Earth Tech Canada Inc.
Edmonton, Alberta

GEOTECHNICAL EVALUATION FOR MUNICIPAL WASTE FACILITIES CAMBRIDGE BAY, NU

1700219

December 2006

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1.0 INTRODUCTION

1.1 GENERAL

This report presents results of a preliminary geotechnical evaluation conducted by EBA Engineering Consultants Ltd. (EBA) for upgrading the existing municipal waste facilities at Cambridge Bay, Nunavut. The existing sewage retention facility needs to be upgraded with respect to both increasing its storage volume and improving the integrity of perimeter berms. As well, the flow path for sewage treatment needs to be better separated from adjacent waste storage areas, including the solid waste landfill and the bulk metal storage area. Finally, seasonal runoff from drainage courses outside the proposed boundary for the sanitary waste lagoon needs to be diverted, by construction of diversion dykes, to minimize the dilution and treatment requirements of the sewage waste stream. Another aspect of this evaluation was to assess the available borrow materials in the area and to recommend potential sources for materials to be used in construction.

1.2 PROJECT DETAILS

This report is completed in accordance with EBA's revised proposal submitted to Earth Tech Canada Inc. (Earth Tech) on August 29, 2006. Authorization to proceed with this project was given by Mr. Ken Johnston, P.Eng., Senior Planner and Engineer with Earth Tech, on September 5, 2006.

The work extends from the November 2005 request for proposal (RFP) from the Government of Nunavut to either upgrade the existing waste facilities or construct new facilities. It is understood that this phase of geotechnical work is to focus on correcting deficiencies and extending the capacity of the existing facilities rather than to assist in locating or designing new facilities and commenting on aspects of the closure of the existing facilities. Provision of detailed engineering, construction monitoring services and recommendations for rock blasting technique that formed part of EBA's initial December 16, 2005 proposal submission are not included within the present scope of work

1.3 SCOPE OF WORK

The scope of work for this project includes:

- Characterize the quality and quantity of the available granular and non-granular materials available near Cambridge Bay for use in the proposed construction;
- Inspect the present condition of the various berms around existing waste facilities;
- Carry out geotechnical investigations of surficial and subsurface conditions in areas associated with the following earth structures:
  - new berm structure for improved containment (seasonal discharge control) of the main retention lagoon,

- existing berm structures for upgrading containment and capacity of the existing retention lagoon,
- new berm structures for diversion of outside drainage away from the waste facilities, and
- new berm structure for isolation of the existing metal waste dump from the adjacent sewage lagoon/treatment area;

- Provide recommendations for the modification and/or design of the various berm structures including provision of standard design criteria; and
- Develop specifications for construction of the various berm structures.

2.0 METHOD OF INVESTIGATION

During the site visit on September 13 to 15, 2006, a meeting with Mr. Mark Calliou, the hamlet Senior Administrative Officer (SAO), and other hamlet representatives was organized to discuss the project. This meeting was followed by Mr. Christopher King, the Industrial Development Officer for the hamlet, driving Mr. Ken Peck of EBA to the various borrow areas that are, or have been, used by Cambridge Bay as well as touring the area of the municipal waste facilities. Mr. King explained how the facility was operated and other details of the project. Afterwards, the hamlet arranged for a wheeled backhoe to be available to excavate test pits at the periphery of the existing lagoon. Mr. Peck supervised the excavation of three such test pits. The presence of soft ground limited the number of test pits that could be machine excavated. Mr. Peck inspected and sampled the various borrow areas and walked the perimeter of the existing waste facilities. He observed the locations where perimeter berms would be required to retain or control effluent or to divert exterior runoff. As well, he obtained surficial soil samples, inspected the general terrain features and noted the condition of the existing earthworks and waste storage facilities.

Recovered samples were packaged and shipped to EBA's Yellowknife laboratory for testing. The results of testing are attached in Appendix B of this report. Existing information on site conditions, project requirements and the latest field survey data at the existing waste facilities that was obtained by Earth Tech this past summer was collected. The survey data is compiled as the contour information on Figure 2 of this report.

The following sections outline site observations, the nature of the available borrow materials and introduces how earthworks can be used to upgrade the existing waste facilities.

2.1 BORROW AREAS

In total, six borrow areas were visited. The most important of these are indicated on Figure 1. Borrow Area 6 is situated a short distance west from the existing facility while the others are situated to the west of the hamlet on either side of the airport. Material composition varies but consists predominantly of sand and gravel with variable amounts of fines as indicated in Tables 1 and 2 below.

A vertical face of hard bedrock was observed within Borrow Area 1 and this could be used to provide rip rap for erosion protection. The bedrock face is well fractured and broken along near horizontal bedding planes. The rock could be removed by ripping with a large crawler excavator rather than blasting. The alternative source for coarser rock of cobble to small boulder size appears to be from sorting these sizes from the local soil cover. In most areas the coarser fractions seem to be heaved up to the ground surface.

Under the bedrock face in Borrow Area 1 and at the adjacent Borrow Area 2, a much less competent dark grey “clay rock” is encountered. This is a deposit of soft fine grained bedrock which readily weathers to a stiff soil and can be crumbled by hand pressure. One gradation analysis on this material indicated a composition with 43% fines including 18% clay sizes. This clay is periodically mixed as a binder with the local sand and fine gravel borrow for use as surfacing on the airstrip.

The gradations of the overburden found in the main borrow areas are presented in Table 1.

TABLE 1: SUMMARY OF GRADATION RESULTS

Sample ID	Depth (m)	Gravel (%)	Sand (%)	Silt/Clay (%)	Soil Type
BA1	0.1 – 0.2	40	31	29	GRAVEL, sandy, silty
BA2 (‘clay’)	0.1 – 0.2	21	36	25/18	SAND, gravely, silty, some clay
BA4	0.1 – 0.2	55	43	2	GRAVEL and SAND, trace of silt
BA6	0.1 – 0.2	50	26	24	GRAVEL, sandy, silty

A falling head permeability test was carried out on a portion of the sample from Borrow Area 6. The results indicate a coefficient of permeability in the range of 3.5×10^{-7} cm/sec. This material contained 24% fines whereas the sample of “clay” obtained from borrow area 1 and 2 contained 43% fines, including 18% clay sized material based on the hydrometer analysis. As such, the ‘clay” material should have noticeably lower permeability by comparison. The ‘clay’ material had Atterburg limits of 29% for the liquid limit and 17% for the plastic limit, indicating a low to medium plasticity.

Based on site observations and GPS coordinates, it is judged that sufficient borrow materials can be developed in the area for construction of the proposed berms. This assessment can be re-evaluated once the estimated quantities for construction of the berms have been developed.

2.2 GENERAL CONDITIONS AT WASTE FACILITIES

The ground surface around the periphery of the lagoon area is covered by a generally thin organic mat except in low-lying swales where the organic cover may become 150 to 200 mm thick. Numerous cobbles, small boulders and coarse gravel have been pushed up to the surface by frost action. These clasts are readily apparent when probing through the generally thin organic cover in the swales. Below a depth of 100 to 150 mm the proportions of sand and silt rapidly increase. On high ground, pieces of broken rock cover the surface and exposed bedrock can be observed at the top of some knolls. In local areas at mid to low elevation, the silt and sand component of the overburden seems to be pushed to the surface (as frost boils) covering most of the larger clasts.

The gradations of the overburden found around the periphery of the existing solid waste lagoon are presented in the following table.

TABLE 2: SUMMARY OF GRADATION RESULTS

Sample ID	Depth (m)	Gravel (%)	Sand (%)	Silt/Clay (%)	Soil Type
S ‘A’	0.1 – 0.2	35	42	23	SAND and GRAVEL, silty
S ‘B’	0.1 – 0.2	49	35	16	GRAVEL and SAND, some silt, trace of clay
S ‘C’	0.1 – 0.2	39	52	9	GRAVEL, sandy, trace of silt
S ‘D’	0.1 – 0.2	88	10	2	GRAVEL, some sand, trace of silt
S ‘E’	0.1 – 0.2	48	41	11	GRAVEL and SAND, trace of silt and clay
S ‘F’	0.1 – 0.2	74	18	8	GRAVEL, some sand, trace of silt
TP 1	0.1 – 0.6	71	18	11	GRAVEL, some sand, some silt
TP 3	0.1 – 1.3	41	47	12	SAND and GRAVEL, some silt, trace of clay

Theses sample locations are indicated on Figure 2.

Subsurface conditions encountered around the waste site are variable, ranging from rocky knolls to local areas of thicker organic growth in swales and along drainage courses. The mineral soil in undisturbed areas around the waste facilities has a fines content ranging from 2 to 23 % as indicated in the above Table 2. Considerably more variability is present in the developed areas of the waste facility where retention berms will need to be (re)constructed to contain the lagoon effluent and separator berms will be required to prevent intermingling of solid waste materials from the lagoon effluent.

At Test Pit 2 a layer of buried solid waste debris was encountered. This consisted of charred wood, pieces of metal, fabrics, etc. The burnt/buried refuse probably includes the whole gamut of discarded debris from the community. It was buried under a thin layer of local overburden. The position of the test pit next to the lagoon berm indicates that the debris layer may extend under the berm. The presence of permafrost and incoming water prevented deep excavation beyond about 0.6 m at this location. The base of the debris layer was not determined.

Mostly mineral soil was encountered in the adjacent Test Pits 1 and 3. However shallow permafrost and the presence of shallow and plentiful water in the excavations suggests that the source of the water may well be from within the lagoon. The presence of black sludge and rank odors in local depressions that were disturbed by the backhoe strongly suggests the possibility that the existing berm along this side of the sewage lagoon leaks sludge as well as water.

Downstream of the proposed retention lagoon is the laydown area for bulky metal waste. This area was partially stripped of surficial soil that was pushed up into berms along its southern and eastern sides before a large number of machine chassis were discarded here. The outlet from the existing sewage lagoon flows into this area and the excavated depression contains a pond of water and, presumably, submerged debris.

A break in the southern berm of the bulky waste area permits the effluent stream to enter a flat area of swale with pockets of open water and marsh vegetation in the lowest areas. Drainage divides at this swale with some flowing to the west into a local pond and some flowing to the south, directly towards the ocean.

3.0 PERMAFROST CONDITIONS

Cambridge Bay is situated in an area of continuous permafrost, Heginbottom et al (1995). The Mean Annual Air Temperature is –14.4 C (Environment Canada, 1971-2000 Normal). The reported ground temperature below 3 m depth is in the range of –4.6 C to –11.7 C and averages about –9 C. The thickness of active layer varies from 0.3 m in poorly drained areas to over 2 m in well-drained areas. Excess ice contents of up to 10 percent have been reported in the subsurface soils. Porewater salinity values range from 3 parts per thousand (ppt) to 52 ppt and average about 30 ppt.

4.0 BEDROCK

Fulton (1989) describes the bedrock geology of the Cambridge Bay area as comprising Paleozoic sedimentary rocks (carbonates, shales and sandstones). Bedrock is generally exposed at sporadic locations close to sea level. Where exposed, the bedrock comprises layers of dolomite and shale, and is jointed and frost shattered.

Shale was the bedrock type observed at potential borrow sources during this site investigation.

5.0 RECOMMENDATIONS AND CONSIDERATIONS

5.1 GENERAL

The present sewage lagoon was originally a local pond where a dumping station was situated towards the upstream end with a natural outlet that eventually flowed into the ocean. One berm was constructed along the south edge to separate the adjacent solid waste landfill area from the sewage lagoon. The effluent from the sewage lagoon currently passes through the depression excavated for the bulky waste area and then into a small wetland. The hamlet officials indicate that the runoff quality meets existing guidelines.

The solid sewage waste currently reaches the surface of the pond at the dumping station where steel chutes have been placed to direct the trucked waste into the lagoon. A previous location for the dumping station may have existed further downstream.

The intention is to relocate the dumping station still further upstream in an arm of the lagoon. Here, the solids will be separated from the main lagoon area by construction of a submerged barrier berm consisting of rockfill. This barrier berm will serve as a divider between the upstream primary lagoon and the downstream retention lagoon. The margin of the upper water level in both compartments will be defined by the 10 m elevation contour. The existing berm separating the sewage lagoon from the solid waste facility will need to be enhanced as the original elevation along this segment of the perimeter is lower than 10 m and the condition of the present berm is suspect. This low area continues across the present natural outlet of the lagoon. As it is the intention to effectively stop natural drainage from the retention lagoon, the outlet will be completely closed by construction of a new outlet barrier berm. The lagoon water level will be lowered seasonally by either pumping/piping or through some control structure.

In conjunction with the above rework of the lagoon area, the natural drainage into the lagoon area from peripheral drainage courses upstream will be curtailed by the construction of a number of cut off berms. Runoff will be diverted into other natural channels. This will help minimize the quantity of effluent that will be held and requiring treatment within the lagoon.

