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National Guidelines for Monitoring Dredged and Excavated Material at Ocean Disposal Sites

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National Guidelines for Monitoring Dredged and Excavated Material
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Separate technical guidance is available on the use of various physical and biological assessment tools and on the available techniques. Enquiries should be directed to:

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Foreword and Acknowledgements

Canada is a maritime nation. It possesses the longest coastline 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. The permit assessment and ocean disposal site monitoring activities undertaken by Environment Canada represent some of the measures in place in Canada to prevent marine pollution by the disposal of wastes at sea. These activities also provide users with assurances that the environmentally preferable and practical disposal alternatives are being used and that suitable disposal sites continue to be available.

The Disposal at Sea Program, and its regulatory controls, have been in place since 1975. Between 1975 and 1990, disposal site monitoring was done on a research basis. In 1991, work and consultation began on the development of a systematic national program to monitor disposal sites, based on a need for long term assessment of compliance and effect, which was identified at both the national and international levels. This document is the result of that development effort.

The *National Guidelines for Monitoring Dredged and Excavated Material at Ocean Disposal Sites* provides advice to managers and professionals on developing and implementing monitoring projects at ocean disposal sites that receive dredged and excavated material. Issues discussed include:

- triggers to monitoring
- developing monitoring plans
- study design
- data analysis
- biological assessment tools

These National Guidelines were prepared through an extensive review and consultation process with scientists and experts across Canada and from around the world. The authors are especially grateful to Jim Osborne, Linda Porebski, and John Karau for their guidance and support.

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1. Introduction: Canada's Disposal at Sea Program

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

In the permit system, each application for disposal at sea is evaluated separately to determine if a permit will be issued. Applicants supply the required information to Environment Canada who then evaluates it to ensure that accepted criteria are met. As set out under the *1996 Protocol*, these criteria ensure that:

- the waste is of a type suitable for disposal at sea (dredged or excavation material, fisheries waste, vessels, other inert or bulky waste);
- disposal at sea is the environmentally preferred and practical alternative for the waste (i.e. reduce, reuse, recycle or alternate disposal options have been evaluated);
- the physical, chemical and biological characteristics do not preclude disposal (this includes an evaluation of load site history and any necessary laboratory analysis);
- the disposal site is suitable based on a prediction of effects (this includes deriving impact hypotheses on the likely environmental effects).

When the analysis of the above information supports ocean disposal, the Disposal at Sea Program develops impact hypotheses and sets permit conditions designed to mitigate known impacts, such as a conflict with a migration route. Permits set clear directions for clients on how, where, when and how much, material is to be disposed. They are published in Part I of the *Canada Gazette*, are legally binding, and may be valid for a term of up to one year.

Each year, disposal operations from selected permits are inspected to verify that they are carried out in accordance with regulations and permit requirements. Long-term monitoring at representative disposal sites is also conducted annually. In some cases, permit conditions require clients to perform some specific monitoring of their site to address short-term concerns during the actual disposal operations, such as impacts of a silt plume.

These Guidelines focus on long-term monitoring of disposal sites after disposal operations have ended. They are intended to be used, in conjunction with national technical guidance documents, by Program officials and other professionals to conduct the long-term assessment of disposal sites receiving dredged and excavated material. The intent is to provide procedural and technical guidance that is nationally consistent, while accounting for site specific differences.

National Technical Guidance Documents

- **Technical Guidance on Physical Monitoring (1994)**
- **Technical Guidance on Biological Monitoring (1996)**
- **Guidance document on the Collection and Preparation of Sediments for Physicochemical Characterization and Biological Testing (1994)**

1.1 Reasons for Monitoring and International Obligations

Environment Canada's Disposal at Sea Program is responsible for ensuring that disposal site monitoring is conducted annually at representative sites and that the results are reported both nationally and internationally through a National Compendium. The National Compendium provides valuable information to clients and other interested parties on monitoring conducted and use of monitoring resources. It is also submitted annually to the International Maritime Organization to meet Canada's treaty obligations under the *London Convention 1972* (LC72) and its recent *1996 Protocol*. The Contracting Parties have agreed to ensure that potential adverse impacts of any disposal activities are minimised and that adequate monitoring is provided for early detection and mitigation of these impacts.

As dredged material constitutes the largest amount of material disposed of at sea internationally, the Contracting Parties adopted the Dredged Material Assessment Framework (DMAF), which details specific monitoring considerations for dredged material. These considerations are also generally applicable to excavation material.

The DMAF defines monitoring as a measurement of:

- compliance with permit requirements; and
- condition (and changes in condition) of the receiving area to assess the impact hypothesis upon which the permit was approved.

To do this, the following questions must be answered:

- What testable hypotheses can be derived from the impact hypothesis?
- What measurements are required to test these hypotheses?
- How should the data be managed and interpreted?

The measurements can be divided into those within the zone of predicted impact and those outside and should determine:

- if the actual zone differs from that projected; and
- if the extent of change projected outside the zone of impact is within the scale predicted.

The DMAF recommends that this information be used to:

- modify or terminate the field monitoring program;
- modify or revoke the permit (including closure of the disposal site);
- refine the basis on which applications to dump dredged material at sea are assessed.

The Canadian approach follows the basic guidance of the DMAF, using *representative* sites and considering the site histories and permits issued between monitoring cycles. Monitoring at every disposal site is not considered necessary, as the current knowledge of impacts related to the disposal of dredged material allows for good assessments to be drawn from representative disposal sites.

