Monitoring Of A Dredged Disposal Site
Great Mosquito Cove, Newfoundland

FINAL REPORT

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1.0 INTRODUCTION AND BACKGROUND

Based upon the request for proposal "Monitoring Dredged Disposal Site, Solicitation No. KW203-040373/A" issued by Public Works and Government Services Canada, October 06, 2004, AMEC Earth and Environmental is pleased to submit the following report

Each year in Canada, two to three million tonnes of material are disposed of at sea. Most of this is dredged material that must be moved to keep shipping channels and harbours clear for navigation and commerce. Only those substances listed in the *Canadian Environmental Protection Act* (CEPA), *1999* may be considered for disposal at sea including dredged material, fisheries waste, ships, inert matter, uncontaminated organic matter and bulky substances.

Disposal at sea is controlled federally by a system of permits issued under CEPA, 1999. The objective of the ocean disposal legislation under CEPA 1999 and its regulations is to prevent marine pollution from the uncontrolled disposal of waste or other matter at sea. Permits are granted on a case-by-case basis after an application and review process and typically govern timing, handling, storing, loading, placement at the disposal site, and monitoring requirements. The permit assessment phase involves public notice, an application that provides detailed data, a scientific review and payment of fees. This system has been in place since 1975 and was included in CEPA 1988.

CEPA, 1999 and the new regulations give the powers needed to strengthen Canadian controls over disposal at sea, and to satisfy the international commitments made under the *1996 Protocol* to the *Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter* (the "London Convention").

To access the Hibernia oilfield, a gravity-based structure (GBS) was constructed in Great Mosquito Cove, Bull Arm, Trinity Bay, Newfoundland. Construction occurred in a 55,000 m^2 dry-dock created by an earth berm extending across a portion of Mosquito Cove. In 1994, after completion of the GBS, Newfoundland Offshore Development Constructors (NODECO) was responsible for removal of the berm. The contract for berm removal was awarded to Great Lakes Dredging and Dock Company with the activity occurring between March 1st and July 1st 1994. The berm consisted of an excess of 450,000 cubic meters of approximately 50% till and 50% rock. The preferred disposal area was a small underwater gorge located within Mosquito Cove. The material removed from the first cut of the dry-dock berm was used to construct an underwater containment berm to prevent till from migrating out of the containment area. Environment Canada issued a permit for the activity.

In issuing a permit for the 1994 dry dock berm removal, Environment Canada concluded that any negative environmental effects of the project could be mitigated and that the disposal would have no long-term effect on the area. Environment Canada (EC)/Public Works and Government Services Canada (PWGSC) issued a contract to AMEC Earth and Environmental (AMEC) in partnership with Narwhal Environmental Consulting Services (NECS), Contract No. KW203-4-0373 issued November 2004 and amended February 2005. The objective of the work was to test the hypothesis that ten years after the project, the ecological health of the benthic community at the Great Mosquito Cove disposal site is not significantly different from reference site conditions.

2.0 OBJECTIVE

The Great Mosquito Cove disposal site is selected for the 2004/05 Atlantic Regional disposal site monitoring program because it meets a trigger of the Environment Canada Disposal Site Monitoring Guidelines.

In accordance with the Request For Proposal (Solicitation No. KW203-040373/A) the objective of the study was to conduct an ecological assessment of the former Great Mosquito Cove waste disposal site to test the hypothesis:

- *In the 10 years following disposal activities the benthic community at the disposal site has undergone a complete recovery.*

3.0 LOCATION OF WORK

- Former ocean disposal site at Great Mosquito Cove, Newfoundland
  47° 48.55'N 53° 52.90' W (Figure 1)

- One representative reference site (no waste disposal) nearby the disposal site (within Mosquito Cove).

4.0 STATEMENT OF WORK

The statement of work required as outlined in Solicitation No. KW203-040373/A is as follows:

Site Access: The ocean disposal site at Great Mosquito Cove and one nearby reference site are required to be included in the assessment. The sediments at the disposal site may be inappropriate for grab sampling and the contractor should be prepared to employ other means to assess the site. Contractors will access the chosen sites using a vessel equipped with an adequate work platform to conduct the work plus space for up to two Environment Canada observers. The vessel should be capable of anchoring to ensure precision of the sample location, be equipped with GPS for position and a sounding system to determine sampling depth. Vessel and operators must be equipped with safety equipment that satisfies Canadian Coast Guard standards.

Dumpsite Verification: Coordinates for the Great Mosquito Cove disposal site have been noted above but may vary slightly. The contractor will verify the disposal site location. The contractor can verify the disposal site through grabs, diver, underwater photography, consultation with the former permit holder or by other methods acceptable to the Departmental Representative.

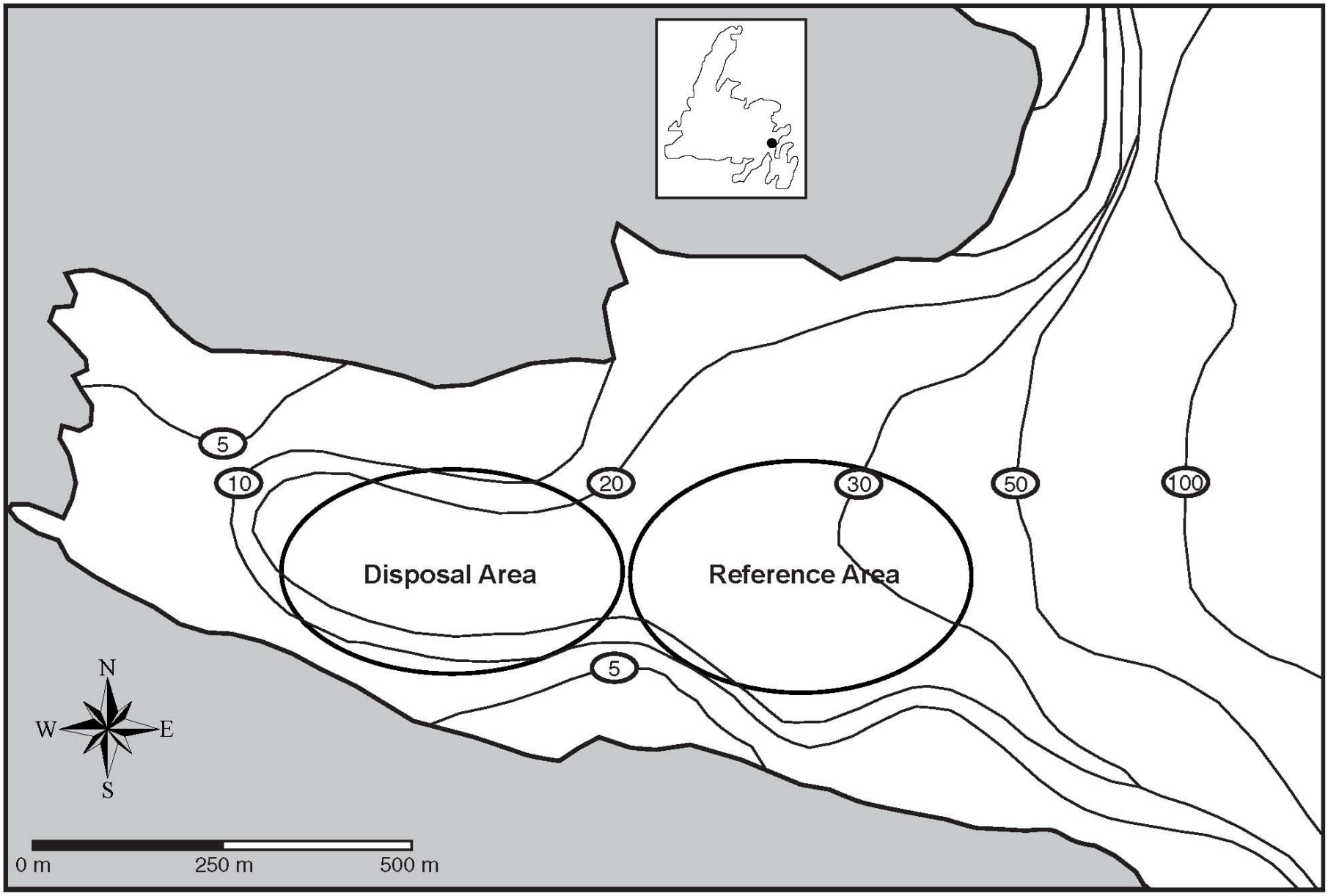


Figure 1. Mosquito Cove study area and approximate locations of disposal and reference areas, Jan-Feb 2005.

Video/Photographic Documentation: Video (VHS) and/or still photographs can be included to document the sampling procedure, disposal site, substrate, representative biota and results analysis and interpretation.

The successful contractor will be required to design a sampling program based on their proposal to identify sampling stations, collect samples, collect ecological information, analyze data and provide necessary statistical analyses on all data.

The monitoring plan will be designed to address the following impact hypothesis:

- *In the 10 years following disposal activities the benthic community at the disposal site has undergone a complete recovery.*

5.0 METHODOLOGY

5.1 APPROACH

AMEC viewed the project as consisting of a number of logically sequenced tasks, these included (note that the details regarding the field methodologies to complete each task are presented in the following section):

- The verification and delineation of the Great Mosquito Cove dredged material disposal site boundaries. The initial step in this process was the recording of a detailed bathymetric record of the substrate in the identified disposal area. This information permitted the correct spatial deployment of detailed video and grab sampling (for particle size and benthic invertebrate analyses) throughout the study area. This was determined via a boat deployed, data logging PC based depth sounder in addition to consultations with the previous permit holder and Environment Canada personnel.

- Characterization of the substrate and benthic communities (flora and fauna) within the dredged material disposal site. This was determined via a combination of video footage analysis (towed video and drop camera) and opportunistic benthic grab sampling for particle size and benthic invertebrate analysis. The utilization of the high-resolution drop camera permitted the identification of zones of suitable substrate material that were amenable to benthic sampling (thus eliminating time-consuming grab attempts upon hard and/or coarse substrate and ensuring sampling success).

- The selection of one nearby reference site within Mosquito Cove. The reference site was selected to replicate as closely as possible the depth, exposure and substrate characteristics of the dredged material disposal site. Site characteristic continuity between the dredged disposal area and the reference area was critical to the scientific validity of testing the hypothesis that the disposal site has undergone a complete recovery. AMEC was cognizant of the fact that the anthropogenic-dredged material may not be representative of the natural substrates characteristic within the Mosquito Cove area.

- The reference site was characterized utilizing the same combination of video (towed video and drop camera) and benthic grabs (particle size and benthic invertebrate analysis) as the dredged material disposal site.

- After field investigations were complete video records were analyzed to determine substrate, flora, and fauna distributions within the dredged material disposal site and the reference area. Benthic grab samples were analyzed with respect to particle size and benthic invertebrate communities.

- Information garnered from field and laboratory investigations for the dredged material disposal site and the reference area was compared and contrasted (where applicable) via appropriate statistical analyses.

5.2 FIELD AND LABORATORY METHODOLOGIES

The Mosquito Cove Field Survey was completed between January 30th and February 3rd, 2005. Due to winter road conditions field personnel traveled to the area on January 30th; prepared equipment on January 31st and conducted the field survey from February 1st through 3rd.

The field personnel included Narcissus Walsh, Deidre Puddister, Robbie Coish (Narwhal ECS) and Andrew Peach (AMEC). Environment Canada personnel, Glenn Worthman, Rick Wadman and Kevin Pike were on site for portions of the survey on February 1st and 2nd. Eugene Lee of AMEC provided project management and drafted the final report.

Heavy snow conditions required the use of a boom truck to launch and recover the survey vessel and Environment Canada's observation vessel as no shoreline access was available at Mosquito Cove or in the immediate area.

5.2.1 Bathymetric Survey

The initial survey task consisted of a georeferenced bathymetric survey conducted on February 1st. Georeferenced bathymetric data was recorded using a data logging PC based depth sounder. Sounder readings were verified prior to the start of the survey using a weighted meter line in a depth range of 10 to 20 m.

The bathymetric survey was centered on disposal area coordinates provided by Environment Canada included in the original request for proposals for this work. A survey grid measuring 200 by 200 m was established in the area of these coordinates and was used as the area for concentrated survey efforts.

The intent of the bathymetric survey was to identify seabed features, such as mounded disposal material and irregular bottom contours, that would identify the main disposal area.

5.2.2 Video Surveys

Following the initial bathymetric survey a towed video survey was initiated using a video camera and light assembly mounted to a V-fin. All video collected was georeferenced using a system which encoded GPS position on the audio track of the recorded tape. GPS locations were recorded for all video segments.

Towing speeds were in the range of 2-3 kilometers per hour.

Following the initial towed video collection it was observed that heavy sedimentation had occurred in the survey area and that visibility was low. As a result, bottom features were distinguishable only when the camera was less than 1 m from the seabed. It was determined that, under these conditions, continued use of the towed system would not provide video images which could be used to clearly show seabed characteristics. It was noted that stopping the survey vessel and lowering the camera provided images which showed distinct bottom features and provided more useable images overall.

The video camera and light system were reconfigured for use as a dropped camera and the survey was continued using this method.

Video was collected on February 1st, 2nd and 3rd, 2005.