Downstream of the outlet barrier berm, an isolation berm will be constructed to separate the area of bulky waste from the seasonal discharge channel. Without some filling of this area or cutting a lower drainage channel, this area may still pond water on both sides of the isolation berm. Downstream of the isolation berm, a larger wetland area will be developed to permit additional natural treatment of the waste stream. If contact of the effluent stream with the natural runoff is to be minimized in this area, an additional cut off berm will be required to the west of the proposed wetland.

5.2 GENERAL RECOMMENDATIONS FOR BERM CONSTRUCTION

The berms should be constructed using compacted locally available low permeability fill. Based on the falling head permeability test carried out on the sample from Borrow Area 6, a sample with 24% fines resulted in a coefficient of permeability of 3.5×10^{-7} cm/sec. Considering that field construction will result in a permeability at least one order of magnitude higher than the lab test result (eg. in the range of 1×10^{-5} to 1×10^{-6} cm per second), this still provides a satisfactory level of containment for the lagoon berms. Based on the results of soil gradation for the samples collected in the vicinity of the waste area, 6 of 8 samples possessed less than 15% fines and only one sample had 23% fines. The latter is considered to be comparable to the sample from Borrow Area 6.

Based on these results the native overburden with a minimum of 20% fines should provide an adequate level of impermeability for the retention lagoon perimeter berms where the material is sufficiently compacted. Such material is available from Borrow Area 6. The minimum fines content that should be used for the cut off berms that are subject to only intermittent use to control flood flows should be 12%. For the limited volumes required to construct these small structures, the local overburden may be sufficient without having to truck fill from Borrow Area 6.

Some conceptual cross sections for the various berms are presented in Figure 3.

A requirement for construction of low permeability perimeter berms around the lagoon is to place the above described fill soils against an undisturbed surface of native overburden with a matrix of sand and silt having a similar percentage of fines. The fill and the native overburden must both be in reasonably dry condition to allow adequate construction control and compaction. In the area near Test Pit 2, a considerable amount of debris should be subexcavated and the local high water level will greatly hamper this work, if not make it impossible. Dewatering of the area would be greatly beneficial and this will require lowering the water level within the existing lagoon.

Dewatering of the lagoon can be facilitated by sequencing the construction. The construction of the cut off berms in advance of the other work will reduce the volume of runoff reporting to the lagoon. Some preparation of the ground at the lagoon outlet such as removal of surficial organics and coarse grained surficial soils will create an improved channel so that flow into the bulky waste area is temporarily improved and the lagoon water level could be lowered by gravity until the outlet barrier berm is constructed. However, lowering the lagoon water level will likely result in more exposure of the existing sewage sludge and could cause it to mobilize and move downstream.

If the submerged rockfill berm that is to be constructed across the outlet to the proposed primary lagoon outlet were at least roughed in ahead of other work in the lagoon, the placement of sewage sludge could be transferred into the primary lagoon area and so reduce the potential for mobilization of sludge in the main retention lagoon. If the rockfill contained sufficient fines, or if a layer of finer grained soil were placed over its upstream side with an additional temporary height of fill placed along its crest, then the primary lagoon area could be temporarily isolated from downstream and used to store all of the effluent. This would allow the water in the downstream retention lagoon area to be significantly lowered to facilitate excavation and construction of the perimeter berms. The extent of mobilization of the existing sludge in the existing retention lagoon would have to be monitored. If it began to flow excessively, a perimeter cofferdam could be constructed at the toe of the sludge pile to help keep it in place. After the berms around the retention lagoon were constructed, the temporary cofferdam around the sludge could be removed or breached and the excess fill placed along the submerged berm at the primary lagoon outlet could be removed to grade. Finally, once the perimeter berms around the retention lagoon were intact, work could commence on the isolation berm along side the bulky waste area as flow of effluent into this area would be stopped.

The crest width of all low permeability berms should be at least 3 m to accommodate the passage of ride-on compaction equipment and construction machinery. Also, the width of low permeability dams should be at least 3 times the head of water for any given height to avoid the requirement for downstream filter zones. With the anticipated maximum head of 1 m against the perimeter berms, these conditions are mutually compatible.

The sides of berms constructed out of local low permeability soil without a cover of rip rap should be sloped at 3H:1V or flatter. The sides of berms exposed to standing or running water should be covered with a minimum thickness of 0.5 m of well graded rip rap of sizes ranging from 0.3 m down to sand sizes. Where so protected, the side slopes can be steepened to 2H:1V. Such rip rap facing should also be placed along both sides of the bulky waste isolation berm. All low permeability berms should be crowned with a 0.3 m thickness of crushed stone to prevent erosion of surface fines and to minimize rutting of the crest by surface traffic.

5.2.1 Primary Lagoon Outlet Berm (submerged)

It is anticipated that organics and sludge have accumulated over the bottom of the pond along the alignment for this berm. The removal of these compressible materials to hard bottom prior to construction would ensure the stability of the rock fill berm. Lowering the water level would help with this removal and with the controlled placement of the rockfill berm. On the other hand, this structure need not be a waterproof or sophisticated design and its construction underwater would likely result in a useable outcome provided some allowance is added for future settlement and sloughing of side slopes. Some additional width and height would compensate for these eventualities.

As indicated above, if this berm were constructed in advance of the perimeter berms and the placement of sewage sludge transferred into the primary lagoon area sooner, it would be easier to dewater the adjacent retention lagoon area and facilitate construction of the perimeter berms.

5.2.2 Cutoff Berms

The crest elevation for the cut off berms will vary with the local terrain, where these structures are situated and to what height the upstream runoff may reach due to storm events, ice jambs, etc. Site selection should be optimized to minimize the berm height and maximize the diversion of surface runoff. A minimum freeboard of 0.5 m should be sufficient where water is not permanently stored against the cutoff berms. Unless routine annual maintenance is carried out, the side slopes are built very flat (6H:1V) or significant quantities of rip rap are used to stabilize the berm side slopes, an additional height of 0.5 m should be included to accommodate eventual erosion and sloughing of the side slopes.

As well as constructing the cutoff berms, the original drainage channel leading towards the berm alignment should be excavated and backfilled with compacted local overburden to help disrupt low flow towards the cutoff berms and diminish the ponding of water upstream of these berms

5.2.3 Retention Lagoon Perimeter Berms

Based on the survey information, the maximum height of the perimeter berms to reach the 10 m elevation would be about 1 m. A freeboard height of at least 1 m should be included. As for the cut off berms, unless routine annual maintenance is carried out or, the side slopes of the berms are built very flat (6H:1V) or, significant quantities of rip rap are used to stabilize the berm side slopes, an additional height of 0.5 m to elevation 11.5± m should be included to accommodate eventual erosion and sloughing of the side slopes.

Another key component for the perimeter berm construction is to ensure that all coarse grained, compressible and deleterious materials are removed from beneath the foot print of the proposed berms so that the low permeability fill used in the core area of the berms is in intimate contact with similar low permeability native overburden. This is of particular importance for the construction of the berm along the south side of the lagoon and the berm to be constructed across the existing outlet of the lagoon where buried landfill debris, organic material and high ground water will have to be dealt with.

Delineation of the extent of buried debris may be helpful to define the extent of work required. Delineation by additional test pitting, perhaps supplemented with a ground penetrating radar (GPR) survey is recommended. Physical delineation by test pitting would be facilitated by advance lowering the water level. Drilling through frozen ground in the winter would also be viable except there may not be a suitable drill available in the hamlet.

It may be necessary to excavate into permafrost as well to reach undisturbed native soil with an intact fine grained matrix rather than the frost modified surficial soil with an increased coarse fraction and the fines removed.

The high groundwater table may be very problematic and may result in significant flow of contaminated water from the lagoon to the point that the existing berm is breached. Lowering the lagoon water level in advance of excavation would be most helpful.

The reinforcement of the south perimeter berm will require the reshaping of the exiting fill used in the construction of the present berm. Excess fill excavated from this berm can be pushed or placed upstream out of the area of construction or used as a temporary cofferdam to keep lagoon sludge and water away from the construction area. The surficial fill soils along the berm are likely contaminated with debris from the landfill and may have inconsistent fines content due to erosion of the exposed fines and so should not be reused.

Once the alignment for this berm has been established, the footprint should be excavated to remove all organics and debris to reach competent native soil with an intact fine grained matrix. If permafrost is encountered, it should be excavated or allowed to thaw to the point where competent native soil is encountered. All excavations should be carried out based on the applicable labour codes with a view to preventing collapse and the possible injury to workers.

If the excavated trench can be kept reasonably dry by pumping or other methods, imported native soil with sufficient fines content can be placed, spread and compacted to bring the trench opening back up to grade. The length of the berm may be constructed in segments rather than all at one time. Where the trench opening cannot be satisfactorily dewatered to permit placement and compaction of the native fill material in the dry, it may be necessary to import 'clay' fill from Borrow Areas 1 or 2 to form a plug within the bottom and sides of the excavation. If this plug can be compacted, then proceed to do so. If not, then overly wet areas of the clay should be removed and replaced with dryer clay that can be compacted. Eventually, even the wet clay will self compact under the weight of the overlying berm to form a low permeability barrier but at the risk of some settlement.

Once the fill placement has reached the ground surface or is well above the water table, placement of native low permeability fill can be carried out normally with the individual lifts placed against the shaped side of the existing berm fill until final elevation is reached.

5.2.4 Bulky Waste Isolation Berm

Once construction of the perimeter berms for the retention lagoon is well underway, drainage of effluent into the bulky waste area will be curtailed. Remaining ponded water in this area should be removed and the bottom should be allowed to dry. The alignment for the isolation berm should be laid out and all debris and auto chassis moved into the bulky waste stockpile area. All debris, coarse soil and soft or wet ground should be removed or sub-excavated and replaced with low permeability overburden. The prepared surface should then be proof rolled and any additional areas of soft ground replaced before continuing with the construction of the low permeability isolation berm.

Consideration should be given to either raising the bottom elevation of this area or to lowering the grade of the outlet end so that water will no longer pond in this section. If this can be accomplished then there will be no need for a low permeability berm to be constructed along this section. A fence or a rockfill berm would suffice to establish the drainage channel from the bulky waste storage area.

5.3 FILL PREPARATION, PLACEMENT AND COMPACTION

The local low permeability sand and gravel should have all oversized cobbles and boulders removed to create a 150 mm minus material with fines content as indicated above for the various berms (i.e. a minimum of 12% fines for the cut off berms and 20% fines for the perimeter berms of the retention lagoon). The separated oversized material can be used as rip rap. The native soils in areas around the lagoon but may not be of sufficient depth or consistency to be economically exploitable but soil of suitable fines content is available from Borrow Area 6. The local contractor has a screening plant and routinely combines the clay source from Borrow Areas 1 and 2 with the local granular overburden to manufacture road and runway topping material. This method is also available to produce the required low permeability fill for this project.

The prepared surfaces of native low permeability soil under areas for construction of berms should be proof rolled under the direction of competent geotechnical personnel and all areas of wet, soft or otherwise deleterious materials should be replaced and suitably compacted to ensure the required level of water tightness. Once the founding surfaces have been approved, low permeability soil, conditioned to a uniform moisture content in the range of 0 to 2% above optimum, should be placed in maximum 300 mm thick lifts. Care should be taken when placing and spreading the fill soils to avoid accumulations of coarse material without fines. Such coarse zones develop at the toe as each load of fill is spread and represent a line of higher permeability across the width of the berm. Such segregated material should be removed to the outside of the berm.

Once spread, each lift should be compacted to a minimum of 95% of its maximum Standard Proctor dry density before commencing the placement of the next lift of fill. The surface of each lift should be scarified immediately prior to the placement of a subsequent lift of low permeability soil. Where the lift surfaces have become dry, the surfaces should be moistened.

If not placed in conjunction with the adjacent cover of rip rap, the edges (width) of the berms should be overbuilt by up to 0.5 m horizontally to facilitate compaction of the entire design envelope for the low permeability zone. After completion, the excess material can be trimmed and used elsewhere before rip rap is placed.

Rip rap should be placed and tamped into position with the excavator bucket if it is not otherwise compacted.

The final cover of crushed stone should be compacted to 95% of its maximum standard proctor dry density.

Further guidelines for the placement and compaction of fill materials are presented in Appendix C.

Final grading around the downstream sides of constructed berms should ensure that surface water downstream of berms can run away in the direction of natural drainage, if possible. This will facilitate inspection of the condition of the berms. Such toe areas should be left exposed and not covered with solid waste materials.

Excavation, conditioning, placement and compaction of the low permeability fill materials for this project should be carried out in the absence of freezing conditions.

