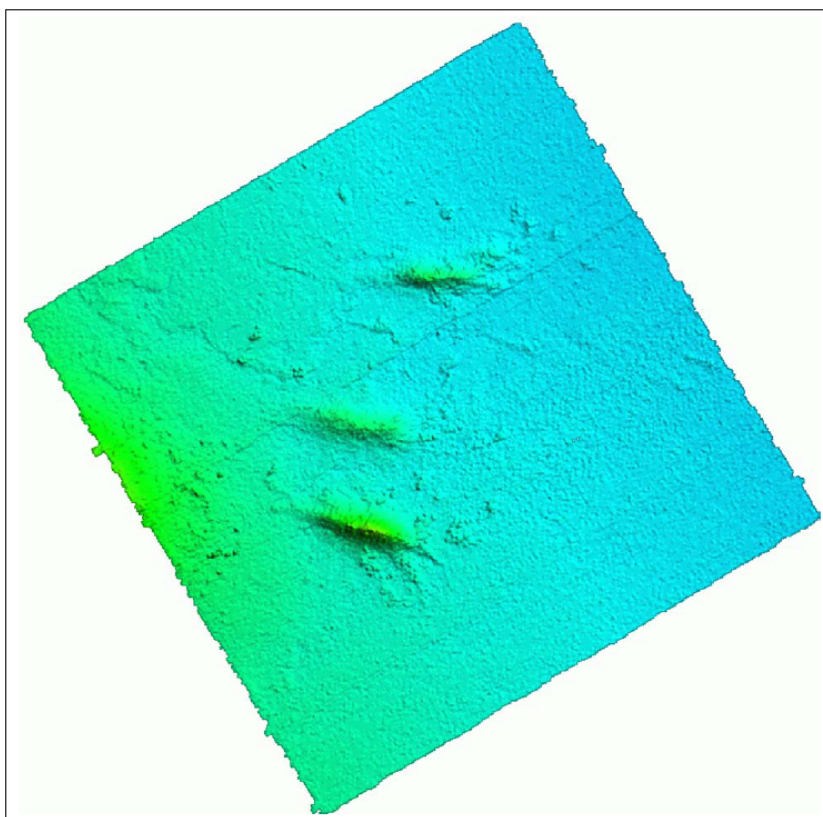


Figure 23. 2001 multibeam sonar survey of disposal area showing distinct piles of dredged spoil.

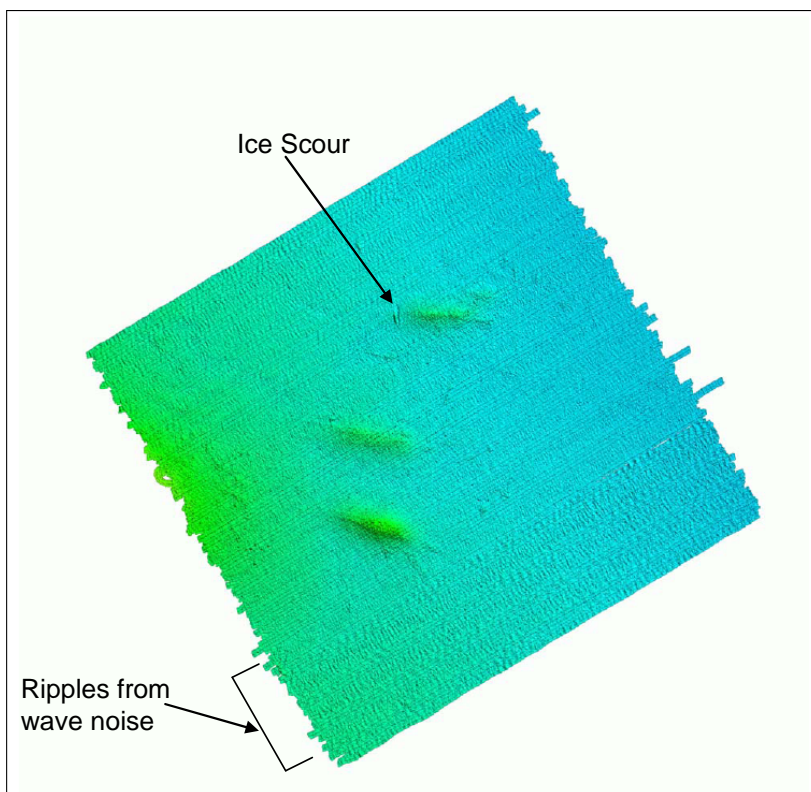


Figure 24. 2002 multibeam sonar survey of the disposal, carried out in 2 sessions.