Video surveys conducted previously in the Mosquito Cove area were accessed, reviewed and compared with the 2005 footage. This included a survey conducted in December 1993 (pre berm removal) and 1995 (one year after berm removal) (Appendix 1).

In December 1993 and January 1995, Polaris Marine Services Ltd. completed video surveys in Mosquito Cove for the Hibernia Management and Development Company (HMDC). The surveys were completed using an ROV.

The 1993 videotapes were obtained from the Hibernia Management and Development Company (HMDC) and are subject to a nondisclosure/ confidentiality agreement. An electronic copy of this agreement is included with the digital files attached to this report. The 1995 tapes were provided from Environment Canada files.

The video surveys were completed during the winter season in each case, minimizing changes in epifauna that would be associated with seasonal changes. The surveys were conducted in the following time periods:

- 1993 - pre-berm removal (December 15th);
- 1995 – post berm removal (January 9, 10 and 11);
- 2005 – 10 years post berm removal (February 01-03).

These surveys cover portions of the area surveyed in February 2005, however detailed positioning information was not available for the 1993 and 1995 surveys; as a result, no direct comparison can be made. It is important to note, however, that distinct visible changes in the general substrate characteristics and occurrences of epifauna were observed, and provided useful qualitative indicators of change.

The complete digital versions of the 1993 and 1995 tapes are direct copies of the VHS tapes provided through HMDC and Environment Canada. The complete version of the 2005 tapes contains all footage in which the substrate is visible. Camera deployment and retrieval segments, as well as short segments in which the bottom is not visible, have been deleted for clarity.

5.2.2.1 Video Analysis

- Prior to commencing the 2005 survey, video from the 1995 survey was viewed to obtain a preliminary impression of bottom type and depth in an effort to fully prepare for sampling conditions.

- Once the 2005 survey was completed, all collected video was initially previewed to obtain a general idea of existing conditions at the site for both the disposal and reference areas.

- Video was then examined in detail and notes made concerning the physical environment (i.e. bottom type, seabed conditions, depth, visibility, construction debris)

- Finally, video was examined in detail for visible flora and fauna and notes made concerning the types and numbers present.

This process was also used when examining video from the 1993 and 1995 surveys (although positional data was unavailable). The video review was intended to identify notable differences in physical or biological characteristics of the area as determined from the 3 years of available video footage.

5.2.3 Benthic Grab Collection

Potential benthic sample locations were identified within the disposal and reference areas (inside and outside respectively of the underwater disposal area berm). Initial sample locations were evenly distributed (10 per area) over each location. Using the dropped video camera each potential sampling location was surveyed to determine suitability of the seabed. In areas of heavy gravels, cobble, boulder, and bedrock which would preclude grab sampling the sampling point was relocated to the nearest suitable location.

Sediment sampling was initiated on February 2nd and completed on February 3rd using a winch deployed, stainless steel, Van Veen grab. Benthic invertebrate samples were collected at ten locations in both the disposal and reference areas (20 in total). Particle size samples were collected from six locations in both the disposal and reference areas (12 in total).

At each station the grab was allowed to advance through the water column into the substrate at a uniform and quick rate of descent. Once the grab was on the bottom a position and depth for each station was recorded via the onboard DGPS unit and depth sounder. Samples were scooped from the surface layer (to about 5 cm depth) of the retrieved grab sample and placed in three replicate, pre-labelled 250 ml glass jars. Samples were placed in coolers upon collection and subsequently preserved in 80% isopropyl alcohol.

5.2.3.1 Benthic Invertebrate Analysis

Triplicate samples from each station were combined and weighed at AMEC's St. John's Materials Laboratory to quantify the amount of substrate sampled (digital scales, 0.01 g accuracy). Each combined sample was sieved through a surber sampler with a mesh size of 1.0 mm to remove fines from the sample. The samples were then collected into 500 ml mason jars until identification and classification commenced.

Identification and classification was conducted utilizing a 40X Stereomaster dissecting microscope. Approximately 125 ml of sediment from each sampling location was placed into petri dishes and the invertebrates collected and classified. In instances where more than 125 ml of sediment was present, the sample was stirred and 125 ml of material was fractioned out (Disposal Area Sample #'s 5,7,8,and 9). Invertebrates were then sorted into like groups and identified to the lowest practical level.

5.2.3.2 Sediment Particle Size Analysis

Sediment samples were analyzed at AMEC's St. John's Materials Laboratory. Samples were rinsed through a series of sieves with decreasing mesh diameter. Results were recorded both graphically and in tabular format as per AMEC's standard operating procedure.

5.2.4 Quality Assurance/Quality Control Program

All field and office work was subject to AMEC's quality assurance/quality control program (QA/QC). The purpose of the QA/QC program was to ensure that the quality of the samples submitted for analyses were representative of the field conditions without interferences from other sources. The QA/QC program also ensures that analytical results are reported accurately and precisely.

All sampling containers were pre-labelled prior to initiating fieldwork to avoid potential confusion. All data collected was backed-up through production of both hard and electronic copies. All sample information was recorded upon chain of custody forms, copies of which will remain at AMEC's St. John's Office/Laboratory.

6.0 RESULTS

6.1 BATHYMETRY

The bathymetric survey was centered on disposal area coordinates provided by Environment Canada. A survey grid measuring 200 by 200 m was established in the area of these coordinates and was used as the area for concentrated survey efforts (Figure 2).

Bathymetry indicated a depth profile within the disposal/reference zone ranging from 15 to 55 m. Depths within the disposal area were fairly uniform ranging from 10 to 40 m. Depths within the reference area were more variable, ranging from 10 to 55 m (Figure 2). The depth range surveyed is consistent with the observed depth for the inner section of Mosquito Cove and concurs with the depth ranges encountered in 1993 and 1995 surveys.

The bathymetric survey identified bottom features that indicated a possible disposal area and probable location of a berm that had been constructed during disposal operations. The berm had been placed at the seaward boundary of the disposal area to reduce sediment dispersal along the seabed. Additional bathymetric data was recorded throughout the survey.

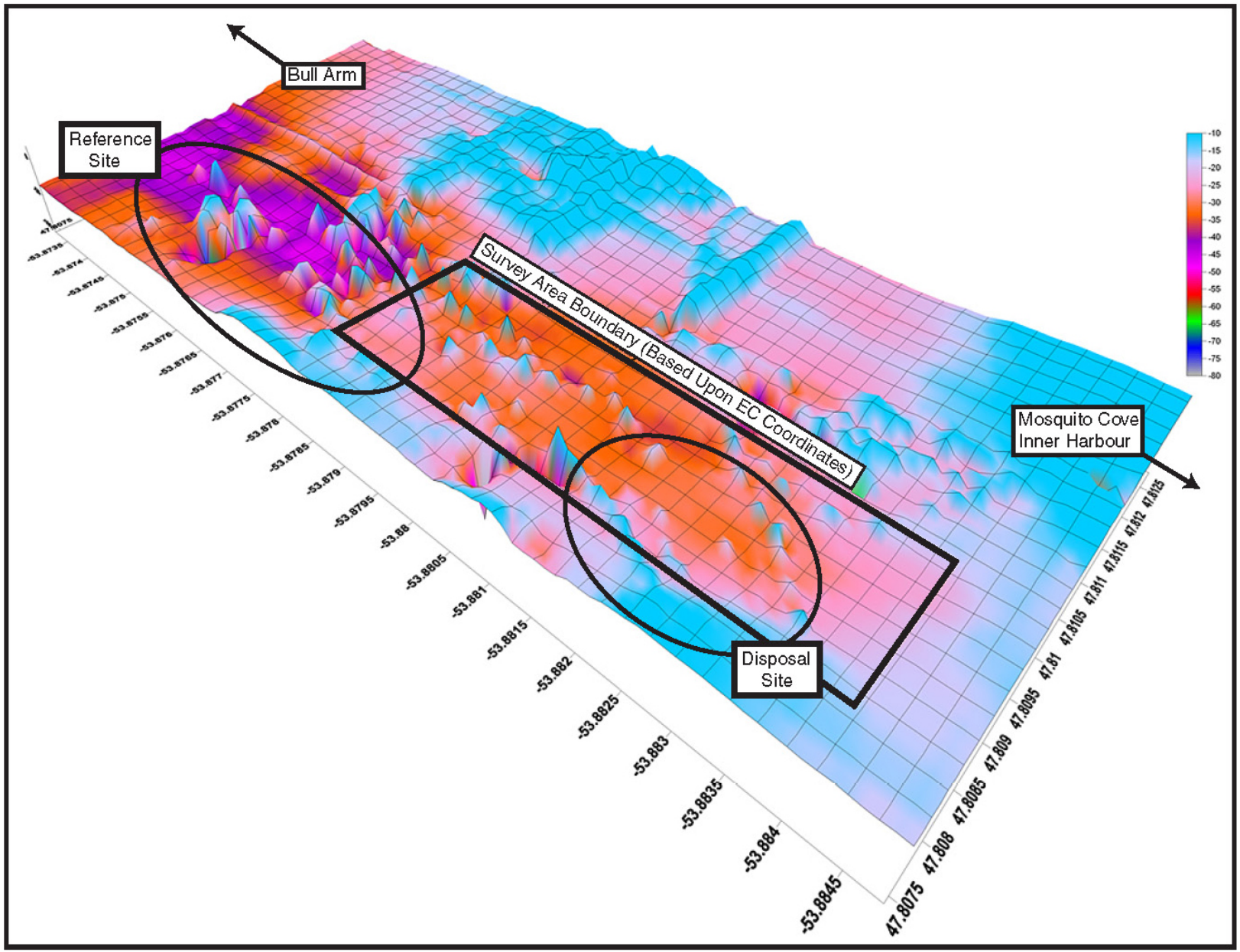


Figure 2. Mosquito Cove bathymetry and approximate boundaries of disposal and reference areas, Jan-Feb 2005.

6.2 VIDEO SURVEYS

6.2.1 1993 Mosquito Cove Video Survey

The 1993 ROV survey collected about 170 minutes of video in a depth range of 5 to 40 m. The majority of the survey was completed in the 15 to 30 m depth range. This is consistent with the observed depth for the inner section of Mosquito Cove and includes the depth range observed for most of the disposal area surveyed in 2005.

In reviewing the 1993 tapes, and comparing to the 1995 and 2005 surveys, there are three features that are most notable in terms of subsequent change:

1. The 1993 tapes indicate a substrate that is coarser than the substrate in subsequent surveys, with more exposed bedrock, boulder, and cobbles visible throughout the surveyed areas. Although the coarse substrate is overlain in some sections by sediment, the cover is typically light and the coarse material is not completely embedded;
2. As noted above, observed areas of sediment indicate a coarser material and lighter coverage than in subsequent surveys. Based on observer experience, much of the sediment observed in the 1993 survey is a result of natural inputs. This is indicated by the:
    - *Resistance to disturbance compared to 1995 and 2005;*
    - *Rapid settlement after disturbance compared to 1995 and 2005;*
    - *Presence of visibly coarser particles compared to 1995 and 2005;*
    - *Reduced effect on visibility by disturbed materials;*
    - *Reduced area of disturbance as a result of camera impact in 1993;*

3. Observed epifauna was notably more abundant in the 1993 survey than in the subsequent 1995 and 2005 surveys and occurred consistently throughout the surveyed area;

The following is a list of specific observations from the 1993 survey, grouped by depth interval and identified by the time of day (TOD) as indicated within the video file.

Depths less than 20 m

- *TOD: 9:00 am – 9:12 am* – the bottom is predominantly cobble, with occasional boulder; algal cover (*Agarum* kelp) is approximately 0 – 30% and anemones are abundant
- *TOD: 11:10* - abundant blue mussel shells and sea stars are noted over bottom which appears to be undisturbed
- *TOD: 11:15* – the depth range is 4 – 5 m indicating a near shore location and abundant rockweed and green algae are noted
- *TOD: 11:22* – following transect lines; bottom is boulder and cobble covered by fines; some green urchins are present
- *TOD: 11:37* – edge of a bedrock ridge leading to soft bottom; anemones and green urchins are present
- *TOD: 1:35 – 2:41* – natural, rocky bottom with kelp and areas of bedrock; coralline on rocks; bottom is not uniform/flat; slight layer of fines; kelp, anemones and urchins abundant

Depths greater than 20 m

- *TOD: 8:42 – 9:11 and 9:21 – 9:45* – the bottom is not uniform depth; characterized by areas of boulder and cobble with patches of sediment noted between areas of cobble and boulder mix;
    - Rock is coralline covered and abundant kelp (*Agarum*) growth is noted, ranging from 20 to 90% coverage;
    - Abundant anemones were observed; urchins and sea stars are noted and rock crab was observed;
- *TOD: 10:32 – 10:42* - bottom is primarily cobble with occasional bedrock and boulder;
    - Areas of fines, mixed and covering gravels; some coralline; some anemones and urchins; occasional large kelp (*Agarum*);
- *TOD: 11:30* – bottom is fines with some rock; mostly flat/uniform bottom; few areas of mounding; sea stars, anemones and urchins present;

- *TOD: 12:46 pm – 1:32* – the bottom is comprised of fines mixed with cobble and boulder; coralline was observed on rock with occasional kelp (*Agarum*), rock crab, sea star and green urchin;

Berm

TOD: 10:43 - 11:10 – the depth is < 20 m with a clear transition between the natural bottom and placed material which is assumed to be a section of berm. The berm is comprised of a mix of cobble and boulder, with some natural rock (indicated by shape and coralline algae cover) included in the mixture. The berm is colonized by urchins, sea stars, and anemones; a layer of filamentous algae is also observed. A light layer of fine sediment was observed over much of the berm material.