6.0 DESIGN AND CONSTRUCTION GUIDELINES

Recommended general design and construction guidelines are provided in Appendix C, under the following headings:

- Construction Excavations (1 page)
- Backfill Materials and Compaction (4 pages)
- Proof-Rolling (1 page)

These guidelines are generic and are intended to present standards of good practice. They have been developed largely from EBA's southern practice. We have attempted to address specific local requirements in the main text of this report. The guidelines are supplemental to the main text of this report. In the event of any discrepancy between the main text of this report and Appendix C, the main text should govern. The design and construction guidelines are not intended to represent detailed specifications for the works, although they may prove useful in the preparation of such specifications.

7.0 REVIEW OF DESIGN AND CONSTRUCTION

EBA should be given opportunity to review details of the design and specifications related to geotechnical aspects of the project prior to construction.

All recommendations presented in this report are based on the assumption that an adequate level of monitoring will be provided during construction, and that all construction will be carried out by suitably qualified contractors, experienced in earthworks and foundation construction in the north. An adequate level of monitoring for earthworks is considered to be full time monitoring and compaction testing.

All such quality assurance monitoring should be carried out by suitably qualified persons, on behalf of the owner, independent of the contractor. One of the purposes of providing an adequate level of monitoring is to check that the provided recommendations, which are based on the findings at discrete test pit locations, are relevant to other areas of the site. EBA will provide these services upon request.

8.0 LIMITATIONS

This report presents the findings at discrete shallow test pit locations over the site. The conditions encountered during the fieldwork are considered to be reasonably representative of the site. If conditions other than those reported are encountered, EBA should be notified and given the opportunity to review the present recommendations. Recommendations and comments presented herein may not be valid if an adequate level of monitoring is not provided during construction.

This report has been prepared for the exclusive use of Earth Tech Canada Inc. together with their agents for application specific to the development described in this report. It has been prepared in accordance with generally accepted soil and foundation engineering practices. No other warranty is made, either expressed or implied.

Reference should be made to the General Conditions in Appendix A of this report for further limitations.

9.0 CLOSURE

EBA trusts that this information satisfies your present requirements. Please contact the undersigned if further information is required.

Respectfully submitted,
EBA Engineering Consultants Ltd.

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Hegginbottom, J.A., Dubreuil, M.A., and Harker, P.T., 1995. Canada – Permafrost. In National Atlas of Canada, Natural Resources of Canada, Ottawa, 1995. Map Number: MCR 4177, Scale: 1:7,500,00

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FIGURES

Note: Background imagery provided courtesy of Google Earth and is for presentation purposes only.
Not To Scale

CLIENT

Earth Tech Canada Inc.

Municipal Waste Facilities Upgrade
Cambridge Bay, NU

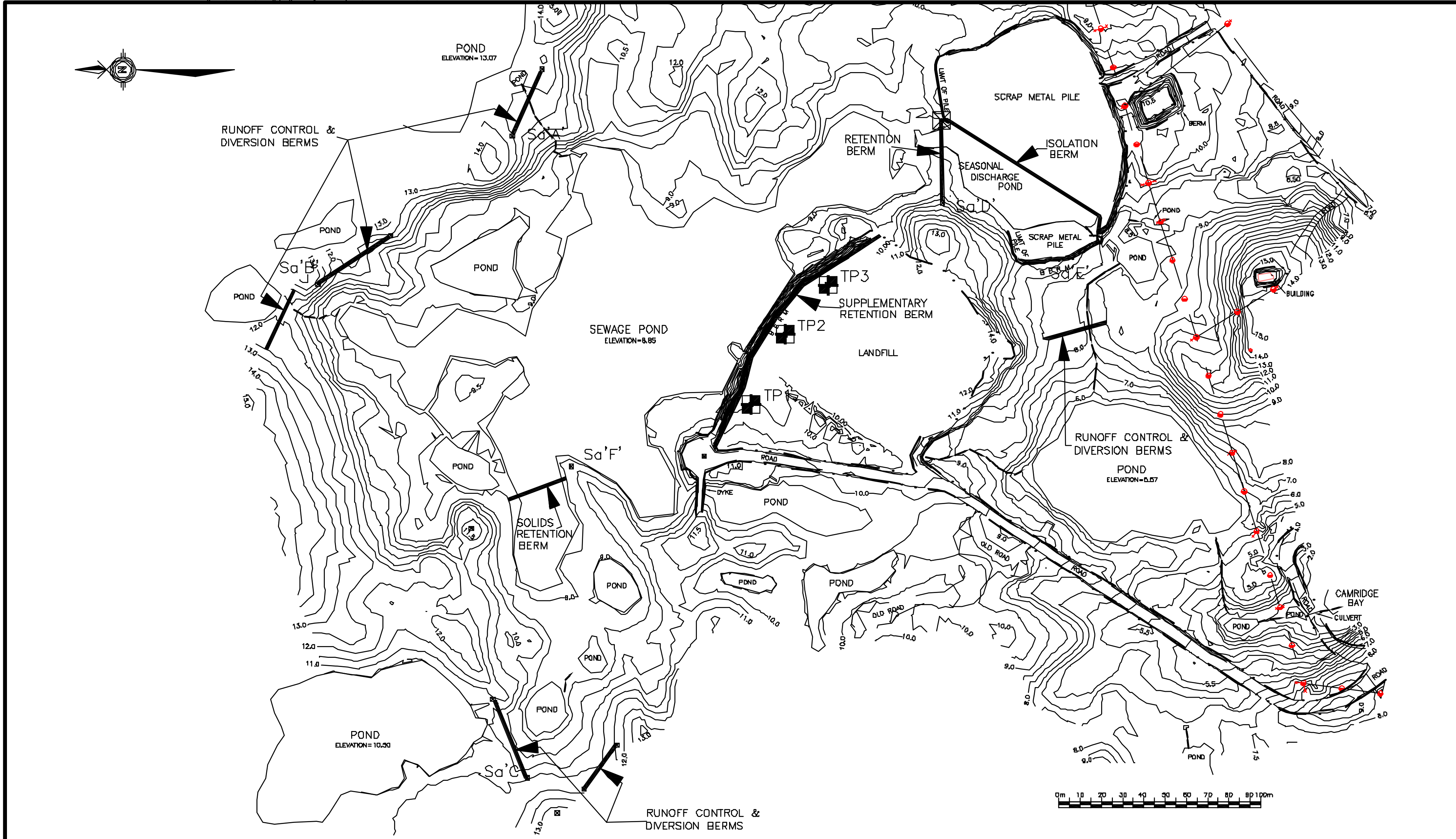
Site Location Plan

EBA Engineering Consultants Ltd.

PROJECT NO./FILE NO.	DWN	CKD	REV
1700219	KWP	EH	0
OFFICE	DATE		
EBA-YK	November 17, 2006		

Figure 1

Q:\Edmonton\Data\0113\Users\Richard\1700219 Fig2-3; Dec21.dwg [Figure 2] January 17, 2007 - 12:10pm Rheoert



LEGEND:

- Test Pit Location

☒ Waypoint

Reference: Earth Tech Canada Inc. survey plan 06-42-ET[1].dwg

CLIENT

Earth Tech Canada Inc.

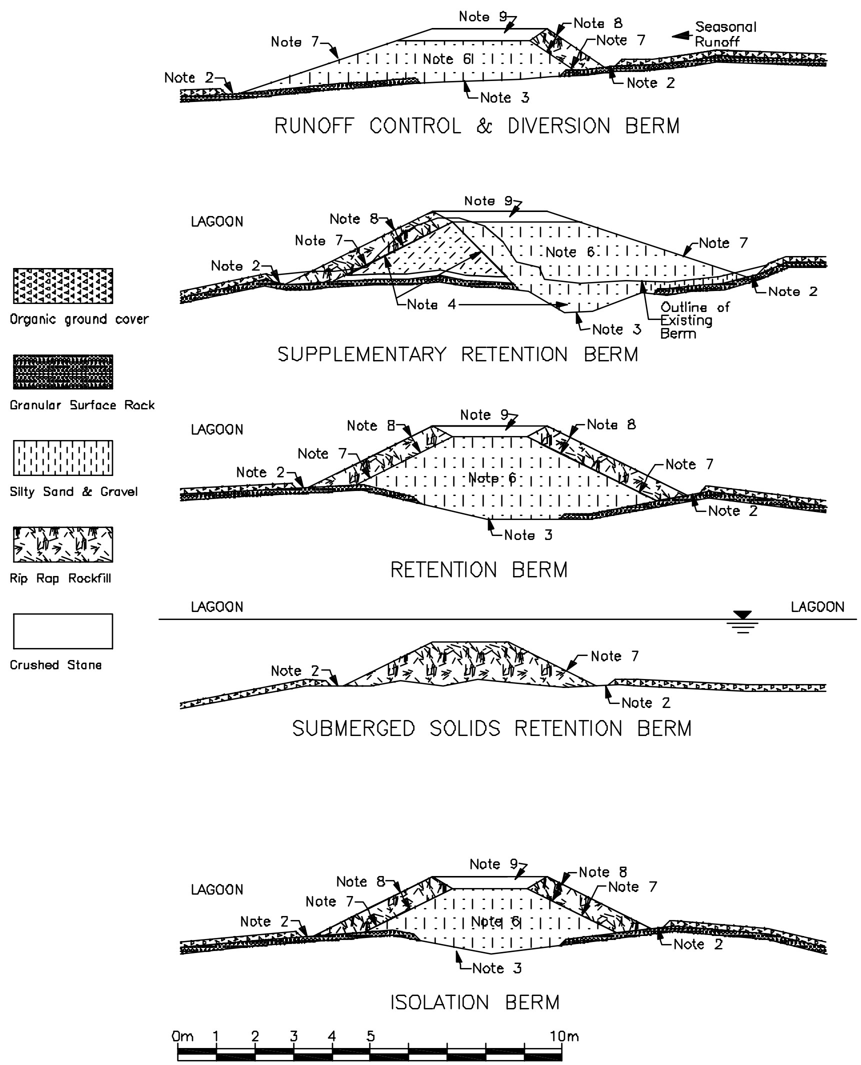
Municipal Waste Facilities Upgrade
Cambridge Bay, NU

Lagoon Location Plan
Site Contours & Test Locations

EBA Engineering Consultants Ltd.

PROJECT NO./FILE NO.	DWN	CKD	REV
1700219	KWP	EH	0
OFFICE	DATE		
EBA-YK	November 17, 2006		

Figure 2



NOTES:

1. Establish centerline and perimeter dimensions of proposed berm.

2. Remove all surface organics to a distance of 0.5 m beyond toe of berm.

3. Establish crest alignment of proposed low permeability berm and excavate a further 150 mm depth or more to a width extending 0.3 m beyond the edges of the crest. Remove all cobbles, boulders and coarse gravel and expose native fine grained soil. Proof roll and compact prepared surface. Ensure all remnants of former drainage channels are removed.

4. Trim existing berms to a 1:1 slope where additional low permeability local fill is to be placed or to 2H:1V where rip rap material is to be placed. Reuse suitable material, dispose of overly wet or contaminated material from berms. Sub excavate at exterior edge of existing berm in the area of TP-2 to remove all burnt debris from former landfill operations from under proposed berm construction area.

5. Remove water from excavations through gravity drainage or pumping. Where incoming water persists, place a mixture of 25% 'clay' (from Borrow Area 1 or 2) with 75% lowpermeability local fill and tamp into bottom of cleaned excavation after removal of excess water. Repeat with additional lifts of similar material until 0.3 m above the level of incoming water/local water table. Allow this fill to stabilize until it can support the passage of a half locaded dump truck. If necessary, cut a 3 m wide trench along the middle of overly wet clay fill and place and compact additional clay fill in lifts to achieve this objective. Additional lifts of local low permeability fill material can then be placed and compacted as spedified.

6. Use local sand and gravel soil (150 mm minus material) with a minimum of 10% fines to construct core of berm in maximum 0.3 m thick lifts. Screen out oversize and use for rip rap. Compact each lift to 95% of it maximum standard proctor dry density at 0 to 2% above its optimum moisture content.

7. Ends of berm should meet with local terrain. Slope sides of fill to a maximum slope of 3H:1V where slope face is not rip rapped and to a maximum slope of 2H:1V where face is rip rapped.

8. Add a 0.7 m horizontal width of rip rap material to all faces exposed to standing or running water as indicated. Rip rap shall consist of hard angular rock with sizes ranging from 0.5 to sand, well graded and tamped into place.

9. Cover crests of above water berms with 0.3 m thick lift of crushed stone with a minimum width of 3 m crest width.

CLIENT

Earth Tech Canada Inc.

EBA Engineering Consultants Ltd.

Municipal Waste Facilities Upgrade
Cambridge Bay, NU

Section Details of Proposed Berms
Sewage Lagoon Upgrade

PROJECT NO./FILE NO.	DWN	CKD	REV
1700219	KWP	EH	0
OFFICE: EBA-YK	DATE: November 17, 2006		

Figure 3

PHOTOGRAPHS

Photo 1
Borrow Area 1 west of Hamlet with brown surficial silty gravel and sand over remnants of broken bedrock with grey 'clay' bedrock over floor of pit.