Improved Decision-Making

Disposal site monitoring at representative sites allows clients continued access to suitable sites. It ensures that the permit conditions were met. It also 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 also plays a critical role in reviewing the overall adequacy of controls. The information compiled nationally or regionally over time provides the basis to assess whether the ocean disposal regulations, guidelines and permit conditions are adequate to protect the marine environment and human health.

Disposal Site Monitoring provides for:

- **maintaining access to suitable sites;**
- **assessing permit decisions;**
- **reviewing the adequacy of controls; and**
- **identifying research and development needs.**

Improved Understanding

Experience gained with monitoring may assist researchers involved in developing better monitoring tools, or may be used to refine the monitoring program on 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. Annual meetings with clients and other interested parties will provide additional comments on past monitoring and a better indication of regional priorities for future assessments.

THE NATIONAL GUIDELINES SEEK TO ENSURE THAT:

- **disposal site monitoring activities are nationally consistent;**
- **disposal site monitoring activities are cost effective;**
- **results are comparable to results obtained with currently accepted scientific approaches; and**
- **information requirements are fair and consistent for clients.**

1.2 Roles And Responsibilities

Canada's Disposal at Sea Program is delivered through regional offices. They are largely responsible for the permit review process, as well as for planning, conducting and reporting on routine monitoring studies at representative sites undertaken in their administrative areas. The National Compendium is produced annually by the Marine Environment Division and is based on detailed regional reports.

Applicants for ocean disposal permits are responsible for disposal site selection and characterisation. Disposal site selection involves characterisation of the proposed disposal site and a consideration of the dispersive characteristics of the site to predict the zone of influence. The required baseline information is specified in the permit application form and further guidance on data requirements can be found in the *Users Guide to the Application Form for Ocean Disposal* (Environment Canada, 1995).

From time to time, permittees may be required to conduct short-term monitoring to meet permit requirements, which are in effect only for the term of the permit. Monitoring done by clients or permittees is discussed with the Disposal at Sea Program on a case-by-case basis, and does not form part of this document.

2. Triggers To Monitoring

Each year in Canada, about 50 disposal sites receive dredged or excavated material. The number of sites and quantities disposed from year to year vary with annual dredging and excavation operations.

Sites receiving greater than 100,000 m^3 in a year are considered major sites, all others are deemed minor sites. Typically in a year, over 90 percent of disposal sites are considered minor while less than 10 percent would be considered major.

Impact concerns also vary by project and are often independent of its size. For example, a disposal site receiving a small quantity (8,000 m^3) of dredged sediment each year may generate significant concern if there are resource and site-use conflict issues such as potential impacts of a commercial fishery. Conversely, a larger site receiving clean sand (50,000 m^3) may not pose any substantial concerns.

Since disposal site monitoring is conducted annually on a representative basis rather than at every site, the following three criteria are recommended to determine where monitoring should be conducted:

1. A permit for the disposal of dredged or excavated material was issued under the Rapidly Rendered Harmless provisions of the *Canadian Environmental Protection Act.*

2. There are possible effects on nearby sensitive areas, including habitats, or potential conflicts with other nearby uses of the sea.

3. The volume of material disposed in a year is greater than 100,000 m^3.

It is recommended to monitor major sites on at least a five year cycle and a number of representative minor disposal sites for dredged and excavation material each year. A further consideration in selecting sites is generating trends data, which can only be achieved by returning to a site at a regular interval.

Annual monitoring activities, subject to changes in disposal activities, should be conducted as follows:

Region	***Sites Monitored***
Atlantic:	***1 major site and 2 minor sites***
Quebec:	***1 minor site***
Prairie and Northern:	***1 minor site***
Pacific and Yukon:	***1 major site and 1 minor site***

2.1 Basic Stages

For all sites, monitoring activities will follow the same basic stages which are presented in these guidelines as follows:

1. *Planning*: developing impact hypotheses, selecting parameters and measurement tools (including a consideration of core parameters and recommended tiers);

2. *Execution*: defining the study area and characterising it;

3. *Analysis*: interpreting the data and relating it to the impact hypothesis; and

4. *Reporting*: preparing and submitting a report to present the findings.

3. Planning: Developing Impact Hypotheses and Selecting Tools

Experience to date, has shown that the disposal of dredged or excavated materials generally results in the same potential concerns:

- acute and chronic effects on biota;
- habitat destruction and unacceptable impacts on fish and fisheries;
- contamination of edible fish and shellfish,
- impacts on sensitive areas; and
- conflicts with other legitimate uses of the sea.

3.1 Developing Impact Hypothesis and Case Studies

The level and effort of monitoring should be linked to the concerns and impact hypotheses identified at the permit approval stage. The permit application review is aimed at determining the likely environmental effects of the proposed disposal. The final stage of this assessment requires a concluding statement to support the decision to issue a permit, including a rationale for the permit's terms and conditions. Impact hypotheses are derived from this analysis and constitute the logical foundation for any subsequent monitoring plan.

Background information about the site, the material, and the use patterns, can also assist in determining the appropriate level of monitoring required to adequately address impact hypotheses, determine trends, or take management action. The following table outlines background information that should be considered.

Concerns increase when:

- Higher levels of contaminants are found in the permitted material (Rapidly Rendered Harmless scenario);
- biological responses are measured in the permitted material (Rapidly Rendered Harmless scenario);
- the load site is in closer proximity to sources of contaminants, pollutants or accidental spills (including historical sources), the frequency of disposal operations at the site is high;
- the number of different users, or sources of material, that the disposal site receives is high;
- the quantity disposed over the monitoring period is high;
- the disposal site is in closer proximity to sensitive areas or other legitimate uses of the sea;
- differences in grain sizes, or other geochemical properties, between the load and disposal sites are significant.