6.2.2 1995 Mosquito Cove Video Survey

The 1995 ROV survey collected about 195 minutes of video in a depth range of 10 m to greater than 100 m. Video quality is reduced compared to 1993, with coverage in deep water of the poorest quality. Good footage was available in the 15 to 40 m depth range depth for the inner section of Mosquito Cove; the depth range observed for most of the disposal area surveyed in 2005.

Note that the tape segments from 1995 are not in chronological order. The tapes were duplicated – without change – from the materials provided and any sequencing errors are part of the original tape production.

In reviewing the 1995 tapes, notable changes from 1993 include:

1. The 1995 tapes indicate a significant reduction (as compared to 1993) in visible coarse substrate, with less exposed bedrock, boulder and cobbles visible throughout the surveyed areas. Coarse substrate is often overlain by sediment, with material being completely or substantially embedded.

2. Epifauna occurs much less frequently than in the 1993 survey and is notably less abundant when it does occur.

3. Observed areas of sediment indicate a predominance of fine material compared to the 1993 survey. Based on observer experience of marine sediment characteristics, the 1995 survey indicates widespread presence of introduced sediments and silt. The sediment observed in 1995 has the characteristics of introduced material as indicated by:
    - *Ease of disturbance*
    - *Slow settlement when disturbed*
    - *The significant effect on visibility*
    - *Dispersal over larger area when disturbed as compared to the 1993 video.*

The following is a list of observations from the 1995 survey grouped by depth interval and identified by the TOD indicated within the video file.

Depths less than 20 m

- *TOD: 8:34 – 8:49 am, Jan 10, –* the bottom is primarily cobble and boulder with a heavy layer of fines visible. Some coralline algae is present with occasional kelp (*Agarum*); some sea stars, urchins, anemones and rock crab present;
- *TOD: 9:21 – 9:48 am, Jan 10,* - bottom type is boulder and bedrock, interspersed with areas comprised of a mud rock mixture; the bottom ridged; coralline algae is present on some rocks; kelp (*Agarum*) is scarce; anemones and urchins are abundant in areas

Depths greater than 20 m

- *TOD: 2:23 – 2:55 pm, Jan 9, –* the bottom is boulder and cobble covered by a heavy layer of fines; whitish mats were observed in areas of sediment and based on observer experience are likely bacteria (*Beggiatoa sp.)*; occasional kelp (*Agarum* sp.) is present and is notably small in size; a small number of green urchins were observed;

- *TOD: 2:29 – 2:58 pm, January 10,* - substrate is predominantly mud and fines over cobble with boulders present; areas of fines and sedimented bottom are frequent; *Beggiatoa* sp*.;* sea anemones and rock crab are present;

- *TOD 3:24 – 3:39, 4:07 – 4:20 pm Jan 10; 9:32 – 9:38, 11:54 – 11:57 Jan 11, –* predominantly mud and fines over cobble with occasional boulders; large areas of soft bottom were noted; sea stars, urchins and *Beggiatoa sp* were occasionally present;

- A large anchor, culverts, lumber, scrap, and other construction debris was present in small quantities;

Depths greater than 100 m

TOD: 10:28 – 10:57 am, January 10; predominantly mud and fines over rock, with some boulder; note that the 1993 or 2005 surveys did not include this depth range.

6.2.3 2005 Mosquito Cove Video Survey

The 2005 video survey collected about 140 minutes of video in a depth range of 15 to about 55 m. Bathymetry for the surveyed area was also recorded.

All collected video was georeferenced at the time of collection, providing accurate location information for all segments. The video collection was completed using a combination of towed and dropped camera set-ups. The use of the dropped camera set-up allowed for better camera control and the collection of close-up seabed images. Approximately 60% of the collected video was obtained using the dropped camera.

Video collection was completed over the Disposal Area that was centered on coordinates provided for the disposal location. In addition, video collection was completed over the Reference Area (located outside the berm). The berm marked the outer boundary of the disposal area.

The depth range surveyed is consistent with the observed depth for the inner section of Mosquito Cove and includes the depth ranges surveyed in 1993 and 1995.

The 2005 tapes do not include a text overlay; tape sections can be located using the tape time (TT) that is displayed in Windows Media Player.

In reviewing the 2005 tapes notable changes from 1993 include:

1. The 2005 tapes indicate little change in the amount of visible coarse substrate relative to 1995. As in 1995, coarse substrate is often overlain by sediment cover, with material being completely or substantially embedded;

2. Epifauna occurs somewhat more frequently than in the 1995 survey, but less frequently than observed in the 1993 survey.

3. Observed areas of sediment indicate a predominance of fine material compared to the 1993 survey and little change from 1995. The direct observations in 2005 (from video and grab samples collected) confirm widespread presence of introduced sediments. The introduced sediment was observed in 2005 in both the disposal and reference areas.

4. Grab samples collected from both areas indicated a material comprised largely of clay/sand and fines for most samples, with clay being a significant portion of most samples. The surface layer of material observed in 2005 also had the characteristics consistent with observations from the 1995 video as indicated by:
    - *Ease of disturbance;*
    - *Slow settlement when disturbed;*
    - *Significant effect on visibility;*
    - *Dispersal over larger area when disturbed as compared to the 1993 video.*

The following is a list of observations from the 2005 survey grouped by tape section and tape time (TT) as indicated in the video file. The depth range is primarily within 20 to 40 m.

6.2.3.1 Section 1; TT (tape time) 0:00 – 27:13:07

This section of video is entirely within the disposal area; corresponding tape time is 0:00:23 to 27:13:07. The seabed surveyed has the following characteristics:

- Dominated by silt and fines over clay and cobble
- Occasional boulders and cobbles but limited occurrence
- Some bedrock
- Heavy sedimentation overlying rock
- Coralline algae present on some rocks
- Significant mounding of sediments in some areas
- Limited kelp and few sea stars observed
- Sculpin, scallop, and sea urchins present
- Evidence of *Beggiatoa sp.*
- Slime worm *(Myxicola infundibulum*) tubes evident in close-up at TT 12:57
- Culvert section protruding from seabed at TT 25:29 (top of frame, center)
- Mounded material observed indicating disposal location

6.2.3.2 Section 2; TT 27:30 – 43:20

This section of video (tape time 27:31:05 to 43:20:22) is mostly within the disposal area, with the exception of one section (approximate tape time 30:41 to 34:32) that briefly crosses the disposal/reference boundary in the area of reference area sample # 1 (north-west of the disposal area).

The seabed surveyed has the following characteristics:

- The bottom is comprised of variable material dominated by sediment/soft bottom
- Some cobbles and boulder noted and occasional bedrock
- Coralline algae observed on rock throughout the video segment
- Mounded material observed indicating disposal areas
- Large mound of disposal material with edge evident at 27:30 to 28:08
- Slime worms, sea urchins, sea stars, anemones, rock crab and kelp are present in limited numbers with sea stars occurring most frequently

6.2.3.3 Section 3; TT 43:22 – 1:04:20

This section of video is entirely within the disposal area; corresponding tape time is 43:22:22 to 1:04:20:16. The seabed surveyed has the following characteristics:

- Bottom is cobble boulder with layer of fines
- Patches of fines/soft bottom observed in open areas
- Coralline algae present on rocks
- Kelp (*Agarum* sp.) abundant is some areas, scarce to absent in others
- Slime worms evident from close views in soft bottom; numerous tubes evident
- Sea urchins present
- Possible edge of berm at TT 46:37 with apparent original seabed in foreground; placed till and rock in background
- Evidence of *Beggiatoa sp.* in open areas of soft bottom

6.2.3.4 Section 4; TT 1:04:21 – 1:08:00

This section of video is entirely within the disposal area; corresponding tape time is 1:01:22:16 to 1:08:00:29. The seabed surveyed has the following characteristics:

- Bottom is cobble/boulder with layer of fines
- Open areas of soft bottom
- Heavy deposition of sediment is evident
- Some kelp (*Agarum*)
- Few sea stars
- Occasional scallop
- Note: tire at TT 1:04:54
- Note: deposited boulder/till present – at TT 1:07:11 – possibly the edge of the berm noted in the 1993 survey

6.2.3.5 Section 5; TT 1:08:02 – 2:20:32

This section of video includes both disposal and reference areas.

Disposal Area - Section 5a; TT 1:08:02 – 1:12:06 and 1:35:22 – 2:00:00

- Substrate is variable – areas of boulder, till, rock or cobble - overlain by fines
- Large sections of bottom are predominantly soft material and fines
- Coralline algae present on some rocks
- Areas of sediment mounding, possibly from dredging or disposal activity
- Areas of rocky bottom with moderate to abundant kelp (Agarum) growth
- Slime worms evident from close views in soft bottom
- Scallop, sea urchin, sea star observed
- Evidence of benthic invertebrates – “holes” in soft sediments
- Note: nets at TT 1:35:00 and TT 1:54:17
- Note: construction debris at TT 1:42:39

Reference Area – Section 5b; TT 1:12:08 – 1:35:20 and 2:00:02 – 2:20:32

- Substrate is variable – areas of boulder, till, rock or cobble - covered by fines
- Large sections of bottom are predominantly soft material and fines
- Coralline algae observed on hard substrate
- Areas of sediment mounding observed, possibly from dredging or disposal activity
- Areas of rocky bottom with abundant kelp (Agarum) growth
- Sea stars, sea urchins, rock crab present

More detailed summaries of the 2005 video surveys are presented in the following tables (Tables 1, 2, and 3). Analysis results were summarized with respect to tape numbers, tape time, time of day, bottom type, and flora and fauna.

Table 1. Mosquito Cove video survey summary – Tapes 1 and 2, February 1, 2005.

~TT*	~TOD**	Bottom Type	Flora/Fauna
Tape #1			
0:00	3:35	Variable – areas of dense rock coverage, areas of boulder/bedrock; silt covered	Sea anemones; kelp (*Laminaria, Agarum*); sculpin; sea stars (*Crossaster*); coralline algae on rocks
6:00	3:42	Silt/rock/boulder	Kelp (*Laminaria, Agarum*)
7:45	3:43	Silt/fines, rock	Kelp (*Laminaria, Agarum*)
9:30	4:22	Rock; boulder/bedrock	Kelp (*Laminaria, Agarum*); sea stars (*Crossaster*); coralline algae on rocks; sea urchins
11:35	4:35	Silt/fines over rock/cobble	Some kelp (*Laminaria, Agarum*)
15:38	4:39	Silt/fines over rock/cobble	Some kelp (*Laminaria, Agarum*), sabellid polychaetes (slime worms)
22:30	4:45	Silt/fines; rock	Scallop; sea anemones; sea urchins; kelp (*Laminaria, Agarum*)
25:45	4:49	Boulder; fines, rock	Kelp (Laminaria, Agarum)
28:00	4:51	Predominantly flat/uniform bottom – fines/mud; areas of rock	Kelp (Laminaria, Agarum); sea stars (Crossaster, Asterias); coralline
Note*: at TOD 4:59 and 5:05 (TT 35:45 and 41) large ridge/wall – likely the edge of the berm; top of ridge – mounding of fines; sea anemones and coralline*			
46:00	5:10	Boulder; fines/mud; rock/cobble, covered by silt; ridge at TT 49:00 Note: areas of mounding	Slime worms; coralline algae; kelp; urchins; rock crab; sea stars
53:00	5:16	Flat/uniform; some rock/cobble, covered by fines/mud	None noted
57:00	5:20	Fines/mud; occasional boulder	Coralline (on boulders); sea stars
59:00	5:22	Fines/mud over rock/cobble	Seas stars; slime worms
Tape #2			
0:00	5:25	Edge of bedrock	Urchins
1:39	5:27	Mud/fines; TT at 2:05 shows edge of ridge; some mounding of sediments	Urchins abundant
2:40	5:29	Edge of ridge; bottom is mud/fines; sloped	Sea stars; kelp (*Agarum*)

* TT = Tape Time
** TOD = Time of Day

Table 2. Mosquito Cove video survey summary – Tape 3, February 2, 2005.