Photo 2
Borrow Area 1 showing 3± m high rockface with underlying 'clay' rock in foreground.

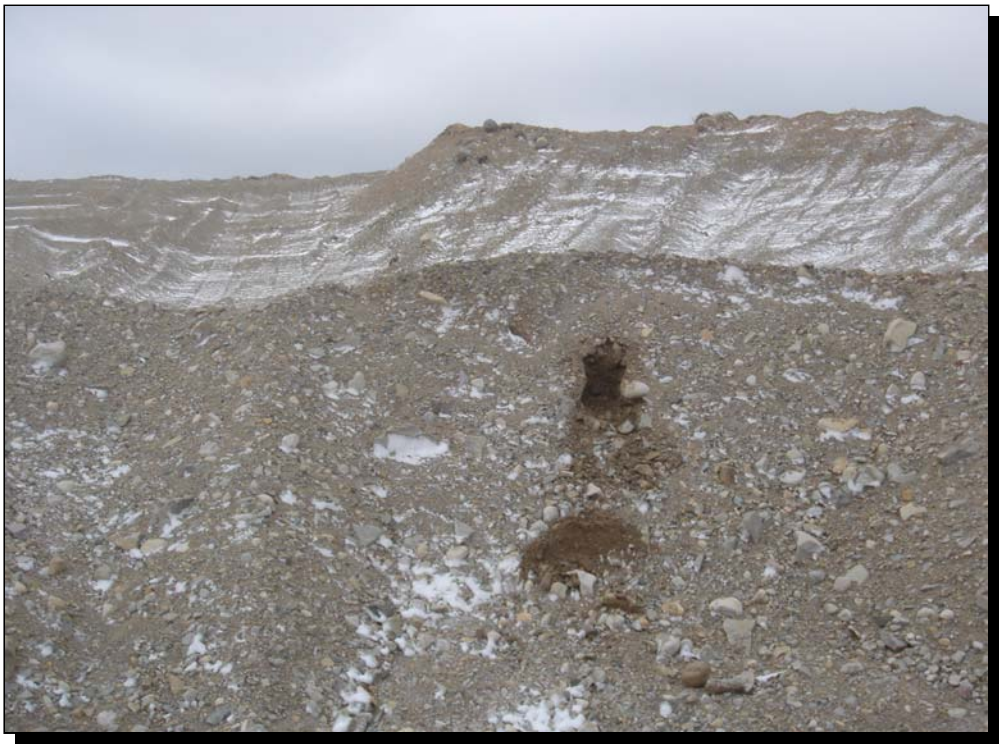


Photo 3
Borrow Area 4 showing sample site. This is a source for sand and gravel with limited fines content.

Photo 4
Borrow Area 5 with crusher in mid ground, radar site and airport in distance. Note boulder strewn native soil in foreground.

Photo 5
Borrow Area 6 north of Hamlet and west of waste facilities. Source of low permeability sandy, silty gravel.

Photo 6
Test Pit 2 immediately south of lagoon perimeter berm. Note boulders in silty sand soil common to the area and the burnt refuse that was buried in the pit.

Photo 7
Existing perimeter berm south of lagoon as viewed from the dumping station. Note ponded water beyond backhoe at same level as the lagoon water. Current solid waste landfill starts at right of photo. Metal waste storage area is in distance at top of backhoe boom.

Photo 8
Typical location for a cut off berm with occasional drainage from pond at left running through the swale outlined with brown organics and gently rolling terrain with tufts of organics and numerous cobbles over the surface.

Photo 9
Borrow Area 6 as seen from west end of proposed expanded lagoon.

Photo 10
Existing dumping station with pick up parked. Submerged berm at outlet to primary lagoon will extend across an arm of the existing lagoon that is situated immediately behind the photographer.

Photo 11
Outlet point of retention lagoon with proposed perimeter berm extending towards the photographer from left side of grey steel trusswork. Isloation berm is required along this side of the metal waste storage area through the right hand pond.

Photo 12
Bulky waste storage in front of metal storage. Retention lagoon in center distance draining towards bulky waste pond in middle ground. Perimeter berm will close outlet to lagoon in the area of the steel trusswork. Isolation berm will extend from trusswork to the photographer.

Photo 13
Outlet from bulky waste pond. Note fine grained nature of local overburden in berms at both sides of channel. Numerous chassis and scrap will have to be relocated to east side of isolation berm.

Photo 14
Proposed wetland area to be developed downstream of outlet from bulky waste area. Cutoff berm required to curtail drainage to pond at right. Drainage will to to the left.

APPENDIX

APPENDIX A GENERAL CONDITIONS

GEOTECHNICAL REPORT – GENERAL CONDITIONS

This report incorporates and is subject to these "General Conditions".

1.0 USE OF REPORT AND OWNERSHIP

This geotechnical report pertains to a specific site, a specific development and a specific scope of work. It is not applicable to any other sites nor should it be relied upon for types of development other than that to which it refers. Any variation from the site or development would necessitate a supplementary geotechnical assessment.

This report and the recommendations contained in it are intended for the sole use of EBA's client. EBA does not accept any responsibility for the accuracy of any of the data, the analyses or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than EBA's client unless otherwise authorized in writing by EBA. Any unauthorized use of the report is at the sole risk of the user.

This report is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of EBA. Additional copies of the report, if required, may be obtained upon request.

2.0 NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS

Classification and identification of soils and rocks are based upon commonly accepted systems and methods employed in professional geotechnical practice. This report contains descriptions of the systems and methods used. Where deviations from the system or method prevail, they are specifically mentioned.

Classification and identification of geological units are judgmental in nature as to both type and condition. EBA does not warrant conditions represented herein as exact, but infers accuracy only to the extent that is common in practice.

Where subsurface conditions encountered during development are different from those described in this report, qualified geotechnical personnel should revisit the site and review recommendations in light of the actual conditions encountered.

3.0 LOGS OF TESTHOLES

The testhole logs are a compilation of conditions and classification of soils and rocks as obtained from field observations and laboratory testing of selected samples. Soil and rock zones have been interpreted. Change from one geological zone to the other, indicated on the logs as a distinct line, can be, in fact, transitional. The extent of transition is interpretive. Any circumstance which requires precise definition of soil or rock zone transition elevations may require further investigation and review.

4.0 STRATIGRAPHIC AND GEOLOGICAL INFORMATION

The stratigraphic and geological information indicated on drawings contained in this report are inferred from logs of test holes and/or soil/rock exposures. Stratigraphy is known only at the locations of the test hole or exposure. Actual geology and stratigraphy between test holes and/or exposures may vary from that shown on these drawings. Natural variations in geological conditions are inherent and are a function of the historic environment. EBA does not represent the conditions illustrated as exact but recognizes that variations will exist. Where knowledge of more precise locations of geological units is necessary, additional investigation and review may be necessary.

5.0 SURFACE WATER AND GROUNDWATER CONDITIONS

Surface and groundwater conditions mentioned in this report are those observed at the times recorded in the report. These conditions vary with geological detail between observation sites; annual, seasonal and special meteorologic conditions; and with development activity. Interpretation of water conditions from observations and records is judgmental and constitutes an evaluation of circumstances as influenced by geology, meteorology and development activity. Deviations from these observations may occur during the course of development activities.

6.0 PROTECTION OF EXPOSED GROUND

Excavation and construction operations expose geological materials to climatic elements (freeze/thaw, wet/dry) and/or mechanical disturbance which can cause severe deterioration. Unless otherwise specifically indicated in this report, the walls and floors of excavations must be protected from the elements, particularly moisture, desiccation, frost action and construction traffic.

7.0 SUPPORT OF ADJACENT GROUND AND STRUCTURES

Unless otherwise specifically advised, support of ground and structures adjacent to the anticipated construction and preservation of adjacent ground and structures from the adverse impact of construction activity is required.

8.0 INFLUENCE OF CONSTRUCTION ACTIVITY

There is a direct correlation between construction activity and structural performance of adjacent buildings and other installations. The influence of all anticipated construction activities should be considered by the contractor, owner, architect and prime engineer in consultation with a geotechnical engineer when the final design and construction techniques are known.

9.0 OBSERVATIONS DURING CONSTRUCTION

Because of the nature of geological deposits, the judgmental nature of geotechnical engineering, as well as the potential of adverse circumstances arising from construction activity, observations during site preparation, excavation and construction should be carried out by a geotechnical engineer. These observations may then serve as the basis for confirmation and/or alteration of geotechnical recommendations or design guidelines presented herein.

10.0 DRAINAGE SYSTEMS

Where temporary or permanent drainage systems are installed within or around a structure, the systems which will be installed must protect the structure from loss of ground due to internal erosion and must be designed so as to assure continued performance of the drains. Specific design detail of such systems should be developed or reviewed by the geotechnical engineer. Unless otherwise specified, it is a condition of this report that effective temporary and permanent drainage systems are required and that they must be considered in relation to project purpose and function.

11.0 BEARING CAPACITY

Design bearing capacities, loads and allowable stresses quoted in this report relate to a specific soil or rock type and condition. Construction activity and environmental circumstances can materially change the condition of soil or rock. The elevation at which a soil or rock type occurs is variable. It is a requirement of this report that structural elements be founded in and/or upon geological materials of the type and in the condition assumed. Sufficient observations should be made by qualified geotechnical personnel during construction to assure that the soil and/or rock conditions assumed in this report in fact exist at the site.

12.0 SAMPLES

EBA will retain all soil and rock samples for 30 days after this report is issued. Further storage or transfer of samples can be made at the client's expense upon written request, otherwise samples will be discarded.

13.0 STANDARD OF CARE

Services performed by EBA for this report have been conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practising under similar conditions in the jurisdiction in which the services are provided. Engineering judgement has been applied in developing the conclusions and/or recommendations provided in this report. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of this report.

14.0 ENVIRONMENTAL AND REGULATORY ISSUES

Unless stipulated in the report, EBA has not been retained to investigate, address or consider and has not investigated, addressed or considered any environmental or regulatory issues associated with development on the subject site.

15.0 ALTERNATE REPORT FORMAT

Where EBA submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed EBA's instruments of professional service), the Client agrees that only the signed and sealed hard copy versions shall be considered final and legally binding. The hard copy versions submitted by EBA shall be the original documents for record and working purposes, and, in the event of a dispute or discrepancies, the hard copy versions shall govern over the electronic versions. Furthermore, the Client agrees and waives all future right of dispute that the original hard copy signed version archived by EBA shall be deemed to be the overall original for the Project.

The Client agrees that both electronic file and hard copy versions of EBA's instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except EBA. The Client warrants that EBA's instruments of professional service will be used only and exactly as submitted by EBA.

The Client recognizes and agrees that electronic files submitted by EBA have been prepared and submitted using specific software and hardware systems. EBA makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.

APPENDIX

APPENDIX B TEST PIT LOGS AND LABORATORY TEST RESULTS

TERMS USED ON BOREHOLE LOGS

TERMS DESCRIBING CONSISTENCY OR CONDITION

COARSE GRAINED SOILS (major portion retained on 0.075mm sieve): includes (1) clean gravels and sands, and (2) silty or clayey gravels and sands. Condition is rated according to relative density, as inferred from laboratory or in situ tests.

DESCRIPTIVE TERM	RELATIVE DENSITY	N (blows per 0.3m)
Very Loose	0 to 20%	0 to 4
Loose	20 to 40%	4 to 10
Compact	40 to 75%	10 to 30
Dense	75 to 90%	30 to 50
Very Dense	90 to 100%	greater than 50

The number of blows, N, on a 51mm O.D. split spoon sampler of a 63.5kg weight falling 0.76m, required to drive the sampler a distance of 0.3m from 0.15m to 0.45m.

FINE GRAINED SOILS (major portion passing 0.075mm sieve): includes (1) inorganic and organic silts and clays, (2) gravelly, sandy, or silty clays, and (3) clayey silts. Consistency is rated according to shearing strength, as estimated from laboratory or in situ tests.

DESCRIPTIVE TERM	UNCONFINED COMPRESSIVE STRENGTH (kPa)
Very Soft	Less Than 25
Soft	25 to 50
Firm	50 to 100
Stiff	100 to 200
Very Stiff	200 to 400
Hard	Greater Than 400

NOTE: Slickensided and fissured clays may have lower unconfined compressive strengths than shown above, because of planes of weakness or cracks in the soil.

GENERAL DESCRIPTIVE TERMS

Slickensided	- having inclined planes of weakness that are slick and glossy in appearance.
Fissured	- containing shrinkage cracks, frequently filled with fine sand or silt; usually more or less vertical.
Laminated	- composed of thin layers of varying colour and texture.
Interbedded	- composed of alternate layers of different soil types.
Calcareous	- containing appreciable quantities of calcium carbonate.
Well Graded	- having wide range in grain sizes and substantial amounts of intermediate particle sizes.
Poorly graded	- predominantly of one grain size, or having a range of sizes with some intermediate size missing.