Other background factors include:

- How many monitoring studies have taken place at that site and if there are any trends;
- how recent that data is and what has changed at and around the site;
- any physical, chemical, or biological results obtained at the disposal site, or at a nearby control or reference site during previous monitoring;
- other supporting information from research, or compliance assessments;
- expressed concerns by interested or affected parties.

Impact hypotheses should be tailored to specific information on the disposal site such as site characteristics, site-specific species, local spatial and temporal scales of variable parameters and the permit terms and conditions. In deriving impact hypotheses, the primary consideration should reflect the above five potential concerns. As much as possible, monitoring objectives should be formulated into testable hypotheses. General examples of impact hypotheses are provided in the following case studies.

3.1.1 Case-study A: Prevent Adverse Effects on Biota

The level of contamination and toxicity of the dredged material was assessed and deemed acceptable for ocean disposal.

IMPACT HYPOTHESES	MEASUREMENTS
Disposal of dredged material will not result in loading of contaminants into the sediments of the disposal site, contaminant uptake by the recolonizing biota and ensuing effects on that biota.	• **Investigate contaminant concentrations in the disposal site sediments and assess in terms of potential concerns for biota.**
Disposal of dredged material will not result in loading of contaminants into the sediments of the disposal site, contaminant uptake by the recolonizing biota and ensuing effects on that biota.	• **Contaminant uptake by selected species and ensuing effects on species may also be investigated, if recolonization is sufficiently advanced.**
Disposal of dredged material will not result in transport of contaminated material from the disposal site, subsequent contaminant loading in the sediments of the area reached by the transported material, contaminant uptake by biota and ensuing effects on the biota.	• **Establish if transport is occurring from the disposal site. Determine the direction of transport and areas of deposition of the transported material.** • **If transport is occurring, investigate contaminant concentrations in the sediments of the area reached by transport and assess in terms of potential concerns for biota.** • **Contaminant uptake by selected species and ensuing effects on these species may also be investigated.**

3.1.2 Case-study B: Prevent Habitat Destruction and Effects on Fish and Fisheries

The disposal site was selected for its dispersal characteristics to prevent the initial deposition of material, or subsequent sediment transport, in the direction of known migration routes, spawning and nursery areas, sport and commercial fishing areas. The level of contamination and toxicity of the dredged material, its compatibility with the disposal site sediments, its likely behaviour at the disposal site, and its predicted transport away, were assessed during the application review and found to be acceptable for ocean disposal. Timing restrictions in the permit sought to ensure that disposal did not take place at high-risk periods for fisheries in the area (e.g. spawning period).

IMPACT HYPOTHESES

The deposited dredged material will not reach any protected habitat, through resuspension, erosion and sediment transport, in amounts sufficient to be of concern in relation to habitat destruction (taking into account the compatibility of the transported material with the sediments of the receiving environment).

Resuspension, erosion and sediment transport of the deposited material will not affect any fishery.

Disposal of dredged material will not result in contaminant loading in the disposal site sediment, subsequent contaminant uptake by commercial species or ensuing effects on species which frequent the disposal site.

Disposal of dredged material will not result in transport of contaminated material from the disposal site, subsequent contaminant loading in the sediments of the area reached by the transported material, contaminant uptake by commercial species or ensuing effects on them.

MEASUREMENTS

- **Establish if transport is occurring in the direction of a protected habitat.**
- **If transport is occurring, assess if the scale of transport is of concern and if habitat alteration is occurring.**
- **Also determine if the nature of the sediments at the disposal site remains compatible with the pre-disposal conditions.**

- **Physical effects on selected commercial species may also be investigated.**

- **Investigate contaminant concentrations in the disposal site sediments and assess in terms of potential concerns for fisheries.**
- **Contaminant uptake by selected commercial species or ensuing effects on them may also be investigated.**

- **If deposition or transport is reaching a protected habitat, investigate contaminant concentrations in the sediments of that area and assess in terms of potential concerns for fisheries.**
- **Contaminant uptake by selected commercial species or ensuing effects on them may also be investigated.**

3.1.3 Case-study C: Address Human Health Concerns (contamination of edible fish and shellfish species)

The level of contamination, toxicity and bioaccumulation potential of the dredged material were assessed during the application review and found to be acceptable for ocean disposal.

IMPACT HYPOTHESES

Disposal of dredged material will not result in contaminant uptake by harvested species and ensuing potential effects on human health.

MEASUREMENTS

- **Assess bioaccumulation potential at the disposal site or any other area reached in significant amount by transported material (particularly fish and shellfish habitat, if any).**

3.1.4 Case-study D: Protect Sensitive Areas

The disposal site was selected for its dispersal characteristics for the purpose of preventing initial deposition of material or subsequent sediment transport from the disposal site in the direction of areas of natural beauty, cultural or historical importance, areas of special scientific or biological importance. The dredged material considered for disposal was assessed in terms of likely behaviour at the disposal site and predicted transport was deemed acceptable. The level of contamination and toxicity of the dredged material was assessed and deemed acceptable for ocean disposal.