~TT*	~TOD**	Bottom Type	Flora/Fauna
0:00	2:30	Rocky bottom	Kelp (*Agarum*)
1:13	2:40	Flat/silt/fines; edge of wall or boulder at TT 1:30	Note noted
2:25	2:45	Silt/fines	None noted
4:20	2:50	Blast rock with coralline, few boulders, silt/fines between rocks	Kelp (*Agarum*) **Note:** *tire at TT 5:50, scoop at 5:52; level at 6:26, survey rods/bag at 6:38*
8:03	2:58	Flat, fairly uniform, mud/fines bottom; some rock/cobble	Scallop **Note:** *holes in sediment – benthic invertebrates*
10:40	3:05	Depth 32 m; bottom is flat, mud/fines, some rock/cobble; kelp	Scallop
13:15	3:12	Mud/fines, some small rock; several urchins	Kelp (*Agarum*)
16:16	3:19	Depth 32 m; blast rock/boulder/cobble; coralline on rock; rock areas adjacent to areas of flat mud/fine areas	Urchins; sea stars; kelp (*Agarum*)
18:35	3:29	Flat/uniform fines with some rock – smaller rock appears to be disposal (blast) rock, larger rock appears natural	Kelp (*Agarum*); sea stars **Note:** *net at 19:15 mins*
21:50	3:37	Depth 28 m; rock/boulder with fines/mud between rocks; some cobble; coralline on rocks	Abundant kelp (*Agarum*); slime worms
25:00	3:45	Depth 44 m; Flat/uniform, mud/fines; **Note:** *within reference area*	None noted
27:36	3:51	Relatively uniform, mud/fines	None noted
29:55	3:57	Depth 44m; mud/fines, few boulders and large rocks; some disposal/blast rock	Sea stars, rock crab; squid; several urchins
34:08	4:05	Depth 39m; relatively flat/uniform, mud/fines; boulder/bedrock with blast rock	Sea stars
37:00	4:12	Depth 43-47m; bottom starts at ridge/wall then moves to a flat, muddy bottom; wall/ridge at edge of location; top of ridge - relatively flat, with mud/fines	Sea stars and sea anemones on incline/ridge
44:00	4:24	Bottom is mud/silt over rock/bedrock; coralline on rocks	Sea stars; urchins

* TT = Tape Time
** TOD = Time of Day

Table 3. Mosquito Cove video survey summary – Tape 4, February 3, 2005.

~TT*	~TOD**	Bottom Type	Flora/Fauna
0:00	8:45	Rock/cobble/boulder with coralline - silt covered; fines/mud	Kelp (dense in areas); coralline; slime worms; urchins
10:45	9:02	Flat/uniform bottom; rock/fines; "organics"	Urchins; sea stars **Note:** *tubes/holes – presence of benthic invertebrates*
19:00	9:36	Flat/uniform bottom; fines	**Note:** *tubes/holes – presence of benthic invertebrates*
21:00	10:28	Silt/fines overlie cobble/boulder	None noted
22:00	10:31	Fines, some algae/detritus overlying sediments	None noted
23:00	10:34	Depth 25 m; some boulder; patches of cobble	None noted
24:00	10:39	Gravel/cobble, occasional boulder; silt – fine layer of sediment over unknown material	Kelp
24:38	10:43	Some algal cover; some boulder; open areas of fine material	Kelp; sea stars
25:00	10:47	Depth 31m; ridge from disposal area – boulder/till; some algal cover	Kelp
26:20	10:51	Ridge – slight slope; rock/silt	Kelp
27:45	10:57	Rock *Note: disposal area – likely inner edge of berm*	None noted
28:00	11:05	Fines/till	Kelp; sculpin
29:35	11:06	Depth 28m; silt over rock	None noted
30:00	11:10	Depth 28-30m; fines/rock	None noted
31:00	11:25	Blast rock; silt covered; some mounding of fines	Sea stars
33:00	11:32	Depth 36m; some mounding; rock/boulder/blast rock	None noted
37:00	11:40	Dense rock coverage; silt over rock; occasional small boulder	Kelp
39:00	11:43	Depth 32m; fines/rock	None noted
41:00	11:50	Depth 33m; bottom is flat, some boulder at fringes	None noted
42:00	11:56	Boulder, cobble/rock, silt covering; disposal material, large/rough material; mounding	None noted **Note:** *location is ~400 m from outer boundary of area designated as disposal*
46:00	12:12	Depth 42-45; some boulder; fines	None noted
47:00	12:17	Depth 27m; rocky material	Abundant kelp
50:00	12:21	Cobble/boulder **Note:** *possible tow-out corridor*	None noted
51:00	12:26	Depth 41m; rock/fines	None noted
53:00	12:39	Depth 37m; rock/fines	None noted
54:00	12:52	Depth 43m; rock/fines	None noted
56:00	12:58	Depth 38-43m; bottom reasonably uniform – some variation	None noted
57:00	1:07	Depth 43m; boulder at fringe	None noted

* TT = Tape Time
** TOD = Time of Day

6.3 SEDIMENT GRAB SAMPLES

Benthic invertebrate samples were collected at ten locations in both the disposal and reference areas (20 in total) (Table 4, Figure 3). Particle size samples were collected from six locations in both the disposal and reference areas (12 in total) (Table 4, Figure 3).

6.3.1 Benthic Invertebrates

Benthic invertebrate communities can be analysed and characterized in many different ways. The most commonly used method is the analysis of community diversity. Diversity is a measure of community complexity that can be increased or decreased by various physical, chemical, and biological factors. For this study, Shannon-Weiner Diversity Indices (H'), evenness (J'), abundances (total individuals), and richness (total species) were calculated for each sampling station (Table 5, Appendix 2).

The most common taxons encountered in both the disposal and reference areas were bivalves and polychaete worms. In terms of site-specific abundance, bivalves accounted for 33.2% and 41.1% of individuals at the disposal and reference sites respectively; polychaete worms accounted for 36.2% and 26.8% of individuals at the disposal and reference sites respectively. The next most common taxon encountered at both sites was the Foraminiferida, which accounted for 16.8% and 19.7% of individuals at the disposal and reference sites respectively.

Invertebrate community indices were higher at the reference site than at the disposal site, although the differences were not always statistically significant (ANOVA, $p \leq 0.05$) (Table 5, Appendix 2).

Overall site abundances (total individuals) were higher at the reference site (mean = 50.8) than at the disposal site of (mean = 36.4) but were not statistically significantly different (Table 5, Appendix 2).

Species richness (total species) at the reference site was significantly higher (mean = 11.9, $p \leq 0.05$) than at the disposal site (mean = 8.1) (Table 5, Appendix 2).

The Shannon-Weiner Diversity Index (H') at the reference site was significantly higher (mean = 2.08, $p \leq 0.05$) than at the disposal site (mean = 1.73) (Table 5, Appendix 2).

The evenness index (J') was slightly higher at the reference site (mean = 0.63) than at the disposal site (mean = 0.57), although the difference was not statistically significant. ($p \leq 0.05$) (Table 5, Appendix 2).

The results of the February 2005 invertebrate sampling program at Mosquito Cove indicate a more robust and rich invertebrate community at the reference site than at the disposal site. The numbers and associated statistical analysis reveal that the reference site had higher values for abundance (total individuals), richness (total species), the Shannon-Weiner Diversity Index, and evenness. Given the lack of baseline benthic invertebrate data from either the disposal or reference areas prior to berm removal there is a level of uncertainty as to whether the observed differences are related to anthropogenic influences or are reflective of natural variability due to habitat related features such as water depth, temperature, wave action, salinity, substrate etc.

Table 4. Mosquito Cove sediment grab sample locations for benthic invertebrate and particle size analysis, Jan-Feb 2005.

Benthic Invertebrates			Sediment					
Date	**Label**	**Waypoint, Time**	**Date**	**Label**	**Waypoint, Time**	**Latitude**	**Longitude**	**Depth (m)**
02/02/2005	**Disposal 1**	wp-13, 14:59:34	02/02/2005	**Disposal 1**	wp-13, 14:59:34	47.8097031	-53.8829034	34
02/02/2005	**Disposal 2**	wp-33, 15:09:20	02/02/2005	**Disposal 2**	wp-33, 15:09:20	47.8090567	-53.8825817	30
02/02/2005	**Disposal 3**	wp-19, 15:22:10				47.8081964	-53.8826003	28
02/02/2005	**Disposal 4**	wp-20, 15:30:44				47.808236	-53.8813166	27
02/02/2005	**Disposal 5**	wp-17, 15:42:10	02/02/2005	**Disposal 5**	wp-17, 15:42:10	47.8089803	-53.8813603	34
02/02/2005	**Disposal 6**	wp-14, 15:53:10	02/02/2005	**Disposal 6**	wp-14, 15:53:59	47.8095689	-53.881477	26
02/02/2005	**Disposal 7**	wp-15, 16:01:30				47.8097157	-53.8794623	32
02/02/2005	**Disposal 8**	wp-16, 16:19:23				47.8091109	-53.8797654	31
03/02/2005	**Disposal 9**	wp-21, 09:59:00	03/02/2005	**Disposal 9**	wp-21, 09:59:00	47.8095167	-53.8806747	32
03/02/2005	**Disposal 10**	wp-22, 10:47:00	03/02/2005	**Disposal 10**	wp-22, 10:50:00	47.8093506	-53.8793732	33

Benthic Invertebrates			Sediment					
Date	**Label**	**Waypoint, Time**	**Date**	**Label**	**Waypoint, Time**	**Latitude**	**Longitude**	**Depth (m)**
03/02/2005	**Reference 1**	wp-23, 11:19:00				47.8097615	-53.8770437	42
03/02/2005	**Reference 2**	wp-31, 11:26:00	03/02/2005	**Reference 1**	wp-31, 11:26:00	47.8093831	-53.8765027	21
03/02/2005	**Reference 3**	wp-26, 11:48:48	03/02/2005	**Reference 2**	wp-26, 11:48:48	47.8087866	-53.8766416	23
03/02/2005	**Reference 4**	wp-27, 12:05:00	03/02/2005	**Reference 3**	wp-27, 12:05:00	47.8078668	-53.8762709	35
03/02/2005	**Reference 5**	wp-32, 12:14:20	03/02/2005	**Reference 4**	wp-32, 12:14:20	47.8084029	-53.8760748	42
03/02/2005	**Reference 6**	wp-25, 12:25:22	03/02/2005	**Reference 5**	wp-25, 12:25:22	47.8089751	-53.8751833	44
03/02/2005	**Reference 7**	wp-39, 12:38:00				47.8083137	-53.8755934	32
03/02/2005	**Reference 8**	wp-29, 13:01:00	03/02/2005	**Reference 6**	wp-29, 13:01:00	47.8080147	-53.8746306	37
03/02/2005	**Reference 9**	wp-28, 13:18:40				47.8091559	-53.874488	42
03/02/2005	**Reference 10**	wp-30, 13:25:30				47.8085864	-53.8733825	46

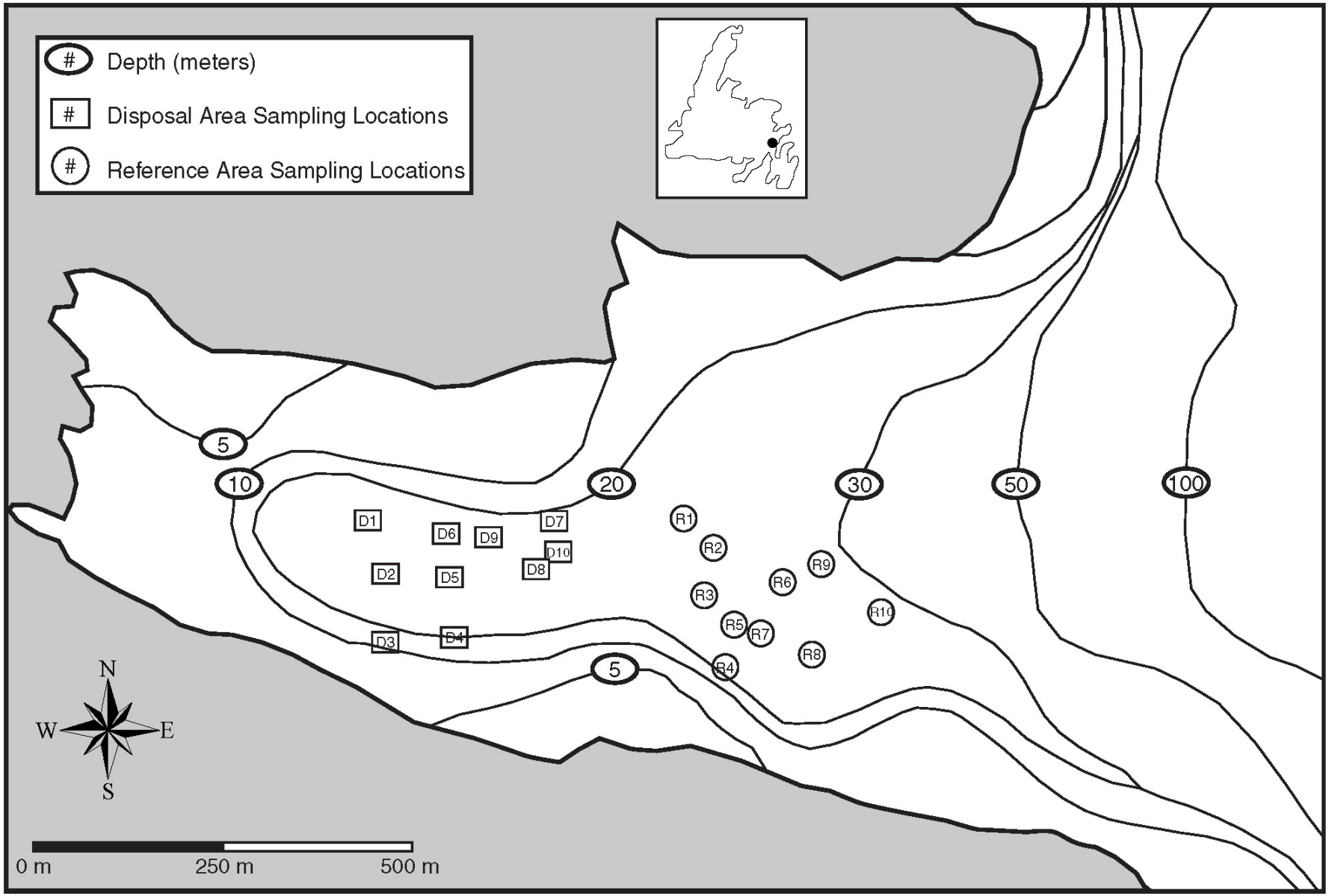


Figure 3. Mosquito Cove disposal and reference area benthic grab sampling locations, Jan-Feb 2005.