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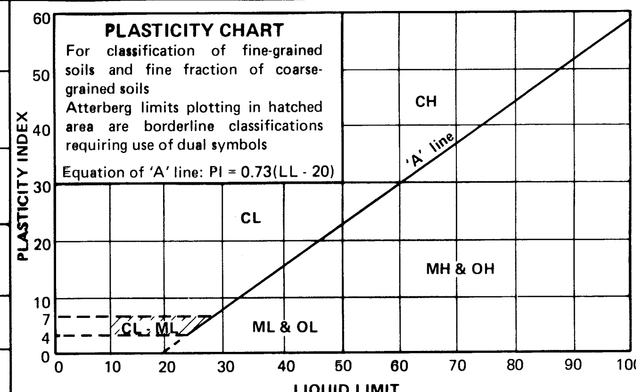
UNIFIED SOIL CLASSIFICATION†

MAJOR DIVISIONS			GROUP SYMBOLS	TYPICAL NAMES	CLASSIFICATION CRITERIA		
COARSE-GRAINED SOILS More than 50% retained on No. 200 sieve*	GRAVELS 50% or more of coarse fraction retained on No. 4 sieve	CLEAN GRAVELS	GW	Well-graded gravels and gravel-sand mixtures, little or no fines	Classification on basis of percentage of fines: Less than 5% pass No. 200 sieve: GW, GP, SW, SP; More than 12% pass No. 200 sieve: GM, GC, SM, SC; 5% to 12% pass No. 200 sieve: Borderline classification requiring use of dual symbols	$C_u = D_{60}/D_{10}$ Greater than 4; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
			GP	Poorly-graded gravels and gravel-sand mixtures, little or no fines		Not meeting both criteria for GW	
		GRAVELS WITH FINES	GM	Silty gravels, gravel-sand-silt mixtures		Atterberg limits plot below 'A' line or plasticity index less than 4	Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols
			GC	Clayey gravels, gravel-sand clay mixtures		Atterberg limits plot above 'A' line and plasticity index greater than 7	
	SANDS More than 50% of coarse fraction passes No. 4 sieve	CLEAN SANDS	SW	Well-graded sands and gravelly sands, little or no fines		$C_u = D_{60}/D_{10}$ Greater than 6; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
			SP	Poorly-graded sands and gravelly sands, little or no fines		Not meeting both criteria for SW	
		SANDS WITH FINES	SM	Silty sands, sand-silt mixtures		Atterberg limits plot below 'A' line or plasticity index less than 4	Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols
			SC	Clayey sands, sand-clay mixtures		Atterberg limits plot above 'A' line and plasticity index greater than 7	
FINE-GRAINED SOILS 50% or more passes No. 200 sieve*	SILTS AND CLAYS	Liquid limit 50% or less	ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands			
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays			
			OL	Organic silts and organic silty clays of low plasticity			
	SILTS AND CLAYS	Liquid limit greater than 50%	MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts			
			CH	Inorganic clay of high plasticity, fat clays			
			OH	Organic clays of medium to high plasticity			
HIGHLY ORGANIC SOILS			PT	Peat, muck and other highly organic soils			



*Based on the material passing the 3 in. (75 mm) sieve
†ASTM Designation D 2487, for identification procedure see D 2488

GROUND ICE DESCRIPTION

ICE NOT VISIBLE

GROUP SYMBOLS	SYMBOLS	SUBGROUP DESCRIPTION
N	Nf	Poorly-bonded or friable
	Nbn	No excess ice, well-bonded
	Nbe	Excess ice, well - bonded

VISIBLE ICE LESS THAN 50% BY VOLUME

GROUP SYMBOLS	SYMBOLS	SUBGROUP DESCRIPTION
V	Vx	Individual ice crystals or inclusions
	Vc	Ice coatings on particles
	Vr	Random or irregularly oriented ice formations
	Vs	Stratified or distinctly oriented ice formations

VISIBLE ICE GREATER THAN 50% BY VOLUME

ICE	ICE + Soil Type	Ice with soil inclusions
	ICE	Ice without soil inclusions (greater than 25 mm (1 in.) thick)

NOTE:
1. *Dual symbols are used to indicate borderline or mixed ice classifications*
2. *Visual estimates of ice contents indicated on borehole logs ± 5%*
3. *This system of ground ice description has been modified from NRC Technical Memo 79, Guide to the Field Description of Permafrost for Engineering Purposes*

LEGEND
Soil Ice

2071/83

TEST PIT LOGS

TP 06-1

Depth	Description
0 to 0.05 m	Black organics and rudimentary topsoil and root mat. Surface reworked.
0.05 to 0.6 m	Brown SAND and GRAVEL with some silt. Occasional cobbles and small boulders.
0.6 m	End of test pit. Refusal on permafrost and due to sides slumping with incoming groundwater.

Notes: 1. Pit was excavated and backfilled on completion on September 14, 2006.
2. Encountered rapid inflow of groundwater at 0.5 m depth.
3. Sample of SAND and GRAVEL soil recovered.
4. Excavated by the Hamlet's Cat 416E.

TP 06-2

Depth	Description
0 to 0.2 m	Brown SAND and GRAVEL with some silt - FILL. Occasional cobbles and small boulders.
0.2 to 0.5 m	Soil mixed with burnt refuse from a former solid waste landfill operation. Pieces of metal framing, lumber, plywood and fabrics along with assorted garbage and ash.
0.5 m	End of test pit. Refusal on permafrost and rapid inflow of groundwater.

Notes: 1. Pit was excavated and backfilled on completion on September 14, 2006.
2. Encountered rapid inflow of groundwater at 0.3 m depth.
3. No sample recovered.
4. Excavated by the Hamlet's Cat 416E.

TP 06-3

Depth	Description
0 to 1.4 m	Brown SAND and GRAVEL with some silt. Occasional cobbles and small boulders. No surficial organics. Surface reworked.
1.4 m	End of test pit. Pit side walls were rapidly caving. Base of pit close to permafrost. Groundwater seeping into pit.

Notes: 1. Pit was excavated and backfilled on completion on September 14, 2006.
2. Encountered seepage of groundwater below 0.3 m depth.
3. Sample of SAND and GRAVEL soil recovered.
4. Excavated by the Hamlet's Cat 416E.

EBA Engineering Consultants Ltd.

GRAIN SIZE DISTRIBUTION

Project: Geotechnical Evaluation for Municipal Waste Facilities

Project Number: 1700219

Client: Earth Tech (Canada) Inc.

Attention: Mr. Ken Johnson, P.Eng.

Date Tested: October 17, 2006

Sample Location: n/a

Depth: n/a

Sample ID: BA 1

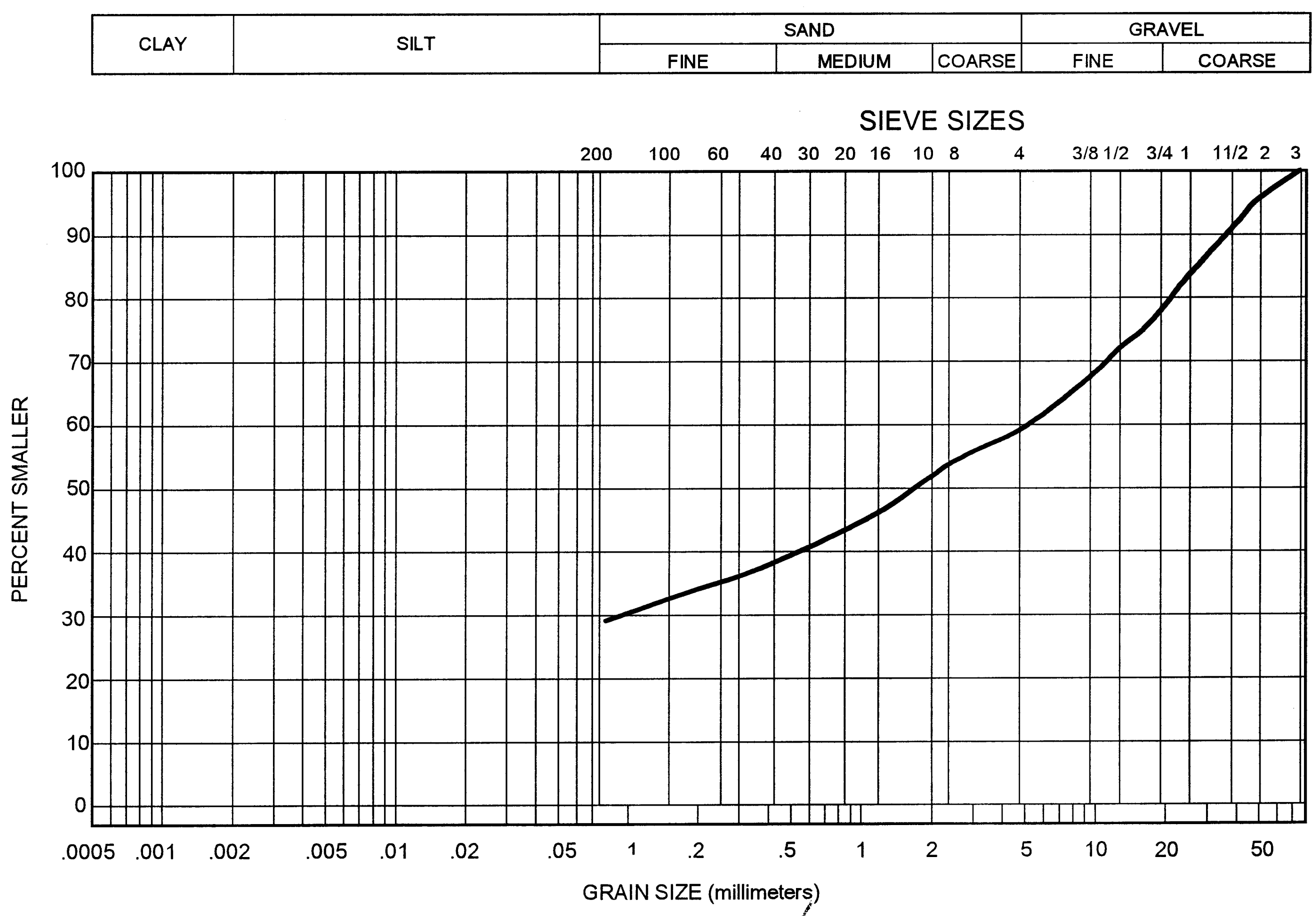
Lab Number: 4332-1

Soil Description: GRAVEL, sandy, silty

Natural Moisture Content: 2.9%

Remarks: Soil contents trace of grass roots

SIEVE	PERCENTAGE PASSING
50	96
40	92
25	83
20	79
16	75
12.5	72
10	68
5	60
2.5	54
1.25	47
0.63	41
0.315	36
0.16	33
0.08	29



Reviewed By:__________________ P.Eng.

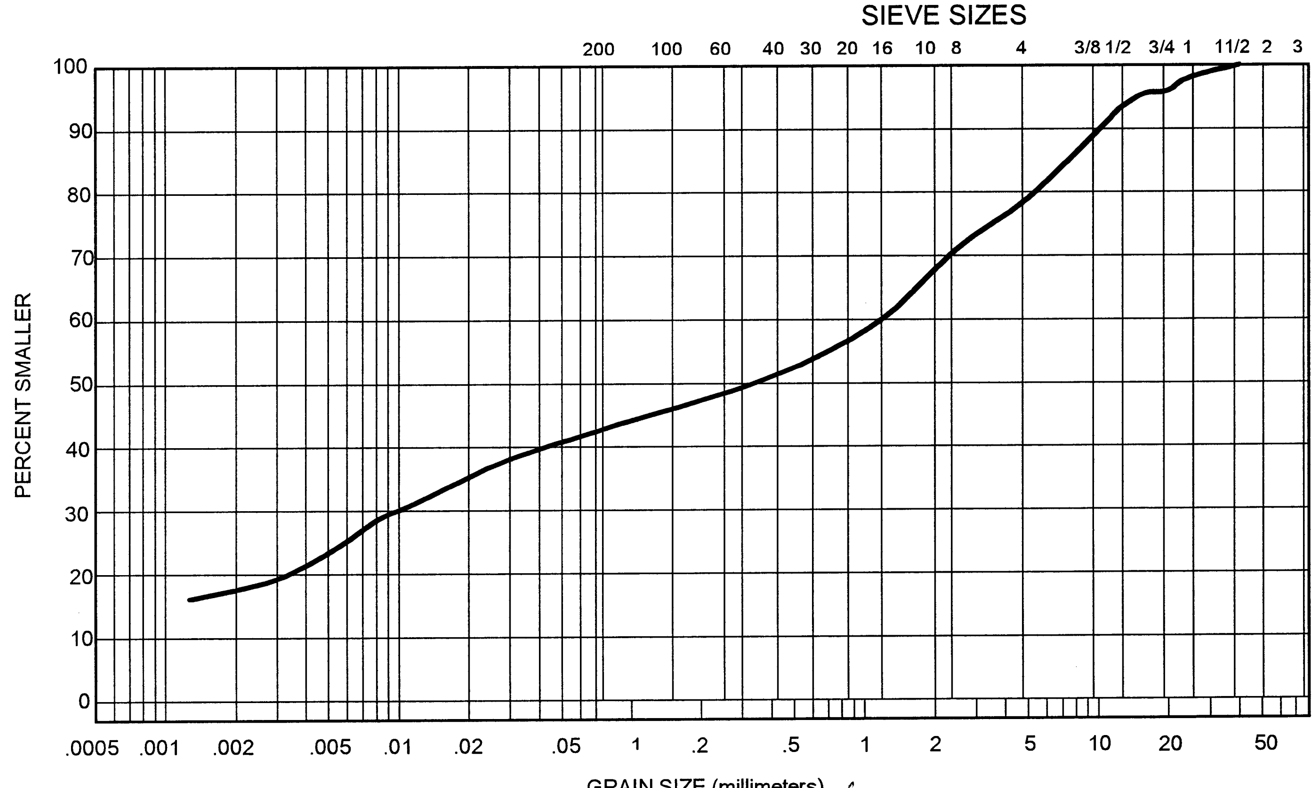
EBA Engineering Consultants Ltd.