IMPACT HYPOTHESES	MEASUREMENTS
The deposited dredged material will not reach any sensitive areas, through resuspension, erosion and sediment transport, in amounts sufficient to be harmful to valued components of the sensitive area (taking into account the compatibility of the transported material with the sediments of the receiving environment).	**• Establish if transport is occurring in the direction of a sensitive area. • If transport is occurring, assess if the scale of transport is of concern in relation to physical impacts on valued components of the sensitive area.**
Disposal of dredged material will not result in transport of contaminated material to a sensitive area, contaminant loading in the sediments of that area, contaminant uptake by the biota inhabiting the sensitive area and ensuing effects on that biota.	**• If deposition or transport is reaching a sensitive area, investigate contaminant concentrations in the sediments of that area and assess in terms of potential concerns for the biota inhabiting the sensitive area. • Contaminant uptake by selected species and ensuing effects on these species may also be investigated.**

3.1.5 Case-study E: Prevent Use Conflicts

The disposal site was selected for its dispersal characteristics to prevent the initial deposition of material, or subsequent sediment transport, into recreational areas, shipping lanes and areas of the sea-floor having engineering uses (mining, cables, desalination or energy conversion sites) and other areas used for human activities. The dredged material considered for disposal was assessed in terms of likely behaviour at the disposal site and the predicted transport was found to be acceptable.

IMPACT HYPOTHESES	MEASUREMENTS
The deposited dredged material will not reach any area where use conflicts may arise, through resuspension, erosion and transport, in amounts sufficient to be of concern with regard to the other use of the sea.	**• Establish if transport is occurring in the direction of an area where use conflicts may arise. • If transport is occurring, assess if the scale of transport is of concern in relation to the other use of the sea.**

3.2 Tiered Monitoring

Testing impact hypotheses derived for dredged or excavated material disposal will generally involve similar measurements. A tiered monitoring approach is recommended (Figure 1) with core parameters (Figure 2) to address the common impact hypotheses in a cost-effective and consistent fashion. Physical monitoring (Tier 1) defines the site boundaries and is followed by concurrent chemical and biological assessments (Tier 2). The results of both Tiers 1 and 2 are used in making decisions on the need for further monitoring (Tier 3) and broadly address most impact hypotheses. At some sites, site-specific concerns will require different parameters or a different emphasis in monitoring resources allocation between tiers. However, it is expected that both Tier 1 and Tier 2, as well as, the core parameters will be used at most sites, while Tier 3 will generally not be required.

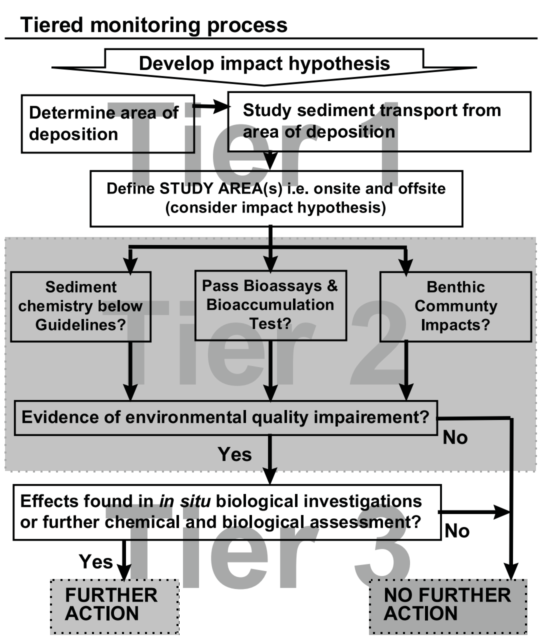


Figure 1 Tiered Monitoring Process

The first tier, physical monitoring, relates to the collection of relevant geological information for 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. The objective of physical monitoring should always be the long-term fate of the disposed material. Concerns associated with transport during disposal should be addressed as part of the permit requirements and restrictions. These tools are primarily used to test impact hypotheses that relate to off-site transport, conflicts with other uses of the sea, and physical changes to nearby habitat or sensitive areas.

The second tier of monitoring involves biological and chemical assessments undertaken concurrently. The monitoring design for these assessments takes into account the size and dispersal characteristics of the site. Chemical monitoring seeks to measure the levels of chemicals in sediments. Biological monitoring is primarily centered on biological tests in the laboratory and limited benthic community surveys. These tools are primarily used to test impact hypotheses that relate to contaminant effects on biota, including commercial species, and changes to the biota in nearby habitat or sensitive areas.

If the data collected thus far indicates that the environmental quality of the study area is possibly impaired, the third tier may be required. This may include further chemical and biological assessment, an investigation of the long-term stability of the site, or *in situ* biological measurements. This information will be collected when necessary to support decision-making on the site's use, remediation or closure.

3.3 Core Monitoring Program: Selecting the Tools

The core parameters are recommended for all monitoring plans, as they support the minimum information requirements for meeting the first two tiers of monitoring. They were selected for consistency with the minimum information requirements of the permit application, which provides baseline information to derive the impact hypotheses. Additional parameters may be required on a site-specific basis.

Available tools for physical monitoring, the first tier, may combine geological surveys and the use of sediment transport models. As a minimum, physical monitoring should include general bathymetry at the disposal site. This will generally involve acoustic surveys appropriate to the site characteristics (e.g. sidescan sonar, high resolution bathymetry, or sub-bottom profiler). Direct or indirect evidence of grain size and physical characteristics of the site will generally be useful in determining site boundaries and supporting the design of Tier 2 monitoring.