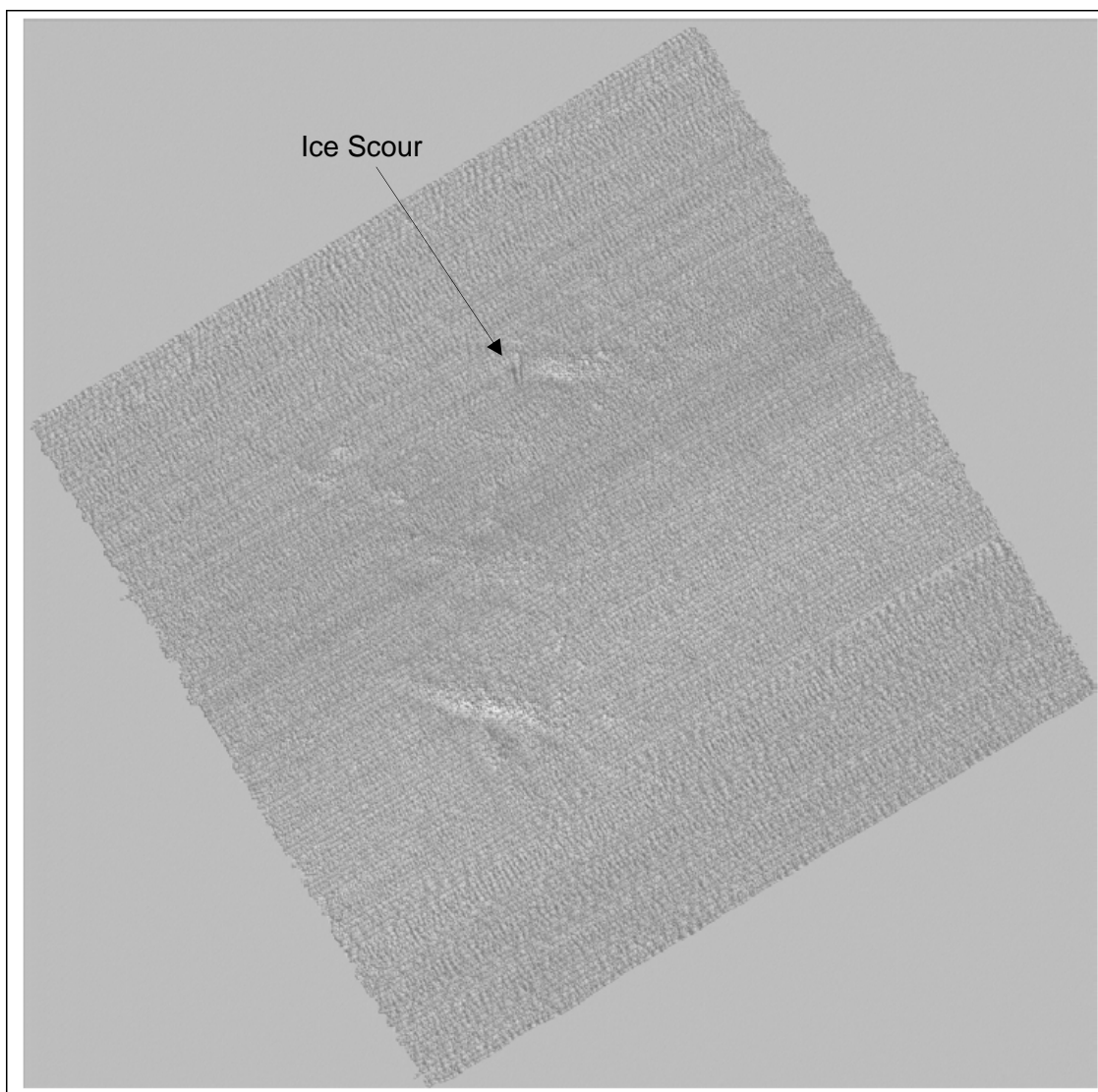


Figure 25. Overlay (subtraction) of 2001 and 2002 surveys; light shades indicate erosion while dark shades indicate deposition.

Sediment analysis

Due to bottom type, time and weather constraints only 8 sediment samples could be collected per sector in 2004. Divers took samples where possible but could not collect samples in areas where the sediments were too coarse to be cored using the hand core tubes. As a result of the coarse material caps placed in accordance with the Fisheries Authorization, the center station was impossible to core. To avoid the coarse material, the samples were collected near the edges of the sectors. In some cases the particle size and chemical composition of the samples mimic the control samples suggesting that they were in fact collected from undisturbed seabed, while the composition of other samples was more similar to the dredge spoil. The analyses presented below were based on the samples collected at sites with characteristics similar to the dredge spoil.

Metals

None of the samples analyzed for metals exceeded the ISQG however some did contain levels of Ti, Fe, Cr, CU and Ni above those found in the control samples. The diversity of metal concentrations is logical given the sample locations, and the similarity of some samples to either control sediments

of dredge spoil. The slightly elevated metal concentrations observed in the disposal site sediment samples were similar to the concentrations found in pre dredging harbour sediment samples.

Particle size

The samples from the western side of the disposal site were generally coarser than the control and eastern samples. This is consistent with the EAR sediment characterization. The control site was located north east of the disposal site and the sediments found there were generally finer than those found within the disposal area. This observation is also consistent with the EAR.