GRAIN SIZE DISTRIBUTION

Project: Geotechnical Evaluation for Municipal Waste Facilities
Project Number: 1700219
Client: Earth Tech (Canada) Inc.
Attention: Mr. Ken Johnson, P.Eng.
Date Tested: October 18-23, 2006
Sample Location: n/a
Depth: n/a
Sample ID: BA 2
Lab Number: 4332-2
Soil Description: SAND, gravelly, silty, some clay
Natural Moisture Content: 12.0%
Remarks: LL=29%; PL=17%; PI=12%; USC = "CL"

SIEVE	PERCENTAGE PASSING
50	
40	100
25	98
20	96
16	96
12.5	93
10	90
5	79
2.5	71
1.25	61
0.63	54
0.315	50
0.16	46
0.08	43

CLAY	SILT	SAND			GRAVEL	
		FINE	MEDIUM	COARSE	FINE	COARSE



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Project: Geotechnical Evaluation for Municipal Waste Facilities

Project Number: 1700219

Client: Earth Tech (Canada) Inc.

Attention: Mr. Ken Johnson, P.Eng.

Date Tested: October 17, 2006

Sample Location: n/a

Depth: n/a

Sample ID: BA 4

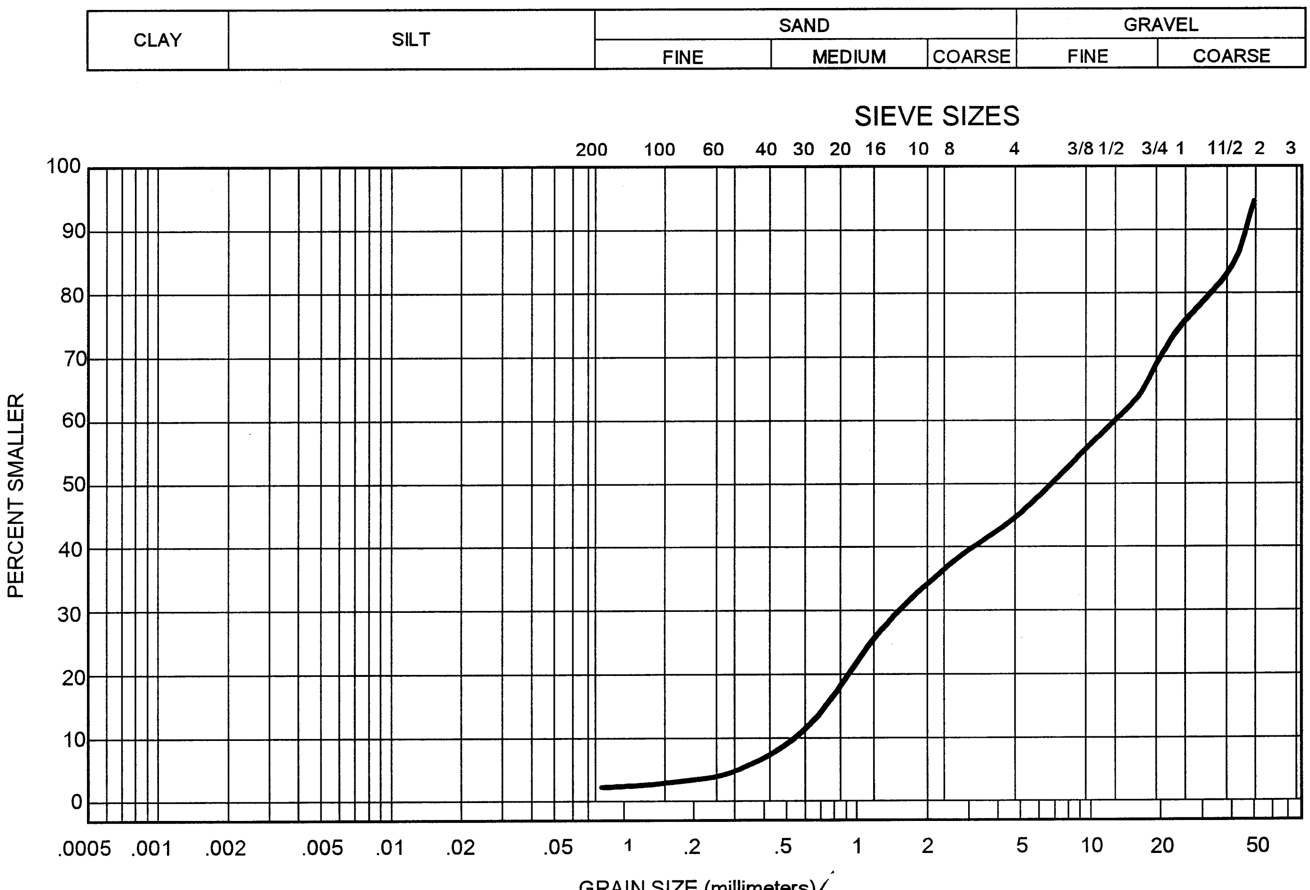
Lab Number: 4332-3

Soil Description: GRAVEL and SAND, trace silt

Natural Moisture Content: 3.2%

Remarks:

SIEVE	PERCENTAGE PASSING
50	94
40	84
25	75
20	70
16	64
12.5	60
10	56
5	45
2.5	37
1.25	27
0.63	12
0.315	5
0.16	3
0.08	2



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GRAIN SIZE DISTRIBUTION

Project: Geotechnical Evaluation for Municipal Waste Facilities

Project Number: 1700219

Client: Earth Tech (Canada) Inc.

Attention: Mr. Ken Johnson, P.Eng.

Date Tested: October 16-17, 2006

Sample Location: n/a

Depth: n/a

Sample ID: BA 6

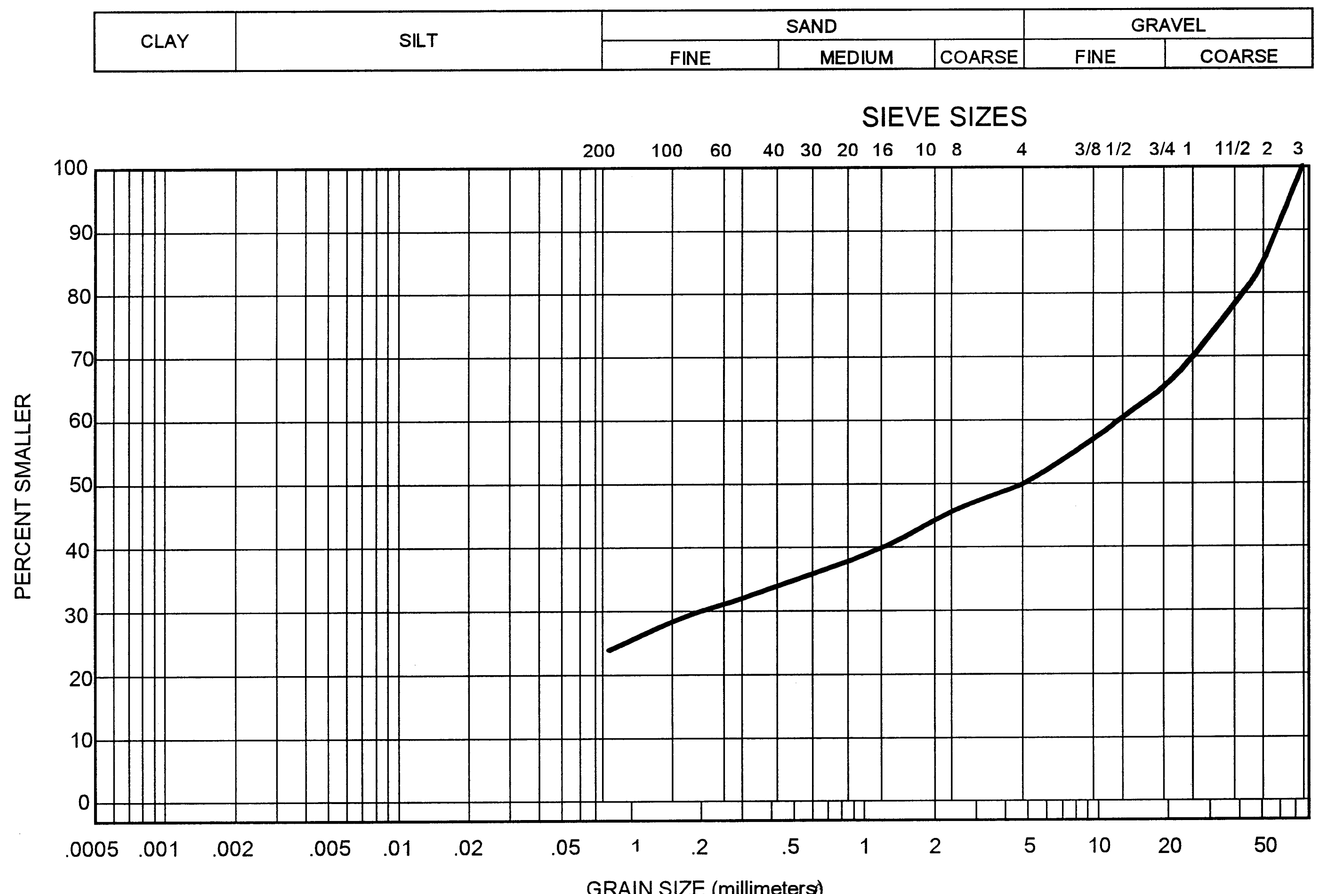
Lab Number: 4332-4

Soil Description: GRAVEL, sandy, silty

Natural Moisture Content: 3.6%

Remarks: Soil contents trace of peat

SIEVE	PERCENTAGE PASSING
50	84
40	79
25	69
20	66
16	63
12.5	60
10	57
5	50
2.5	46
1.25	40
0.63	36
0.315	32
0.16	29
0.08	24



Reviewed By: _______________ P.Eng.

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GRAIN SIZE DISTRIBUTION

Project: Geotechnical Evaluation for Municipal Waste Facilities

Project Number: 1700219

Client: Earth Tech (Canada) Inc.

Attention: Mr. Ken Johnson, P.Eng.