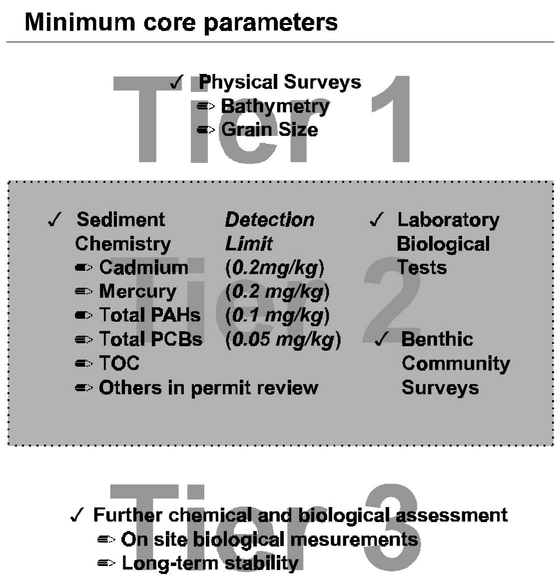


Figure 2 Core monitoring parameters for disposal site monitoring. Detection limits are provided for chemical parameters subject to regulatory controls.

Chemical monitoring seeks to determine the concentrations in the sediments of all chemical parameters measured in the permit review. Each monitoring plan, therefore, should minimally include: cadmium, mercury, PCBs, PAHs and total organic carbon. Where additional chemical information was requested during the permit review, those parameters must also be included. To support the interpretation of biological monitoring, certain chemical measurements may be helpful to determine if natural toxicants are influencing toxicity test results (e.g. ammonia, sulphides).

For biological monitoring, a battery of at least three bioassays should be selected, mainly from those employed in the permit review. The bioassays currently used for dredged material assessment are single species tests. They include: an acute test for sediment toxicity using marine or estuarine amphipods, a test for fertilisation success using echinoids in a porewater assay, a sediment solid-phase test using luminescent bacteria, and the USEPA's 28-day bioaccumulation test using *Macoma sp*. (Environment Canada, 1992a, b, c; USEPA, 1993). As well, a bacterial exoenzyme bioassay has been employed successfully in disposal site surveys and may provide useful insight on community level responses (Lee and Tay, 1997).

Benthic community studies seek to examine the number of species and individual organisms present in sediments, and hence will generally be conducted at the lowest possible taxonomic level for infaunal surveys. At some sites, epifaunal surveys may be useful to address site-specific impact hypotheses. As the number of samples is likely to be limited for practical reasons and costs, benthic surveys will generally provide only cursory information on the status of the benthic community onsite. Cursory surveys may provide information on the overall environmental quality of the site if conducted at the same sampling stations as the chemical and biological testing. The full data set could then be analysed with integrative assessment tools such as the triad. The assessor, however, should keep in mind that recent disposal activity will likely confound all or part of the benthic community results because of smothering and transplantation of organisms from the load site. Generally, benthic community surveys will be most useful in documenting recolonization on a site after disposal operations have ceased, and no further operations are pending, or to identify impacts off site. In such cases, the benthic community surveys will be designed to address site-specific impact hypotheses and therefore require a more extensive sampling effort. Benthic community studies may be complemented by *in situ* measurements of bacterial community exoenzyme activity.

4. Execution: Study Design and Sampling

Monitoring requires a sound study design to address the impact hypotheses identified at the site. The impact hypotheses identify which parameters should be sampled. At most sites, the site-specific impact hypotheses will be adequately addressed by the recommended Tiered Monitoring and the related core parameters. Once the parameters have been selected, a sampling plan can be developed to determine the time and location of sampling stations, the number of samples, the level of replication and the required QA/QC samples.

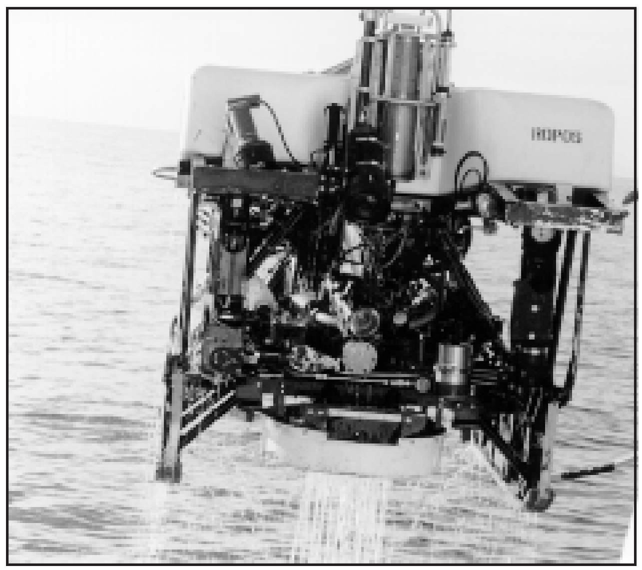
4.1 Physical Monitoring — Defining the Study Area

Physical monitoring seeks to define the study area — the area were the disposed material was deposited and if any sediment transport warrants off-site investigation.

Sediment transport predictions provided with the permit application will help in predicting the initial area of deposition. When site monitoring begins, physical monitoring will contribute to verifying these predictions. Historical information (such as, use pattern of the site, cumulative disposal since the site was last monitored, use by various permittees, and impacts of disposal techniques on the dispersion of the material) will help interpret the information collected with physical monitoring and assist in the delineation of the disposal site boundaries.

The efforts expended in determining the likelihood of sediment transport off-site after disposal should be related to site-specific concerns and the expected scale of effects. Generally, physical monitoring efforts will be primarily directed at establishing the disposal site boundaries. The same information can be used to identify broad patterns of deposits of material or general physical characteristics of the sea-floor. Physical monitoring provides useful information for the planning of Tier 2 and any further monitoring.