Table 5. Mosquito Cove benthic invertebrate community summary, disposal and reference areas, Jan-Feb 2005.

Station	Abundance (Total Individuals)	Richness (Total Species)	Shannon-Weiner Diversity Index (H')	Eveness (J')
Disp-1	58	9	1.60	0.53
Disp-2	19	5	1.30	0.44
Disp-3	30	8	1.80	0.59
Disp-4	35	9	1.90	0.61
Disp-5	23	10	2.03	0.67
Disp-6	44	9	1.92	0.63
Disp-7	20	5	1.36	0.45
Disp-8	12	8	1.98	0.65
Disp-9	14	5	1.30	0.43
Disp-10	109	13	2.08	0.68
Means	**36.4**	**8.1**	**1.73**	**0.57**
Ref-1	45	11	1.83	0.56
Ref-2	62	17	2.42	0.74
Ref-3	62	11	1.96	0.59
Ref-4	55	11	1.96	0.59
Ref-5	92	16	2.26	0.69
Ref-6	13	8	1.93	0.58
Ref-7	33	13	2.26	0.68
Ref-8	91	12	2.15	0.65
Ref-9	15	7	1.78	0.54
Ref-10	40	13	2.21	0.67
Means	**50.8**	**11.9**	**2.08**	**0.63**
ANOVA ($p < 0.05$)	**0.270609**	**0.00793***	**0.008887***	**0.119656**

* = disposal and reference areas statistically significant difference

6.3.2 Sediment Particle Size Analysis

Particle size analysis of samples from the disposal and reference areas at Mosquito Cove indicate that sediment profiles for both areas were similar (Table 6, Appendix 3). The predominant particle size classification was sand and fines that accounted for 83% and 90% of sample composition from the disposal and reference areas respectively (Table 6). Gravel was the next most common particle size at 13.2% and 10.1% in the disposal and reference areas respectively. Larger sized particles in the pebble and cobble range were encountered only at disposal area station #5 accounting for 7.9% and 15.0% of the sample and 1.3% and 2.5% of the ten combined disposal area samples.

Prior to construction and removal of the berm in Mosquito Cove, sediment grab samples were taken from the general vicinity (coordinates not provided) of the disposal/reference area in October of 1989 (Newfoundland Geosciences Limited 1990). Particle size analysis of five samples collected in depths ranging from 20 to 47 m were dominated by gravels with trace amounts of natural silt. Attempts to sample a number of areas were hampered by bedrock outcroppings. This led to the overall conclusion that a shallow layer of gravel overlaying a bedrock base characterized the Mosquito Cove substrate.

Results of the 2005 particle size analysis indicate that a substantial layer of sand/fines have been deposited within Mosquito Cove as a result of berm construction and removal. Although sediment particle size analysis was not available post berm removal (after 1994), comparison of benthic video survey collected in 1995 (after berm removal) and those collected in 2005 indicate that the disposal and reference areas were dominated by comparable levels of anthropogenic sand and fine material. Benthic survey video collected in 1993 (prior to berm removal) indicated a coarser substrate dominated by gravels, cobble and boulders interspersed with bedrock outcrops.

Table 6. Mosquito Cove particle size analysis summary, disposal and reference areas, Jan-Feb 2005.

		Grab Sample													
		Disp 1.0 WP-13 (% Pass)	Disp 2.0 WP-33 (% Pass)	Disp 3.0 WP-17 (% Pass)	Disp 4.0 WP-14 (% Pass)	Disp 5.0 WP-21 (% Pass)	Disp 6.0 WP-22 (% Pass)	**Disposal Means**	Ref 1.0 WP-31 (% Pass)	Ref 2.0 WP-26 (% Pass)	Ref 3.0 WP-27 (% Pass)	Ref 4.0 WP-32 (% Pass)	Ref 5.0 WP-25 (% Pass)	Ref 6.0 WP-29 (% Pass)	**Reference Means**
Sieve Size (mm)															
< 150								**0.0**							**0.0**
>100								**0.0**							**0.0**
> 75						100.0		**16.7**							**0.0**
> 50.0	Cobble					85.0		**14.2**							**0.0**
> 25.4	Pebble					77.1		**12.9**							**0.0**
> 19.0		100.0	100.0	100.0	100.0	69.0		**78.2**	100.0	100.0	100.0	100.0	100.0	100.0	**100.0**
> 12.5		100.0	98.8	98.8	100.0	63.4	100.0	**93.5**	100.0	100.0	100.0	100.0	98.1	93.9	**98.7**
> 4.76	Gravel	98.5	98.0	91.0	98.1	44.6	97.7	**88.0**	94.9	98.8	97.9	99.6	93.8	91.0	**96.0**
> 2.0		95.6	96.2	81.8	95.2	34.7	94.4	**83.0**	73.4	96.7	94.5	96.1	90.1	88.9	**90.0**
> 1.18		93.7	94.5	76.3	93.0	30.0	91.5	**79.8**	66.7	94.8	91.8	92.7	88.1	87.4	**86.9**
> 0.425		91.4	91.8	67.7	87.3	23.9	82.3	**74.1**	60.6	90.6	83.4	81.8	84.1	84.2	**80.8**
> 0.3		84.7	90.7	63.5	83.1	21.1	72.9	**69.3**	58.7	87.0	75.9	72.7	82.0	82.4	**76.5**
> 0.15		71.4	87.7	55.5	73.4	17.3	58.9	**60.7**	54.1	80.2	59.4	56.9	76.7	77.2	**67.4**
> 0.075	Sand/Fines	58.9	83.6	46.7	60.2	14.3	46.1	**51.6**	46.4	74.3	43.8	43.7	72.1	69.6	**58.3**
	% Sand/Fines	95.6	96.2	81.8	95.2	34.7	94.4	**83.0**	73.4	96.7	94.5	96.1	90.1	88.9	**90.0**
	% Gravel	4.4	3.8	18.2	4.8	42.4	5.6	**13.2**	26.6	3.3	5.5	3.9	9.9	11.1	**10.1**
	% Pebble					7.9		**1.3**							**0.0**
	% Cobble					15.0		**2.5**							**0.0**

7.0 CONCLUSION

The overall conclusion of the 2005 Mosquito Cove dredged disposal site investigation is a rejection of the impact hypothesis:

- *In the 10 years following disposal activities the benthic community at the disposal site has undergone a complete recovery*.

While there is evidence of substantial benthic recovery in the disposal area, epifaunal observations (video surveys), benthic invertebrate analysis, and particle size analysis indicate an area that is still impacted by deposition of materials from berm removal and disposal or other site construction related activities.

Video surveys indicated a large volume of fine material was deposited in the disposal area as a result of berm removal in 1994. This deposition of material effectively shifted the substrate characteristics of the area from a coarse substrate dominated by gravel/cobble/boulder (1993 video survey) to a substrate dominated by sand/fine material (1995 and 2005 video surveys). There was no appreciable change in substrate characteristics from 1995 to 2005.

Video surveys revealed that there was some deposition of fine materials within the selected reference area as well. This is most likely due to drift of fine materials outside of the berm disposal area during the berm disposal process (i.e. fine material drifted over the underwater containment berm that demarcated the disposal/reference area boundary) or other activities at the construction site over the life of the project that may have resulted in deposition of fine material to the area. Video evaluations indicated that deposition of fines was more sporadic and to a much lesser extent in the reference area than in the disposal area. This impact within the reference area was noted during the field surveys, however the increasing depths (50 to 100 m) and exposure immediately outside of the selected reference (towards Bull Arm) area precluding changing its location. A field decision was made that the potential effects of the observed fine material deposition within the reference area was outweighed by the potential effects upon the epifauna and benthic invertebrates of shifting the reference area to a deeper more exposed location.

Video surveys indicated a substantial reduction in epifaunal species presence and distributions from 1993 (pre-berm removal) to1995 (post berm removal). 2005 video surveys indicated an increase in epifaunal species presence and distributions from 1995 (post berm removal) to 2005 (10 years post berm removal), however distributions were still not as high as those observed previously in 1993 (pre berm removal).

Benthic invertebrate community comparisons between the disposal and reference areas in 2005 indicate a more robust and rich invertebrate community at the reference site than at the disposal site. The numbers and associated statistical analysis reveal that the reference site had higher values for abundance (total individuals), richness (total species), the Shannon-Weiner Diversity Index, and evenness.

Based upon the video surveys, invertebrate community structure, and sediment particle size analysis conducted in Mosquito Cove in 2005, and comparisons with previous work conducted in Mosquito Cove (1993 pre-berm removal, 1995 post-berm removal) it is concluded that the benthic community at the disposal site has undergone considerable recovery since 1994 when the berm was removed. However, the data indicates the benthic community of the Mosquito Cove disposal area is not as rich and diverse as it was prior to berm removal (1993)

Appendix 1

Summary of Mosquito Cove 1993 HMDC Video Transect Survey.

Summary of Mosquito Cove 1995 HMDC Video Transect Survey

SUMMARY OF HMDC VIDEO TRANSECT SURVEY

Mosquito Cove 1993

HMDC Environmental Survey – Pre-Construction December 1993
Tapes provided courtesy of HMDC- see PDF file-***HMDC Release Conditions READ ME***
Capture Files: MC93T1a/ MC93T1b
Tape Sections Time of Day (TOD): 08:41 – 09:45 am; TOD: 10:32 – 11:39 am

Habitat Notes:

- Rock/cobble bottom with coralline algae over some fines, some boulder, abundant large algal growth (*Agarum*); depth ~ 20 - 30 m; anemones abundant in areas; sea urchins and sea starts present; toad crab; Note: sediment @ ~09:11:00
- Areas of fines/soft bottom; areas of rock/cobble bottom, some boulder; sea anemones, sea stars, sea urchins; depth ~ 10 - 20 m;
  Note: section of video in very shallow water (0-2m) @ 11:16 am;
- **Pictures and Video Clips:** MC93-1 - MC93-14

HMDC Environmental Survey – Pre-Construction 1993
IOD files: MC93T2a/ MC93T2b; TOD: 12:46 – 14:34 pm
Habitat Notes:

- Predominantly rock bottom covered in fines, moving to rock/cobble bottom; areas of boulder; sea anemones, sea stars, sea urchins, toad crab; some algae (*Agarum*) depth > 28 m
- Depth ~ 10 -20 m after 1:33 pm; bottom changes to rock/cobble bottom @ shallower depth with coralline algae over some fines, some boulder, abundant large algal growth (*Agarum*), anemones, urchins, sea stars
- Rock/cobble bottom with coralline algae over some fines, some boulder, abundant algal growth (*Agarum*), slightly smaller plants than other areas
- **Pictures and Video Clips:** MC93-15 – MC93-20

SUMMARY OF HMDC VIDEO TRANSECT SURVEY
Mosquito Cove 1995

HMDC Environmental Survey - GMC Post Berm Removal

South Line Survey Jan. 9 & 10, 1995, Dives 1 & 2
From clip: Mosquito Cove T1 A 1:02:39
Habitat Notes: *depth range: ~ 13 m - ~ 30 m; bottom type is mud with some rock to 15 m; from 15 m – 30 m bottom is predominantly rock and bedrock.*

HMDC Environmental Survey - GMC Post Berm Removal

North Line Survey Jan. 10, 1995, Dive 3, 27:31 mins (2)
From clips: Mosquito Cove T1 A 1:02:39 and Mosquito Cove T1 B 59:35
Habitat Notes: depth range: ~ 10 m - 15 m; bottom type is boulder/bedrock, interspersed with mud/rock.

HMDC Environmental Survey - GMC Post Berm Removal

Roving Station Jan. 10, 1995, Dive 4, 45:00 mins (3)
From clip: Mosquito Cove T1 B 59:35
Habitat Notes: depth range: ~ 98 m – 108m; predominantly mud and fines over rock, with some boulder.

HMDC Environmental Survey - GMC Post Berm Removal

LGL Grab Site Jan. 10, 1995, Dive 5, 22:00 mins (4)
From clip: Mosquito Cove T1 C (starts @ ~ 3.5 mins)
Habitat Notes: depth range: ~ 110 – 130m; predominantly mud and fines over rock, with some boulder.