Video

The 2001 video footage of the sediments around the disposal site revealed bedforms such as small sand waves indicative of a low-medium energy environment. By 2004 the bedforms in the disposal area were similar to those found on the surrounding seabed.

Video footage of the central areas of the disposal site revealed coarse material such as cobble and gravel where the caps were placed. Benthic epifauna were evident on the rock and other coarse material capping the site but were not evident in areas dominated by sand/silt. Video footage also revealed general smoothing of the disposal pile contours.

Benthic Organisms

Comparison of the predisposal benthic community at the disposal site to the community after disposal cessation revealed a marked decline in numbers and diversity. For instance, in 2004 Polychaetes ranged from 3-14 per sample (30 spp) while in 1999 they ranged from 89 – 596 (45 spp) and Harpacticoid copepods ranged from 4 – 26 as opposed to 17 – 371 in 1999.

Conclusions:

In general the evidence suggests that the predictions made regarding site stability and recovery in the pre-permit EAR were accurate. More specifically, the differences observed between the 2001 and 2002 sonar surveys are largely due to settling and minor off site transport. The surveys also clearly show that the material was deposited in the areas prescribed in the permit, and sediment chemical and particle size analyses support this conclusion. As predicted, no evidence of metal contamination was found in the deposited material. Both the video and sediment sample evidence confirms that the benthos is colonizing the site but indicate that the density and diversity of organisms is still low. Though not quantified, the benthos colonization of harder substrates appears to be faster than on the surrounding sandy substrate. The particle size data gathered during this study support the conclusions presented by the proponent in their EAR.

Issues/Challenges:

Monitoring the disposal site at Churchill Manitoba has proven more challenging than originally expected. The majority of the issues have resulted from inclement weather and the logistical challenges of using unusual and temperamental equipment in a relatively remote community. These two issues took a heavy toll on the productivity of the first two site visits, but sediment samples and video footage were successfully collected in 2004. The collection and analysis of future samples will refine the conclusions that can be drawn from this monitoring program.

Annex 1. Monitoring Expenditures

In March 1999, pursuant to Treasury Board policy on cost recovery, Environment Canada introduced a monitoring fee of \$470 per 1000m³ of dredged or excavated material. This fee is known as a “right or privilege” fee and is meant to provide Canadians with a fair return for use of public resources. Proceeds from this fee are used to cover the cost of disposal site monitoring, thus allowing environmentally sound management and allowing users continued access to their disposal sites.

Part of Environment Canada’s commitment was to provide an annual summary of revenues and expenditures related to disposal site monitoring. The figures below represent the seventh year of cost recovery. In the 2005-2006 fiscal year, Environment Canada collected slightly less than in the previous fiscal year, with revenues amounting to just under \$1.04 million. The total net cost to the federal government was \$693,400.

Monitoring Expenditures 2005-2006

Atlantic Region	\$407,971.05
Quebec Region	\$58,072.09
Prairie and Northern Region	\$277.38
Pacific and Yukon Region	\$465,114.59
Headquarters	\$37,681.00
Environment Canada indirect costs	<u>\$405,090.53</u>
Sub total costs for Environment Canada	\$1,374,206.64
In-kind support from other federal departments	\$358,650
Total cost for federal government	<u>\$1,732,856.64</u>

Resources Recovered 2005-2006

Monitoring Fees	<u>\$1,039,456</u>
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Net costs 2005-2006

Resources collected over federal government costs	-\$693,400.64
Net Environment Canada costs	<u>-\$334,750.64</u>

Annex 2. Offices for the Disposal at Sea Program

The Disposal at Sea Program Offices are located in the following Environment Canada offices.

Atlantic Region-Maritimes
Disposal at Sea Program
Environmental Protection Branch
Environment Canada
45 Alderney Drive, 4th Floor
Dartmouth, Nova Scotia
B2Y 2N6

Quebec Region
Disposal at Sea Program
Environmental Protection Branch
Environment Canada
105 McGill Street, 4th Floor
Montreal, Quebec
H2Y 2E7

Pacific and Yukon Region
Disposal at Sea Program
Environmental Protection Branch
Environment Canada
201 - 401 Burrard Street
Vancouver, British Columbia
V6C 3S5

Atlantic Region-Newfoundland and
Labrador
Disposal at Sea Program
Environmental Protection Branch
Environment Canada
6 Bruce Street, Mount Pearl
Newfoundland and Labrador
A1N 4T3

Prairie and Northern Region
Disposal at Sea Program
Environmental Protection Branch
Environment Canada
5204 - 50th Avenue, Suite 301
Yellowknife, Northwest Territories
X1A 1E2

National Capital Region
Disposal at Sea Program
Environmental Protection Service
Environment Canada
351 St. Joseph Boulevard, 7th Floor
Hull, Quebec
K1A 0H3

Further details may be found on-line at the Program's web site www.ec.gc.ca/seadisposal/