When sediment transport outside or beyond the site boundaries is observed, its significance should be established in terms of the impacts off-site such as fish habitat loss, biological effects, or conflicts with other legitimate uses of the sea. Water-column chemical investigations will generally not be required, unless there is evidence of long-term resuspension or diffusion of contaminants. The monitoring effort should again be linked to site-specific concerns and the expected scale of effects.



4.2 Spatial Design and the Reference Area

An important component of the study design is the selection or designation at a suitable reference area. Data from the reference area are compared with similar data collected in the study area. The reference area, therefore, serves as a spatial control to determine if effects observed in the study area are attributable to the disposal activity. The reference area should have oceanographic, geochemical and biological conditions similar to the area under investigation but should not be affected by any ocean disposal activity. In sediment toxicity testing, test results are compared with those obtained with a clean sediment of similar physical and chemical characteristics. As cost savings would be made by visiting only one area, the reference area will preferably be selected to provide both an adequate spatial control and a suitable reference sediment for toxicity testing.

A spatial control area should be selected with a view at using it as an indicator that other potential sources of pollution or disturbance in the area have not been affecting the disposal site (e.g. any impacts are due to disposal).

When on-site and off-site study areas are being studied, more than one reference area may be required if bathymetry and or geochemistry on and off-site are different.

If an adequate reference area cannot be located, a gradient approach may be used, with near field and far field stations serving as a spatial control (Figure 3). Emphasis should then be put on far field stations as near field stations are more likely to be under the influence of disposal. Near field stations, however, may help in confirming the disposal site boundaries and may be particularly useful in cases where concerns are associated with possible sediment transport after disposal.

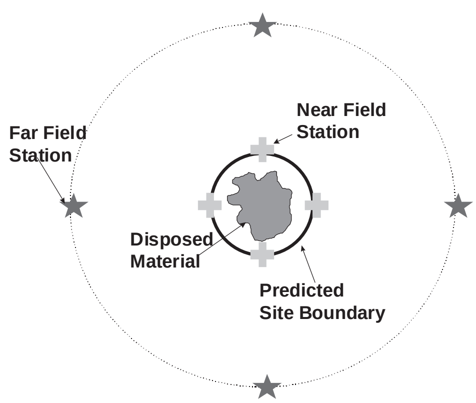


Figure 3 Near Field and Far Field Sampling Stations

When a site is re-visited, care must be taken in maintaining some consistency in the location of the sampling stations as this will allow for trend analysis and may be essential to some site-specific impact hypotheses. A core group of sampling stations should be consistently retained every time a site is visited.

4.3 Temporal Design and Baseline Information

An optimal study design would also include a temporal control, namely data about the disposal site before start of any disposal activity. For new disposal sites, permittees will be required to provide baseline information as part of their permit application. This baseline information can subsequently be used as a temporal control in a monitoring plan. Many disposal sites, however, have been in use for years and information on conditions at the site prior to any disposal activity will generally not be available or may not be comparable with current data. In these cases, data gathered in the first cycle of monitoring can be used as baseline for the next cycles.

Temporal variability should be controlled in the design (e.g. sampling should be conducted at the same time of year every time the site is monitored). Monitoring cycles at major and minor sites can provide trends to estimate the potential for long-term changes. To ensure proper long-term trends data, care must be taken to ensure consistency in the location of some sampling stations and seasonal timing of sampling.

4.4 Number of Samples and Sampling Stations

The number of samples and sampling stations must be appropriate to the volume of material deposited and the desired degree of precision. A sample refers to a discrete quantity of material collected for analysis. A sampling station is the location where that sample is collected.

For sites that cover a large area, a stratified sampling approach dividing the site into discrete zones (strata) could be implemented to focus sampling on areas where the expected impact is greatest, as illustrated in Figure 4. Further guidance on stratification can be found in the *Users' Guide to the Application Form* (Environment Canada 1995).

In Figure 4, strata are selected based on the accumulation patterns of dredged material within the disposal site boundaries. Alternatively, they could be based on apparent differences in grain size. As a wide variety of deposition patterns can occur (with and without mounds) and as bottom physical characteristics may vary within a disposal site, physical monitoring will generally provide useful information for the optimum placement of sampling stations. The need to revisit some stations for trend analysis should be considered concurrently and incorporated into the sampling plan.

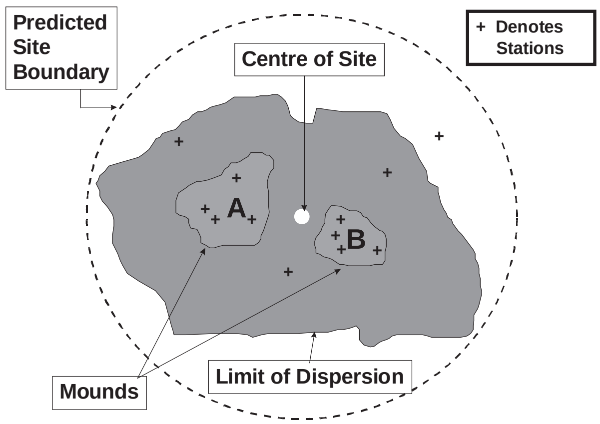


Figure 4 Possible Scenario to Stratify Sampling Stations at a Disposal Site Receiving 45,000 m^3

Note: ***The physical survey found that the site comprises two mounds of deposited material and a field of dispersed material within the predicted site boundary. Stations are stratified to focus on the mounds, where it is assumed the impact is greater. Other stations are sampled to confirm the limits of the impacted zones.***

The number of sampling stations can be determined for the site, or stratum, using Table 1. An absolute minimum for any *disposal site* should be 15 stations where a very small zone of influence is found. Strata may have a smaller number. Typically, one sample will be collected from each station. For quality assurance and control, 10% of these stations should be sampled and analysed in triplicate. As well, at least three samples should be collected in the reference area and if off-site sampling is undertaken, a minimum of 3 samples should be taken.