Date Tested: October 11, 2006

Sample Location: n/a

Depth: n/a

Sample ID: TP1

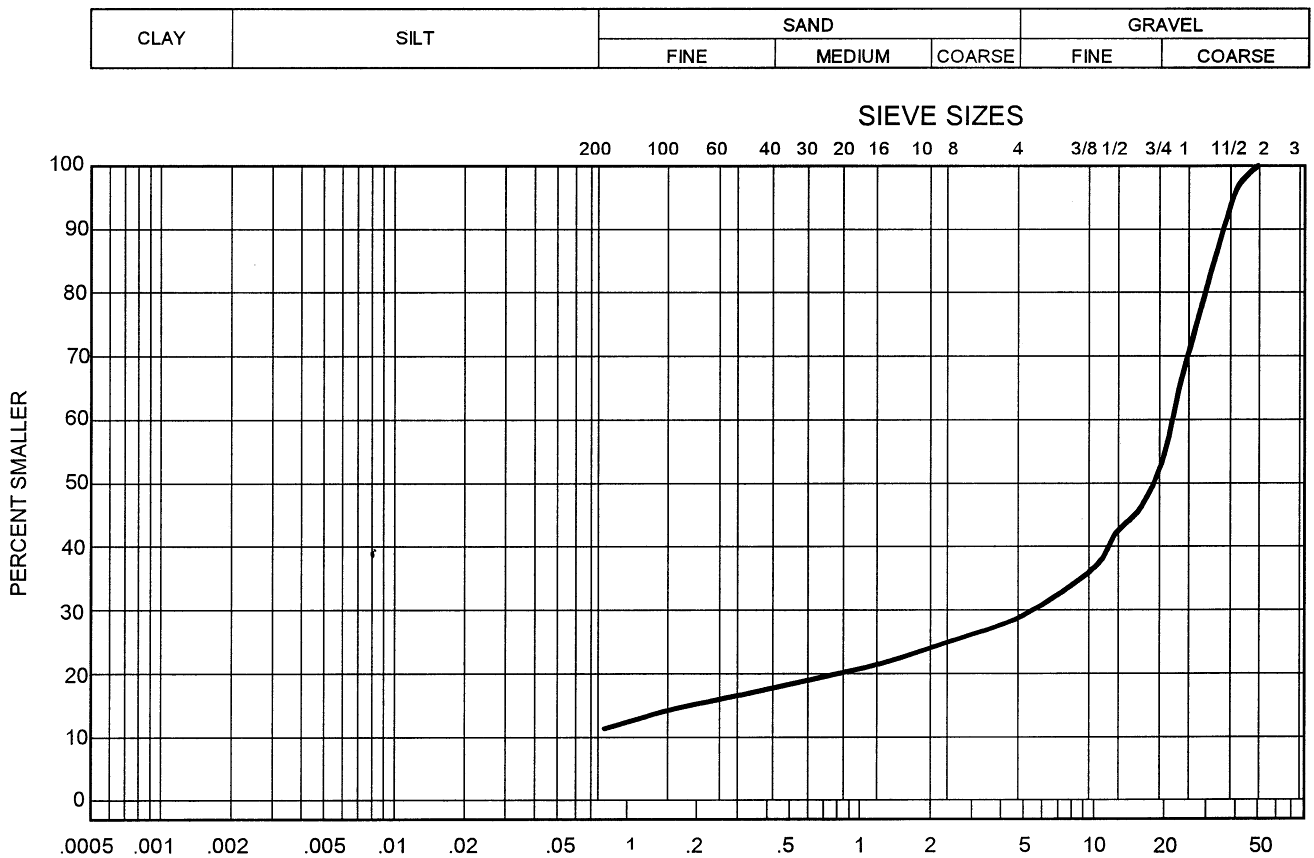
Lab Number: 4332-5

Soil Description: GRAVEL, some sand, some silt

Natural Moisture Content: 9.0%

Remarks: Soil contents trace of grass roots

SIEVE	PERCENTAGE PASSING
50	100
40	96
25	69
20	54
16	46
12.5	42
10	37
5	29
2.5	25
1.25	22
0.63	19
0.315	17
0.16	14
0.08	11



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GRAIN SIZE DISTRIBUTION

Project: Geotechnical Evaluation for Municipal Waste Facilities

Project Number: 1700219

Client: Earth Tech (Canada) Inc.

Attention: Mr. Ken Johnson, P.Eng.

Date Tested: October 11,13-14, 2006

Sample Location: n/a

Depth: n/a

Sample ID: TP3

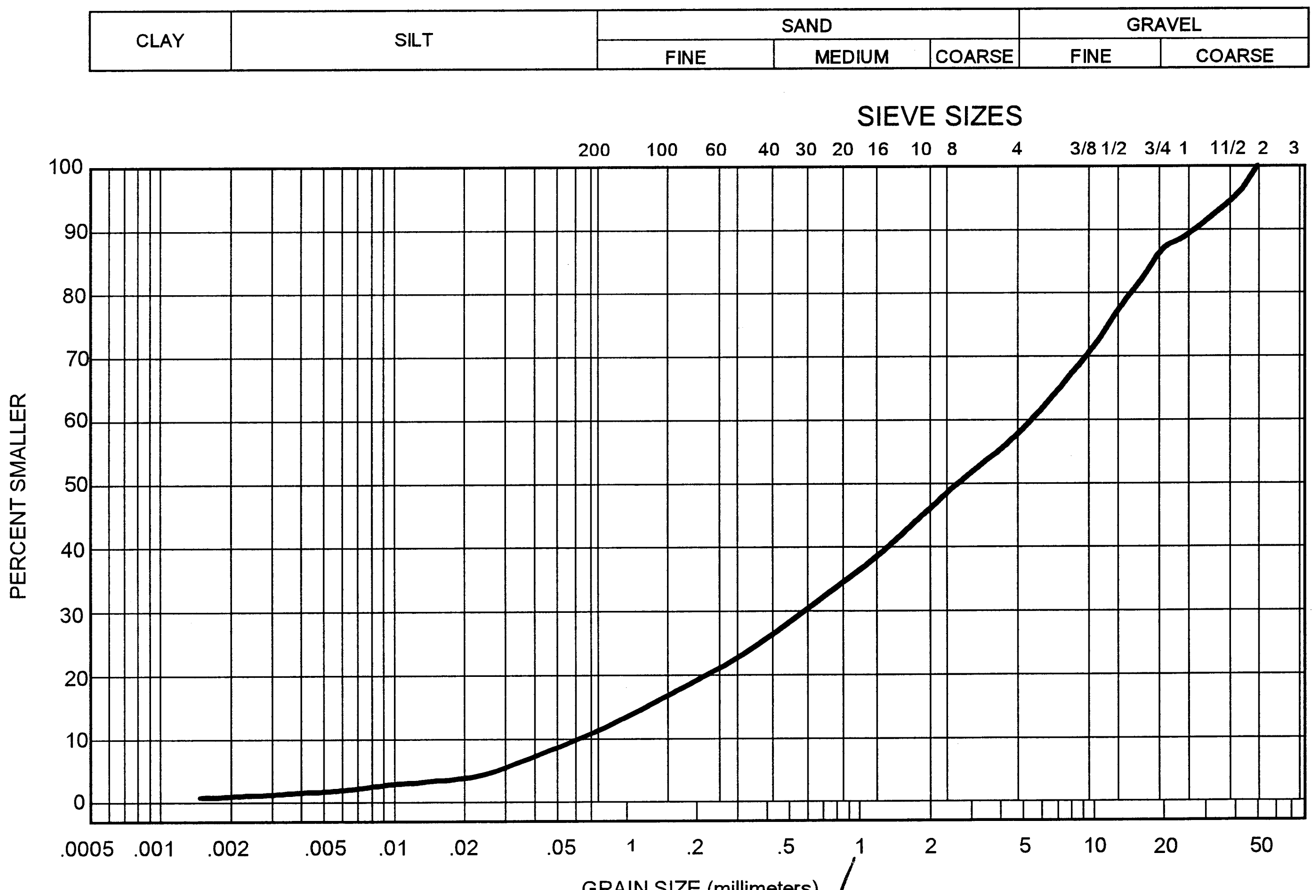
Lab Number: 4332-7

Soil Description: GRAVEL and SAND, some silt, trace clay

Natural Moisture Content: 5.9%

Remarks: Nonplastic fines

SIEVE	PERCENTAGE PASSING
50	100
40	95
25	89
20	87
16	82
12.5	77
10	72
5	59
2.5	49
1.25	39
0.63	31
0.315	23
0.16	17
0.08	12



Reviewed By: ____________ P.Eng.

EBA Engineering Consultants Ltd.

GRAIN SIZE DISTRIBUTION

Project: Geotechnical Evaluation for Municipal Waste Facilities

Project Number: 1700219

Client: Earth Tech (Canada) Inc.

Attention: Mr. Ken Johnson, P.Eng.

Date Tested: October 11, 2006

Sample Location: n/a

Depth: n/a

Sample ID: S'A'

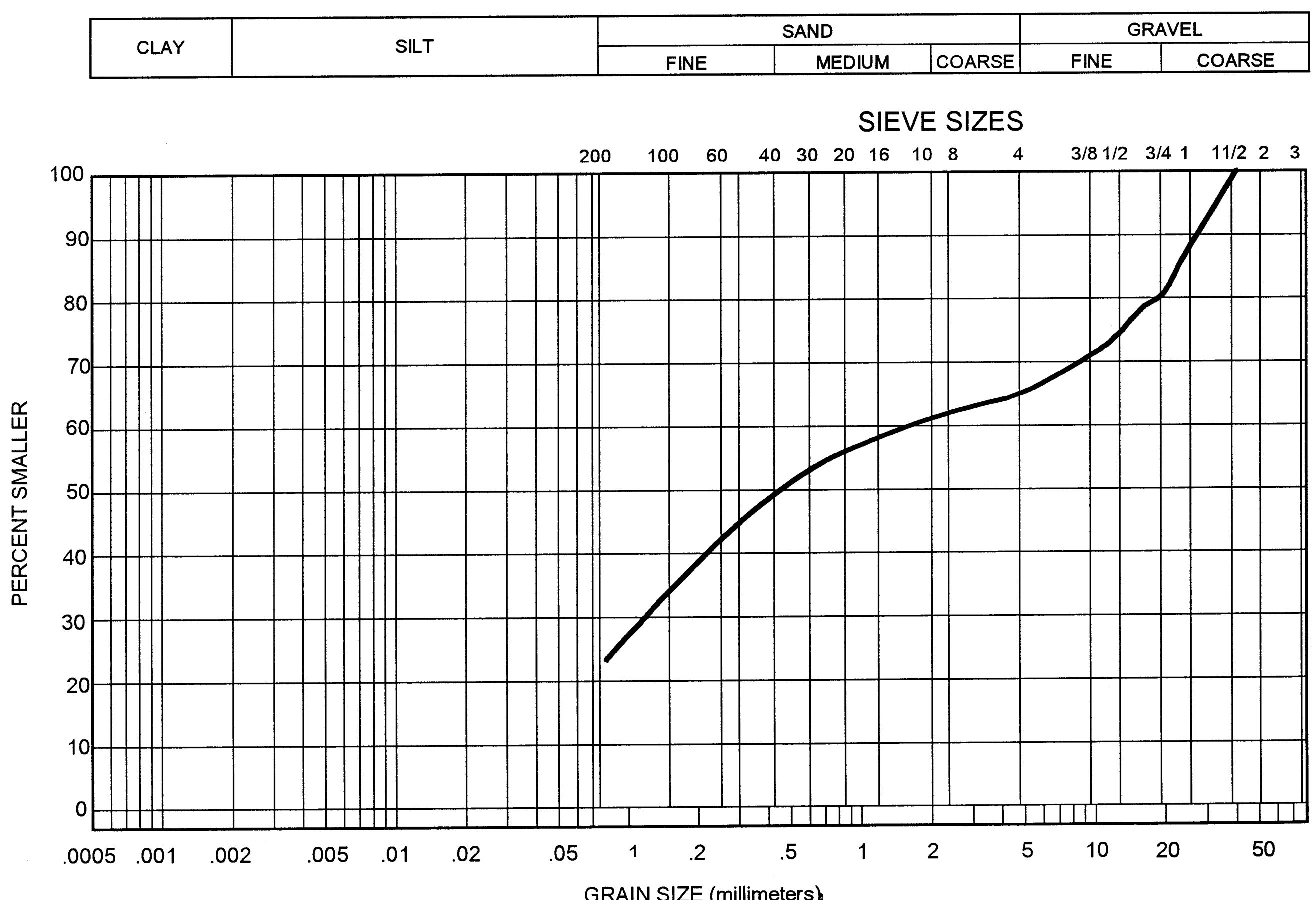
Lab Number: 4332-8

Soil Description: SAND and GRAVEL, silty

Natural Moisture Content: 16.8%

Remarks: Soil contents trace of grass roots

SIEVE	PERCENTAGE PASSING
50	
40	100
25	88
20	81
16	78
12.5	74
10	71
5	65
2.5	62
1.25	58
0.63	53
0.315	45
0.16	35
0.08	23



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GRAIN SIZE DISTRIBUTION

Project: Geotechnical Evaluation for Municipal Waste Facilities

Project Number: 1700219

Client: Earth Tech (Canada) Inc.

Attention: Mr. Ken Johnson, P.Eng.