HMDC Environmental Survey - GMC Post Berm Removal (5)

Dump Zone Survey Rock Berm Jan.10, 1995 Dives 6-12, 1995, 1: 24:00 mins
From clip: Mosquito Cove T2 A
Habitat Notes: depth range: <40 m; predominantly mud/fines over rock/boulder; culverts, lumber, scrap, etc in ~ 24 m depth @ ~ 25 mins into clip

NOTE: ***Pictures MC95-1 to MC95-10 are from HMDC Tape 1; Pictures MC95-10 to MC95-19 are from HMDC Tape***

Appendix 2

Mosquito Cove Disposal and Reference Areas

Benthic Invertebrate Community Raw Data

January-February 2005

Disposal Area Invertebrate Data

Station	Disp-1	Disp-2	Disp-3	Disp-4	Disp-5	Disp-6	Disp-7	Disp-8	Disp-9	Disp-10	
Date	2/2/05	2/2/05	2/2/05	2/2/05	2/2/05	2/2/05	2/2/05	2/2/05	2/3/05	2/3/05	
Taxa											**Means**
Nematoda				4	2	7			1	5	**1.9**
Total	**0**	**0**	**0**	**4**	**2**	**7**	**0**	**0**	**1**	**5**	**1.9**
Mollusca: Bivalvia											
Tellinidae	17	7	6	8	4	11	7	3	5	8	**7.6**
Cardiidae	1		2	1	1	2	4	1		14	**2.6**
Pectinidae										1	**0.1**
Mya arenaria	2	1			1		1			5	**1**
Crenella glandula				6							**0.6**
Mytilus edulis			1			1					**0.2**
Total	**20**	**8**	**9**	**15**	**6**	**14**	**12**	**4**	**5**	**28**	**12.1**
Mollusca: Gastropoda											
Pyramidellidae					1						**0.1**
Calliostoma occidentale								1			**0.1**
Nassarius spp.	1							1			**0.2**
Total	**1**	**0**	**0**	**0**	**1**	**0**	**0**	**2**	**0**	**0**	**0.4**
Annelida: Polychaeta											
Aphroditacea	6	1	9	10	3	6			1	1	**3.7**
Terebellidae				1		2		2		1	**0.6**
Pectinaria gouldii	23	7	7	3	7	10	7	2	6	10	**8.2**
Goniada maculata	2			1			1	1		2	**0.7**
Total	**31**	**8**	**16**	**15**	**10**	**18**	**8**	**5**	**7**	**14**	**13.2**
Foraminiferida											
Nonion spp.	5	3	2		2	4				32	**4.8**
Quinqueloculina spp.	1		2		1	1				6	**1.1**
Triloculina spp.										2	**0.2**
Total	**6**	**3**	**4**	**0**	**3**	**5**	**0**	**0**	**0**	**40**	**6.1**
Crustacean											
Diastylis spp.			1					1		22	**2.4**
Total	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**1**		**22**	**2.4**
Echinodermata											
Ophiurina					1						**0.1**
Strongylocentrotus droebachiensis				1							**0.1**
Asterias spp.									1		**0.1**
Total	**0**	**0**	**0**	**1**	**1**	**0**	**0**	**0**	**1**	**0**	**0.3**
Abundance (Total Individuals)	***58***	***19***	***30***	***35***	***23***	***44***	***20***	***12***	***14***	***109***	***36.4***
Richness (Total Species)	***9***	***5***	***8***	***9***	***10***	***9***	***5***	***8***	***5***	***13***	***8.1***
Shannon-Weiner Diversity Index	***1.6***	***1.3***	***1.8***	***1.9***	***2.03***	***1.92***	***1.36***	***1.98***	***1.3***	***2.08***	***1.727***
Evenness	***0.53***	***0.44***	***0.59***	***0.61***	***0.67***	***0.63***	***0.45***	***0.65***	***0.43***	***0.68***	***0.568***

Reference Area Invertebrate Data

Station	Ref-1	Ref-2	Ref-3	Ref-4	Ref-5	Ref-6	Ref-7	Ref-8	Ref-9	Ref-10	
Date	2/3/05	2/3/05	2/3/05	2/3/05	2/3/05	2/3/05	2/3/05	2/3/05	2/3/05	2/3/05	
Taxa											**Means**
Nematoda	2	10		5	1	1		3	1		**2.3**
Total	**2**	**10**	**0**	**5**	**1**	**1**	**0**	**3**	**1**	**0**	**2.3**
Nemertea	1										**0.1**
Total	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0.1**
Mollusca: Bivalvia											
Tellinidae	20	6	9	11	8	4	8	16	1	7	**9**
Cardiidae	2	1	3		9	2	3	24	5	5	**5.4**
Yoldia spp.					2						**0.2**
Mya arenaria	3	1	4		6		4	10	2	4	**3.4**
Crenella glandula		1			8					4	**1.3**
Astarte undata				6	5						**1.1**
Hiatella arctica					1			3			**0.4**
Mytilus edulis									1		**0.1**
Total	**25**	**9**	**16**	**17**	**39**	**6**	**15**	**53**	**9**	**20**	**20.9**
Mollusca: Gastropoda											
Pyramidellidae				2			1			1	**0.4**
Calliostoma occidentale	1			2	1		1				**0.5**
Buccinum undatum							1				**0.1**
Nassarius spp.			2				1	5		1	**0.9**
Total	**1**	**0**	**2**	**4**	**1**	**0**	**4**	**5**		**2**	**1.9**
Annelida: Polychaeta											
Aphroditacea		5	1	17	19		1			1	**4.4**
Terebellidae		1	2								**0.3**
Arabellidae		1	1	1	1		1	7	2	1	**1.5**
Pectinaria gouldii	6	10	11	8	22	2	3	3			**6.5**
Goniada maculata	1	2			1	1		2		1	**0.8**
Phyllodoce spp.		1									**0.1**
Total	**7**	**20**	**15**	**26**	**43**	**3**	**5**	**12**	**2**	**3**	**13.6**
Foraminiferida											
Nonion spp.	6	6	22	1	6	1	6	13	3	10	**7.4**
Quinqueloculina spp.	2	1	3		1		1	3		3	**1.4**
Triloculina spp.	1	4	4	1		1				1	**1.2**
Total	**9**	**11**	**29**	**2**	**7**	**2**	**7**	**16**	**3**	**14**	**10**
Crustacean											
Tanaidae		1									**0.1**
Diastylis spp.		10		1	1	1	2			1	**1.6**
Total	**0**	**11**	**0**	**1**	**1**	**1**	**2**	**0**	**0**	**1**	**1.7**
Echinodermata											
Ophiurina								2			**0.2**
Echinarachnius parma		1									**0.1**
Total	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**2**	**0**	**0**	**0.3**
Abundance (Total Individuals)	***45***	***62***	***62***	***55***	***92***	***13***	***33***	***91***	***15***	***40***	***50.8***
Richness (Total Species)	***11***	***17***	***11***	***11***	***16***	***8***	***13***	***12***	***7***	***13***	***11.9***
Shannon-Weiner Diversity Index	***1.83***	***2.42***	***1.96***	***1.96***	***2.26***	***1.93***	***2.26***	***2.15***	***1.78***	***2.21***	***2.076***
Evenness	***0.56***	***0.74***	***0.59***	***0.59***	***0.69***	***0.58***	***0.68***	***0.65***	***0.54***	***0.67***	***0.629***

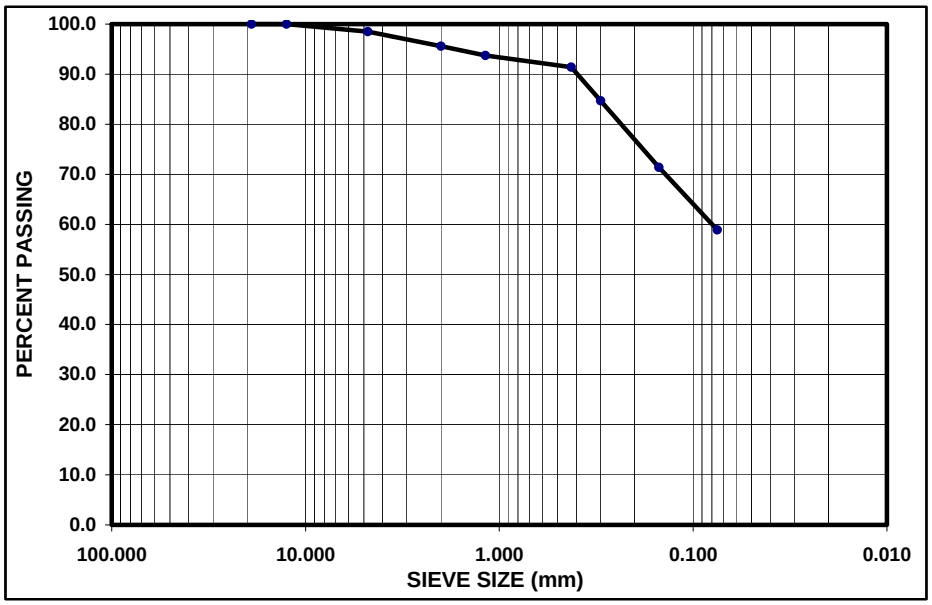
Appendix 3

Mosquito Cove Sediment Particle Size Analysis

Disposal and Reference Areas

January-February 2005

Project No:	TF 4107658	**Sample No.:**	#1
Project:	Mosquito Cove - Benthic	**Sample Type:**	Marine Sediment
Client:	PWGSC/EC	**Sample Depth:**	N/A
Sampled By:	A. Peach of AMEC	**Date Sampled:**	02-Feb-05
Sample Location:	Disposal #1	**Date Tested:**	08-Feb-05



SIEVE SIZE (mm)	PERCENT PASSING	GRADING LIMITS	
19.000	100.0		
12.500	100.0		
4.760	98.5		
2.000	95.6		
1.180	93.7		
0.425	91.4		
0.300	84.7		
0.150	71.4		
0.075	58.9		

Comments: Dry Sample Weight of 1504.7 g.
Water used to rinse fines from sample bag.

Reporting of these test results constitutes a testing service only.
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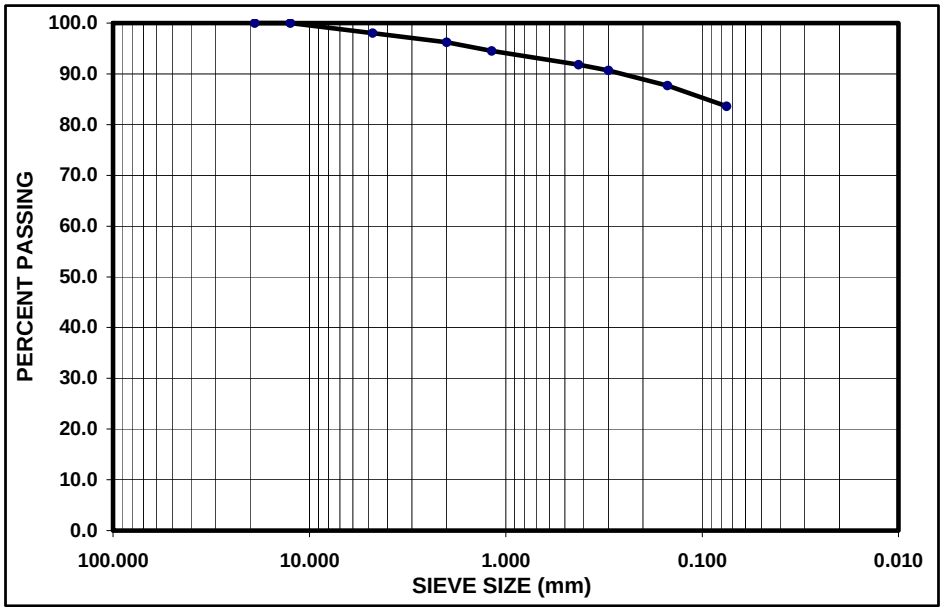
Project No:	TF 4107658	**Sample No.:**	#2
Project:	Mosquito Cove - Benthic	**Sample Type:**	Marine Sediment
Client:	PWGSC/EC	**Sample Depth:**	N/A
Sampled By:	A. Peach of AMEC	**Date Sampled:**	02-Feb-05
Sample Location:	Disposal #2	**Date Tested:**	04-Feb-05



SIEVE SIZE (mm)	PERCENT PASSING	GRADING LIMITS	
19.000	100.0		
12.500	100.0		
4.760	98.0		
2.000	96.2		
1.180	94.5		
0.425	91.8		
0.300	90.7		
0.150	87.7		
0.075	83.6		

Comments: Dry Sample Weight of 1300.2 g.
Water used to rinse fines from sample bag.