4.5 Quality Assurance and Control (QA/QC)

It is essential to ensure precise and accurate positioning of vessels. Guidance on positioning equipment can be found in Environment Canada (1994c). The method of positioning should be documented.

Table 1 Recommended Number of Sampling Stations for the Volume of Material Accumulated

Volume (1,000's m^3) Greater than	Less than	Number of Stations
0	10	6
10	17	7
17	23	8
23	30	9
30	37	10
37	43	11
43	50	12
50	58	13
58	67	14
67	75	15
75	83	16
83	92	17
92	100	18
100	141	19
141	182	20
182	223	21
223	264	22
264	305	23
305	346	24
346	386	25
386	427	26
427	468	27
468	509	28

Note: ***The volume of material accumulated within a stratum can be estimated using the height of accumulated material within each detectable mound. A minimum of 15 cm should be used as the height in the calculation of volumes.***

Many analytical methods, which can be used for sediment chemical characterisation, are presented by the St. Lawrence Centre (1993) and CCME (1993a, b). The detection limit of the chosen method should be sufficiently low to ensure adequate quantification at the ocean disposal screening levels (see Figure 2). The QA/QC guidance recommended for the characterisation of dredged material in the permit assessment phase should be employed when determining levels of chemicals in sediments at the disposal site

(Environment Canada, 1996). Chemical results must be reported on a dry weight basis. Further guidance on data reporting for chemical analysis can be found in Chapter 18 of *St. Lawrence Centre* (1993) and in the *QA/QC Guidelines for Ocean Disposal* (in preparation).

Bioassays must be conducted in conformity with *Environment Canada Biological Test Methods* (Environment Canada 1992 a,b,c) and the US EPA *Bioaccumulation Protocol* (USEPA 1993). Where formal reference methods are available, they should be used.

5. ANALYSIS: INTERPRETING THE DATA

Where applicable, criteria used for assessments of ocean disposal sites should be harmonized with the permit assessment criteria and guidelines. In addition, data interpretation should take into account comparisons with spatial and temporal controls. Data interpretation guidelines are presented in relation to the three Tiers of the tiered monitoring approach.

5.1 Physical Assessment

In the context of determining the area of deposition, the disposal site boundaries and evidence of sediment transport off-site, the following definitions apply:

- a site is non-dispersive if material remains within the boundary during placement and placed material is static or reworked within the boundary;
- a site is dispersive if placed material is transported beyond the site boundary.

If monitoring indicates that grain size is changing at a site as a result of disposal activities, management actions should be considered only if there are undesirable effects.

When sediment transport is observed, the significance should be established in relation to the impacts off-site such as fish habitat loss, biological effects, or conflicts with other legitimate uses of the sea.

5.2 Chemical and Biological Assessment

Data interpretation of chemical and ecotoxicological data relies primarily on criteria employed during the permit application review. In addition, cursory benthic surveys can assist in assessing the overall quality of the sediments.

Chemistry

Regarding sediment chemistry, determination of sediment quality currently uses national screening levels presented in Table 2. Environment Canada is considering a proposal to replace the current screening levels with sediment quality guidelines or SQGs. In either case, the following rules are applied for any contaminant concurrently with bioassays:

- if the observed values are below the national screening level, the disposal site sediments are considered harmless for the parameter measured;
- if the observed values are above the national screening level, further determination of sediment quality is based on the concurrent biological measurements;
- if there are clear spatial patterns of contamination or biological responses, or both, stratification of the study area can be considered for further monitoring and making further determinations of sediment quality. For any specific contaminant, if some values are above and some below the national level, the upper 95% one-sided confidence limit on the mean concentration is calculated and the sediments are considered clean of the contaminant, if this 95% upper confidence limit is less than the national screening level. Given this, sediment chemistry concentrations are recommended to be presented as the upper 95% one-sided confidence limit or 95% U.C.L.

Table 2 National Screening Levels for Chemicals in Sediments (mg/kg, dry weight)

Chemical	Current Level	Proposed SQG
Cadmium	0.6	0.65
Mercury	0.75	0.13
Total PCBs	0.1	0.0215
Total PAHs	2.5	replaced by 13 individual PAHs

Bioassays

Concerning bioassays, interim Pass-Fail criteria are employed to determine toxic effects. Bioassay protocols currently used for sediment assessment include:

- an acute toxicity test using marine or estuarine amphipods (the end point is lethality);
- a fertilization assay using echinoids (the endpoint is significant reduction in fertilization);
- a toxicity test using a photoluminescent bacteria, the Microtox® solid-phase test (the end point is significant reduction in bioluminescence);
- a bedded sediment bioaccumulation test using the USEPA guidance manual (the end point is significant bioaccumulation).

(Environment Canada, 1992a, b, c; USEPA, 1993)

For the amphipod acute test, toxicity is determined by comparing the mean 10-day survival to species specific criteria, found in Table 3. The sediment is considered toxic when survival is less than the criteria for test sediment and the survival in the reference sediments is greater than or equal to its species specific criteria.

Determinations for the Echinoid test are based on a comparison of responses between pore water extracted from the sediment and control water ran concurrently. The sediment is considered toxic if its porewater induces at least an absolute ***25% decrease*** in fertilisation success.

For the Microtox® solid-phase test, a sediment is considered toxic if the concentration of sample that is estimated to cause 50% inhibition of light production by the bacteria after five minutes of exposure is ***less than 1,000 ppm***.

For the bioaccumulation test, the sediment is considered bioaccumulative when a statistically significant difference is observed in the tissue concentrations of a toxicant between the organisms exposed to the test sediment and the organisms exposed to the reference sediment. Tissue levels that indicate a bioaccumulative response should be compared to established criteria for environmental protection. As well, a bioaccumulative response for a sediment should be considered with results from the other bioassays.

Table 3 Interim Pass — Fail Criteria for Biological Testing

Test	Failure		
Amphipod 10-day acute test	***Species***	***Reference Sediment Survival***	***Test Sediment Survival***
	Amphiporeia virginiana	≥ 70 %	< 50 %
	Eohaustorius washingtonianus	≥ 75 %	< 55 %
	Eohaustorius estuarius	≥ 80 %	< 60 %
	Rhepoxynius abronius	≥ 80 %	< 60 %
Microtox® solid-phase	The concentration of sample that is estimated to cause 50% inhibition of light production by the bacteria after 5 minutes of exposure is ***less than 1,000 ppm***.		
Echinoid fertilisation	A ***decrease in fertilisation of at least 25%*** is observed between the test sediment and control water*.		
Bioaccumulation	A ***statistically significant difference in the tissue concentrations*** is observed of a toxicant between the organisms exposed to the test sediment and the organisms exposed to the reference sediment.		

** The observed difference must be statistically significant.*

Other biological tests, including the bacterial exoenzyme bioassay (Lee and Tay, 1997), should be employed as complementary information and data interpretation will be site-specific.

Interpreting Concurrent Results

If sediments are below national screening levels for contaminants and pass all bioassays, no further action is required. However, if levels of contaminants or bioassay results demonstrate 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 will generally involve checking potential sources of pollutants and conducting further site characterization. After considering this information, the following hierarchy of interpretation guidance can be applied to the concurrent chemical and toxicological data:

1. If sediments at the disposal site contain substances in excess of national screening levels, pass the acute toxicity test, but fail one sublethal or bioaccumulation test: consideration could be given to modifying further use of the site and investigating the long term stability of the material onsite;

2. If the sediments contain substances below the national screening levels, yet fail any of the biological tests: 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

3. 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: further monitoring, site closure or remediation could be considered.

As data interpretation is difficult and the number of samples will be limited, the cursory benthic community surveys afforded by most plans can be used as a general sediment quality indicator. *In situ* bacterial exoenzyme measurements can complement this data and its interpretation will be site-specific. Where recolonization or off-site impacts are primary concerns, benthic community studies could assist with verifying the impact hypothesis: *to minimize physical impacts, recolonization is expected at minor sites and preferable at major sites in between disposal seasons or years, depending on the use patterns of the site*.

Data interpretation should combine a hypothesis testing approach, where desirable for individual parameters with integrative approaches, such as the sediment quality triad or multivariate techniques. This includes using physical, chemical and biological data to derive a concluding statement, in support of any monitoring related decision. All available information from the physical, chemical and biological monitoring is considered in the overall assessment of the disposal site. In most cases, the final objectives of monitoring specific sites will focus on the assessment of impacts from disposal activities to determine if a given site, or site conditions, are suitable for ongoing disposal operations and verifying permit decisions. Results from monitoring at several sites may be pooled within a region, or nationally, to assess the overall adequacy of controls and identify research needs where there are gaps in understanding.

5.3 Further Biological Assessment

Further biological assessment will generally not be essential to decision-making related to contaminant loading and toxicity of sediments. The overall assessment of the disposal site can be based on the lower tiers of monitoring, but data interpretation should be done carefully to take into account the limitations inherent to the available data.

Data interpretation of *in situ* biological measurements will be site-specific. It is expected that they will rarely be employed, either as Tier 3 monitoring tools or in response to an impact hypothesis specific to a given site (e.g. concerns raised about a nearby shellfish growing area).

Should there be a need to consider remediation, decision-making should consider the *CCME Contaminated Sites Criteria and Guidelines* as well as the ocean disposal permit assessment criteria. Decision-making should take into account other factors, such as the likelihood of dispersal off-site.

6. REPORTING

A final report should be prepared for each disposal site monitoring study, within the calendar year following the field survey, and preferably within the same fiscal year as the field survey. To meet Canada's national and international reporting requirements, a national compendium will be produced annually by the Marine Environment Division (MED) using the information provided in the regional reports.

An electronic copy of the report should be sent to the Chief, Marine Environment Division, in Hull. Copies will be made available to each Environmental Protection Service regional office responsible for the implementation of ocean disposal site monitoring. One copy will be kept by MED to maintain a National Depository and one copy will be made available to each site user.

The regional reports should clearly identify the linkages between the impact hypotheses derived during the permit application review and the monitoring plan. The reports should include information on: parameters, monitoring tools, sampling plan, data analysis, data interpretation, conclusions and recommendations. As well, they should clearly identify results that verify if permit conditions were met and indicate whether the assumptions of the permit review and site selection process were correct.

The national compendium and regional monitoring reports will contribute to the periodic evaluation and updating of the *National Guidelines for Monitoring Dredged and Excavated Material at Ocean Disposal Sites*. The information gathered will also be used nationally to assess the adequacy of controls with a view at determining whether ocean disposal regulations, guidelines and permit conditions are adequate in protecting the marine environment.

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