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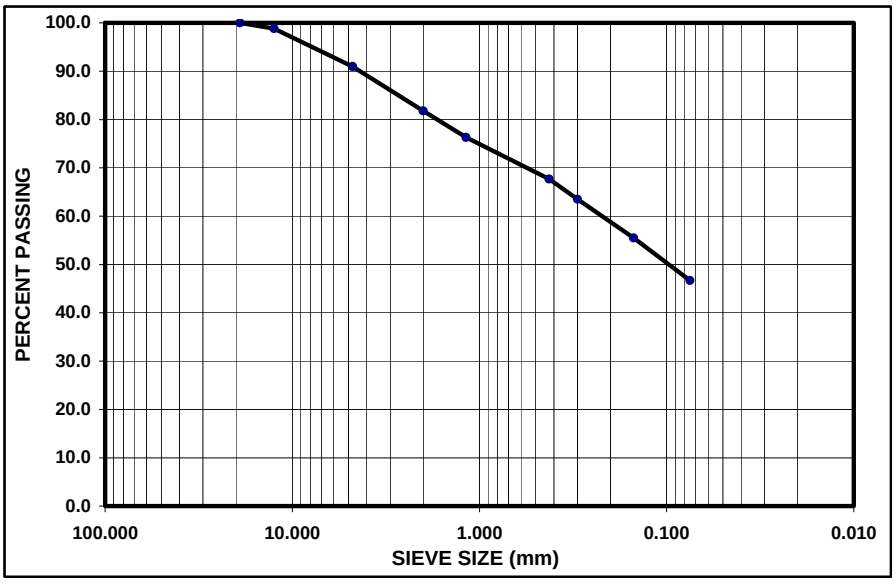
Project No:	TF 4107658	**Sample No.:**	#3
Project:	Mosquito Cove - Benthic	**Sample Type:**	Marine Sediment
Client:	PWGSC/EC	**Sample Depth:**	N/A
Sampled By:	A. Peach of AMEC	**Date Sampled:**	02-Feb-05
Sample Location:	Disposal #3	**Date Tested:**	08-Feb-05



SIEVE SIZE (mm)	PERCENT PASSING	GRADING LIMITS	
19.000	100.0		
12.500	98.8		
4.760	91.0		
2.000	81.8		
1.180	76.3		
0.425	67.7		
0.300	63.5		
0.150	55.5		
0.075	46.7		

Comments: Dry Sample Weight of 1252.8 g.
Water used to rinse fines from sample bag.

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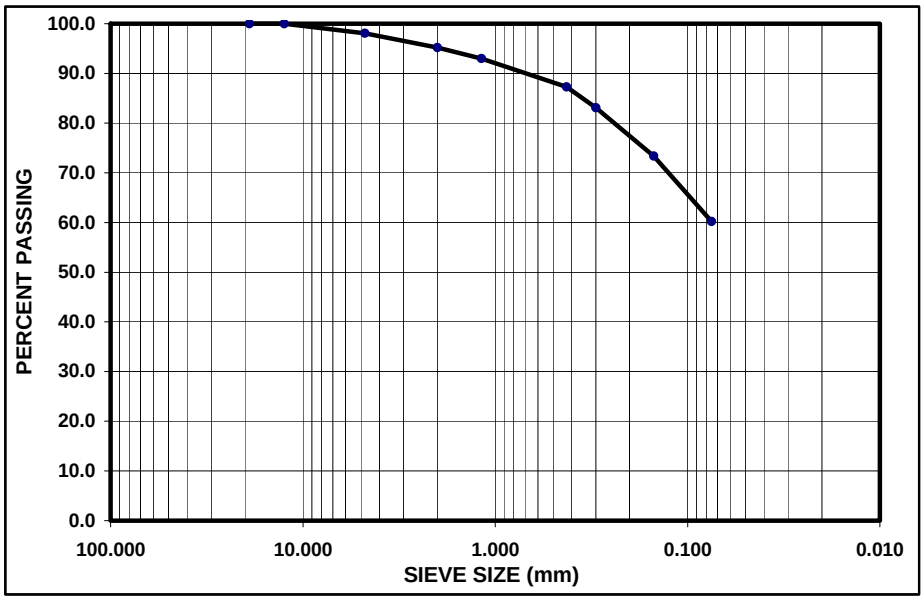
GRADATION ANALYSIS REPORT

Project No:	TF 4107658	**Sample No.:**	#4
Project:	Mosquito Cove - Benthic	**Sample Type:**	Marine Sediment
Client:	PWGSC/EC	**Sample Depth:**	N/A
Sampled By:	A. Peach of AMEC	**Date Sampled:**	02-Feb-05
Sample Location:	Disposal #4	**Date Tested:**	08-Feb-05



SIEVE SIZE (mm)	PERCENT PASSING	GRADING LIMITS	
19.000	100.0		
12.500	100.0		
4.760	98.1		
2.000	95.2		
1.180	93.0		
0.425	87.3		
0.300	83.1		
0.150	73.4		
0.075	60.2		

Comments: Dry Sample Weight of 1334.3 g.
Water used to rinse fines from sample bag.

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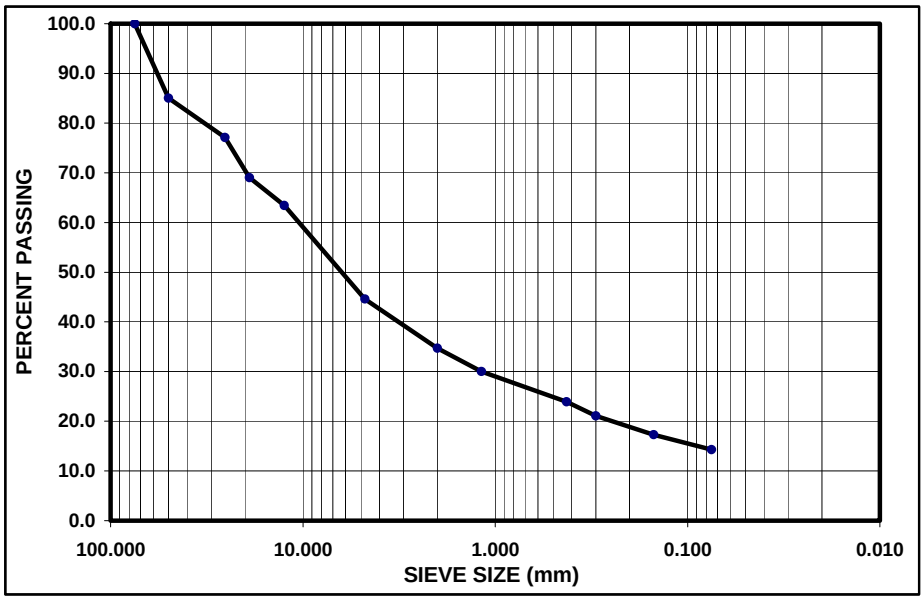
GRADATION ANALYSIS REPORT

Project No:	TF 4107658	**Sample No.:**	#5
Project:	Mosquito Cove - Benthic	**Sample Type:**	Marine Sediment
Client:	PWGSC/EC	**Sample Depth:**	N/A
Sampled By:	A. Peach of AMEC	**Date Sampled:**	02-Feb-05
Sample Location:	Disposal #5	**Date Tested:**	04-Feb-05



SIEVE SIZE (mm)	PERCENT PASSING	GRADING LIMITS	
75.000	100.0		
50.000	85.0		
25.400	77.1		
19.000	69.0		
12.500	63.4		
4.760	44.6		
2.000	34.7		
1.180	30.0		
0.425	23.9		
0.300	21.1		
0.150	17.3		
0.075	14.3		

Comments: Dry Sample Weight of 2172.9 g. Total sample used for analysis.
Water used to rinse fines from sample bag.

Reporting of these test results constitutes a testing service only.
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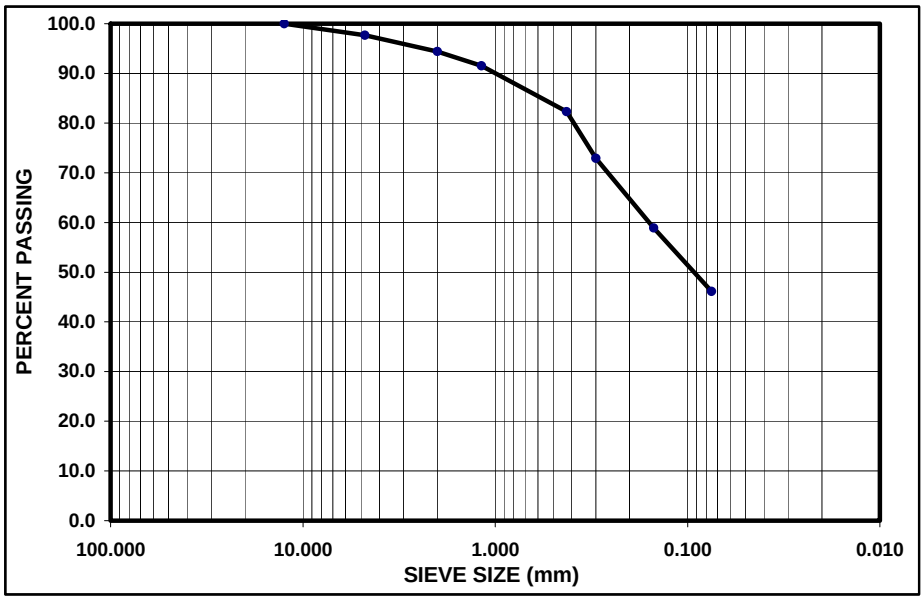
GRADATION ANALYSIS REPORT

Project No:	TF 4107658	**Sample No.:**	#6
Project:	Mosquito Cove - Benthic	**Sample Type:**	Marine Sediment
Client:	PWGSC/EC	**Sample Depth:**	N/A
Sampled By:	A. Peach of AMEC	**Date Sampled:**	02-Feb-05
Sample Location:	Disposal #6	**Date Tested:**	04-Feb-05



SIEVE SIZE (mm)	PERCENT PASSING	GRADING LIMITS	
12.500	100.0		
4.760	97.7		
2.000	94.4		
1.180	91.5		
0.425	82.3		
0.300	72.9		
0.150	58.9		
0.075	46.1		

Comments: Dry Sample Weight of 946.5 g.
Water used to rinse fines from sample bag.

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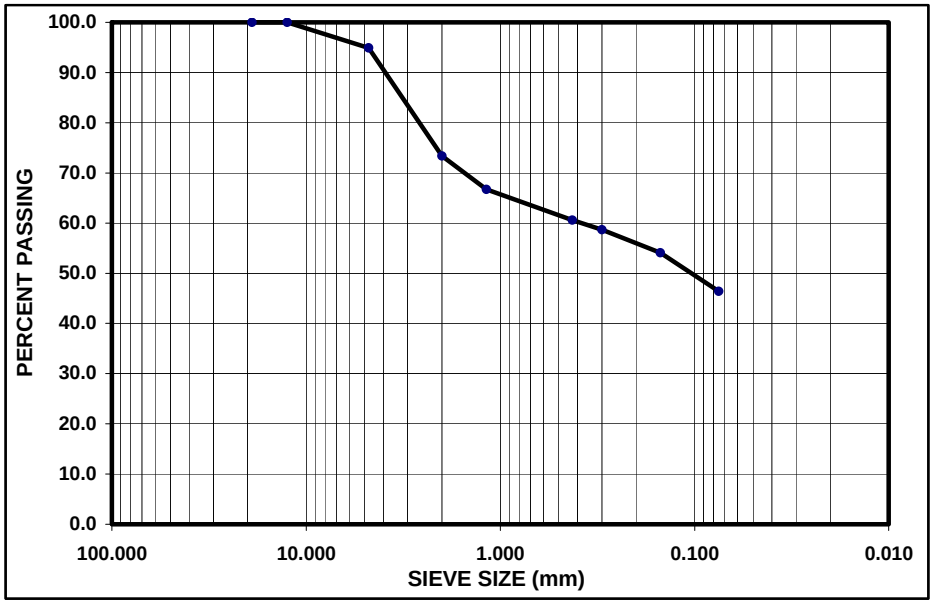
GRADATION ANALYSIS REPORT

Project No:	TF 4107658	**Sample No.:**	#7
Project:	Mosquito Cove - Benthic	**Sample Type:**	Marine Sediment
Client:	PWGSC/EC	**Sample Depth:**	N/A
Sampled By:	A. Peach of AMEC	**Date Sampled:**	02-Feb-05
Sample Location:	Reference #1	**Date Tested:**	08-Feb-05



SIEVE SIZE (mm)	PERCENT PASSING	GRADING LIMITS	
19.000	100.0		
12.500	100.0		
4.760	94.9		
2.000	73.4		
1.180	66.7		
0.425	60.6		
0.300	58.7		
0.150	54.1		
0.075	46.4		

Comments: Dry Sample Weight of 1217.8 g.
Water used to rinse fines from sample bag.

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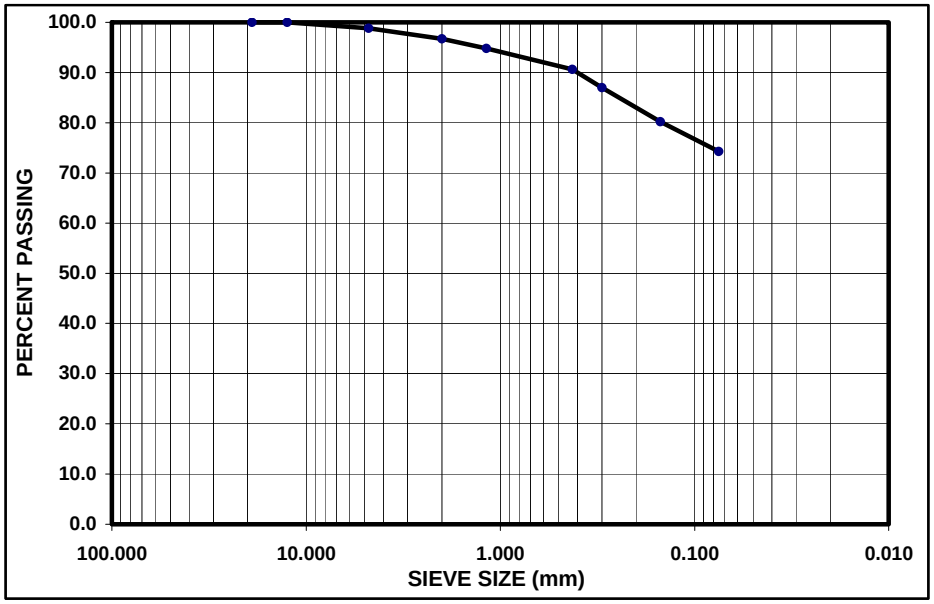
GRADATION ANALYSIS REPORT

Project No:	TF 4107658	**Sample No.:**	#8
Project:	Mosquito Cove - Benthic	**Sample Type:**	Marine Sediment
Client:	PWGSC/EC	**Sample Depth:**	N/A
Sampled By:	A. Peach of AMEC	**Date Sampled:**	02-Feb-05
Sample Location:	Reference #2	**Date Tested:**	08-Feb-05



SIEVE SIZE (mm)	PERCENT PASSING	GRADING LIMITS	
19.000	100.0		
12.500	100.0		
4.760	98.8		
2.000	96.7		
1.180	94.8		
0.425	90.6		
0.300	87.0		
0.150	80.2		
0.075	74.3		

Comments: Dry Sample Weight of 1499.9 g.
Water used to rinse fines from sample bag.

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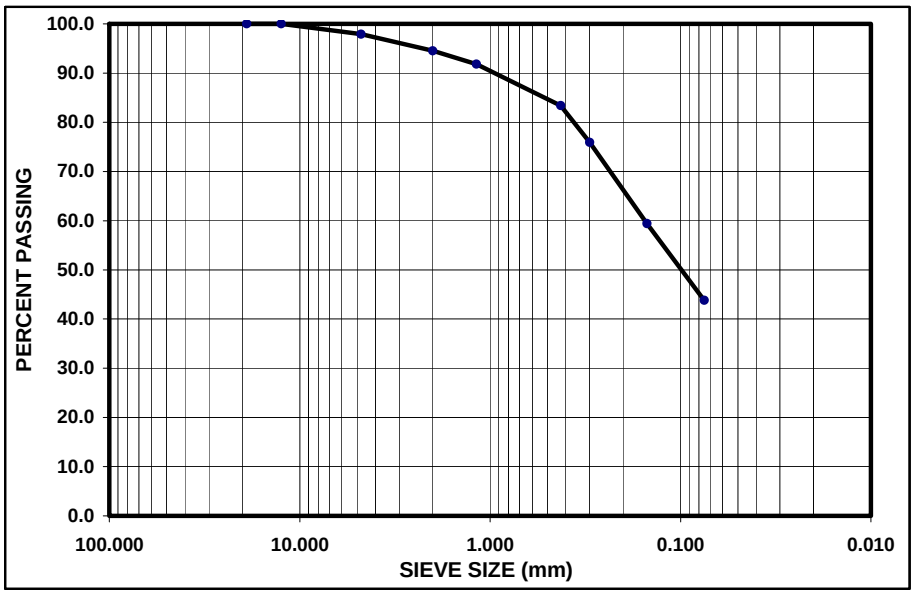
GRADATION ANALYSIS REPORT

Project No:	TF 4107658	**Sample No.:**	#9
Project:	Mosquito Cove - Benthic	**Sample Type:**	Marine Sediment
Client:	PWGSC/EC	**Sample Depth:**	N/A
Sampled By:	A. Peach of AMEC	**Date Sampled:**	02-Feb-05
Sample Location:	Reference #3	**Date Tested:**	04-Feb-05



SIEVE SIZE (mm)	PERCENT PASSING	GRADING LIMITS	
19.000	100.0		
12.500	100.0		
4.760	97.9		
2.000	94.5		
1.180	91.8		
0.425	83.4		
0.300	75.9		
0.150	59.4		
0.075	43.8		

Comments: Dry Sample Weight of 1290.2 g.
Water used to rinse fines from sample bag.

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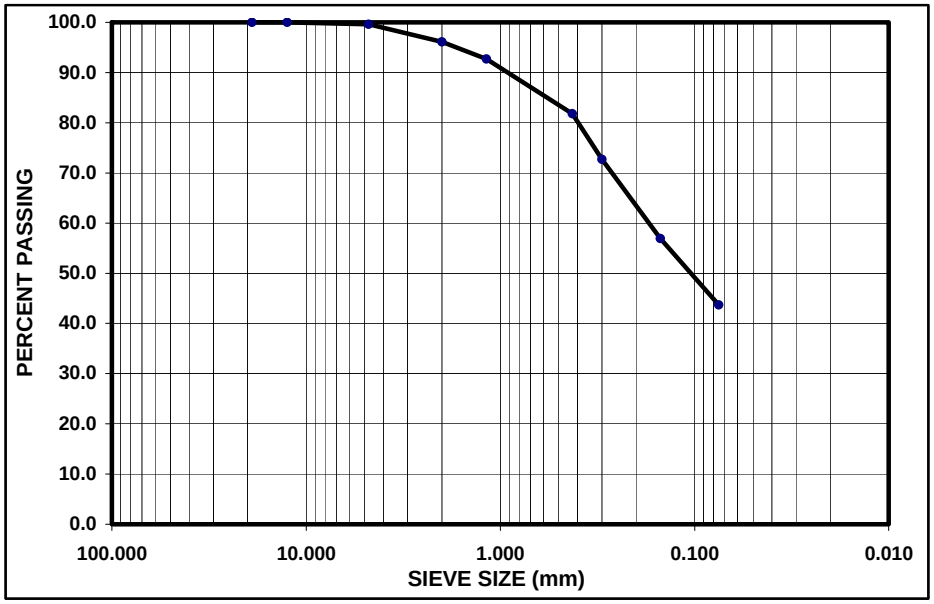
GRADATION ANALYSIS REPORT

Project No:	TF 4107658	**Sample No.:**	#10
Project:	Mosquito Cove - Benthic	**Sample Type:**	Marine Sediment
Client:	PWGSC/EC	**Sample Depth:**	N/A
Sampled By:	A. Peach of AMEC	**Date Sampled:**	02-Feb-05
Sample Location:	Reference #4	**Date Tested:**	04-Feb-05



SIEVE SIZE (mm)	PERCENT PASSING	GRADING LIMITS	
19.000	100.0		
12.500	100.0		
4.760	99.6		
2.000	96.1		
1.180	92.7		
0.425	81.8		
0.300	72.7		
0.150	56.9		
0.075	43.7		

Comments: Dry Sample Weight of 1053.2 g.
Water used to rinse fines from sample bag.

Reporting of these test results constitutes a testing service only.
Engineering interpretation or evaluation of the test results is provided only on written request.

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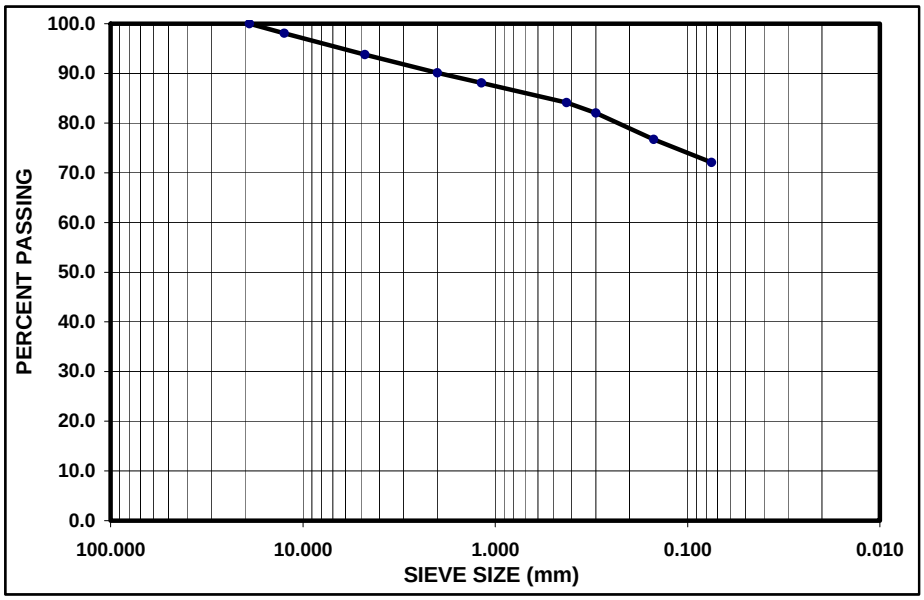
GRADATION ANALYSIS REPORT

Project No:	TF 4107658	**Sample No.:**	#11
Project:	Mosquito Cove - Benthic	**Sample Type:**	Marine Sediment
Client:	PWGSC/EC	**Sample Depth:**	N/A
Sampled By:	A. Peach of AMEC	**Date Sampled:**	02-Feb-05
Sample Location:	Reference #5	**Date Tested:**	08-Feb-05



SIEVE SIZE (mm)	PERCENT PASSING	GRADING LIMITS	
19.000	100.0		
12.500	98.1		
4.760	93.8		
2.000	90.1		
1.180	88.1		
0.425	84.1		
0.300	82.0		
0.150	76.7		
0.075	72.1		

Comments: Dry Sample Weight of 1288.2 g.
Water used to rinse fines from sample bag.

Reporting of these test results constitutes a testing service only.
Engineering interpretation or evaluation of the test results is provided only on written request.

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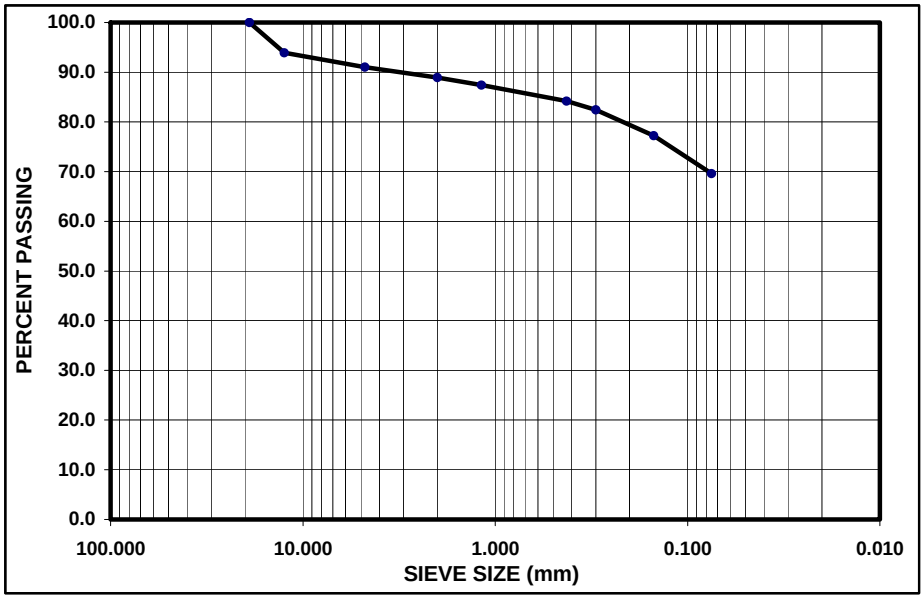
GRADATION ANALYSIS REPORT

Project No:	TF 4107658	**Sample No.:**	#12
Project:	Mosquito Cove - Benthic	**Sample Type:**	Marine Sediment
Client:	PWGSC/EC	**Sample Depth:**	N/A
Sampled By:	A. Peach of AMEC	**Date Sampled:**	02-Feb-05
Sample Location:	Reference #6	**Date Tested:**	08-Feb-05



SIEVE SIZE (mm)	PERCENT PASSING	GRADING LIMITS	
19.000	100.0		
12.500	93.9		
4.760	91.0		
2.000	88.9		
1.180	87.4		
0.425	84.2		
0.300	82.4		
0.150	77.2		
0.075	69.6		

Comments: Dry Sample Weight of 1811.9 g. Total sample used for analysis.
Water used to rinse fines from sample bag.

Reporting of these test results constitutes a testing service only.
Engineering interpretation or evaluation of the test results is provided only on written request.

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Appendix 4

Mosquito Cove CD Video Compilations

1993 (HMDC)
1995 (HMDC)
2005 (Environment Canada)

Disk 1: **Mosquito Cove Survey**
2005 Video Survey CD
1993, 1995, and 2005 Video Samples
(Windows Video Format)

- Selected Clips from HMDC 1993, 1995, and EC 2005 Surveys
- Selected Photos (JPEG) from Tapes 1-4, 2005-06-28
- MS Word Descriptions
- Location and Bathymetry Files

Disk 2: **Mosquito Cove Survey**
Video Conversions DVD
HMDC 1993 VHS Tapes 1 and 2 converted to Windows Video File

- HMDC 1993 Tapes 1 and 2
- Selected Photos (JPEG) From Video
- MS Word Description

Disk 3: **Mosquito Cove Survey**
Video Conversions DVD
HMDC 1995 VHS Tapes 1 and 2
Converted to Windows Video File

- HMDC 1995 Tapes 1 and 2
- Selected Photos (JPEG) From Video
- MS Word Descriptions

Disk 4: **Mosquito Cove Video Survey**
2005 Video Survey DVD
February 1-3, 2005
MiniDV Video Converted to Windows Video Format

- Complete MC2005 Tapes 1-4
- Selected Clips MC2005 Tapes 1-4
- Selected Photos (JPEG) From Tapes 1-4
- MSWord Description
- Location and Bathymetry Files