Date Tested: October 11, 13-14, 2006

Sample Location: n/a

Depth: n/a

Sample ID: S'B'

Lab Number: 4332-9

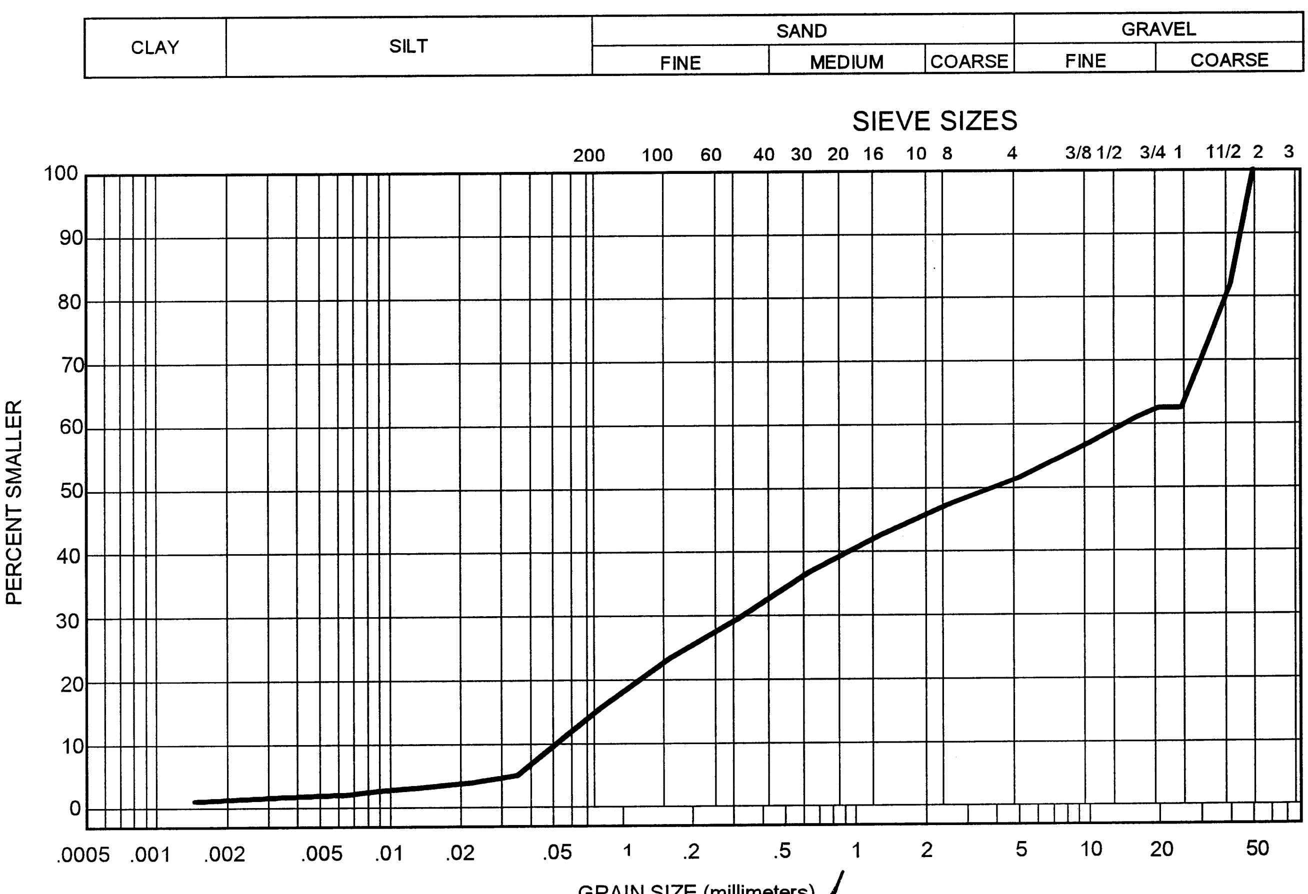
Soil Description: GRAVEL and SAND, some silt, trace clay

Natural Moisture Content: 14.0%

Remarks: Soil contents trace of peat and grass roots

Nonplastic fines

SIEVE	PERCENTAGE PASSING
50	100
40	82
25	62
20	62
16	61
12.5	59
10	57
5	51
2.5	47
1.25	42
0.63	37
0.315	30
0.16	23
0.08	16



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EBA Engineering Consultants Ltd.

GRAIN SIZE DISTRIBUTION

Project: Geotechnical Evaluation for Municipal Waste Facilities

Project Number: 1700219

Client: Earth Tech (Canada) Inc.

Attention: Mr. Ken Johnson, P.Eng.

Date Tested: October 12, 2006

Sample Location: n/a

Depth: n/a

Sample ID: S'C'

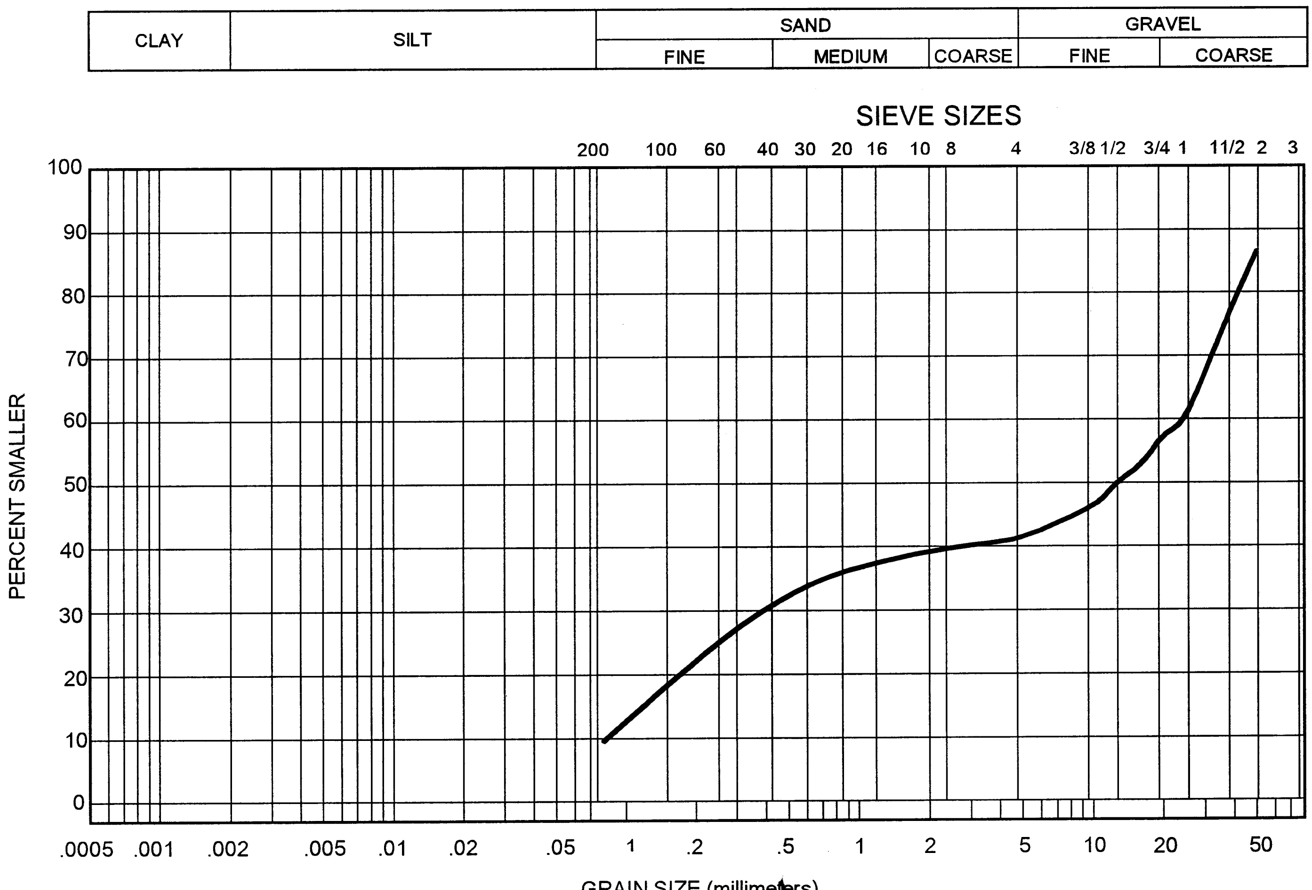
Lab Number: 4332-10

Soil Description: GRAVEL, sandy, trace silt

Natural Moisture Content: 10.3%

Remarks: Soil contents trace of peat and grass roots

SIEVE	PERCENTAGE PASSING
50	86
40	79
25	61
20	57
16	53
12.5	50
10	46
5	41
2.5	40
1.25	38
0.63	34
0.315	28
0.16	19
0.08	9



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EBA Engineering Consultants Ltd.

GRAIN SIZE DISTRIBUTION

Project: Geotechnical Evaluation for Municipal Waste Facilities

Project Number: 1700219

Client: Earth Tech (Canada) Inc.

Attention: Mr. Ken Johnson, P.Eng.

Date Tested: October 12, 2006

Sample Location: n/a

Depth: n/a

Sample ID: S'D'

Lab Number: 4332-11

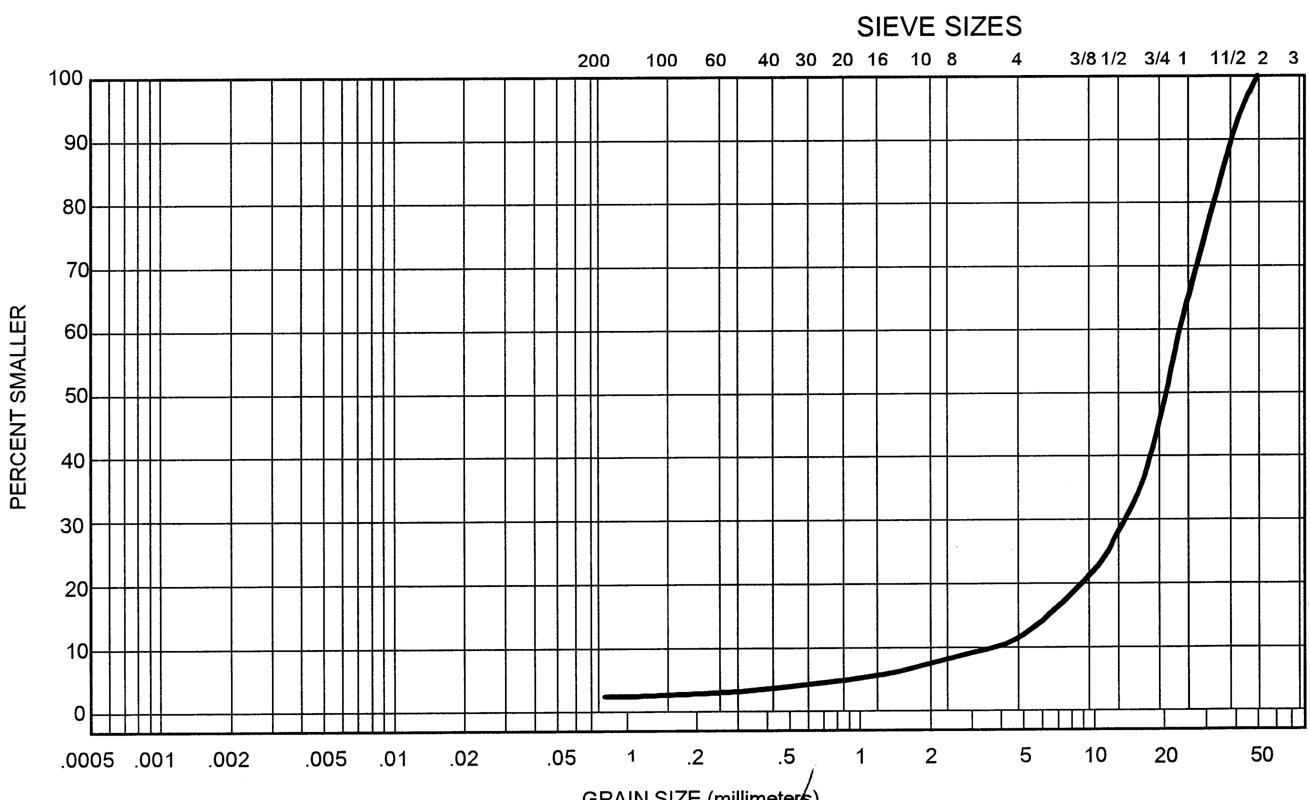
Soil Description: GRAVEL, some sand, trace silt

Natural Moisture Content: 8.0%

Remarks: Soil contents trace of peat and grass roots

SIEVE	PERCENTAGE PASSING
50	100
40	92
25	64
20	48
16	35
12.5	28
10	22
5	12
2.5	8
1.25	6
0.63	4
0.315	3
0.16	3
0.08	2

CLAY	SILT	SAND			GRAVEL	
		FINE	MEDIUM	COARSE	FINE	COARSE



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EBA Engineering Consultants Ltd.

GRAIN SIZE DISTRIBUTION

Project: Geotechnical Evaluation for Municipal Waste Facilities

Project Number: 1700219

Client: Earth Tech (Canada) Inc.

Attention: Mr. Ken Johnson, P.Eng.

Date Tested: October 12, 13-14, 2006

Sample Location: n/a

Depth: n/a

Sample ID: S'E'

Lab Number: 4332-12

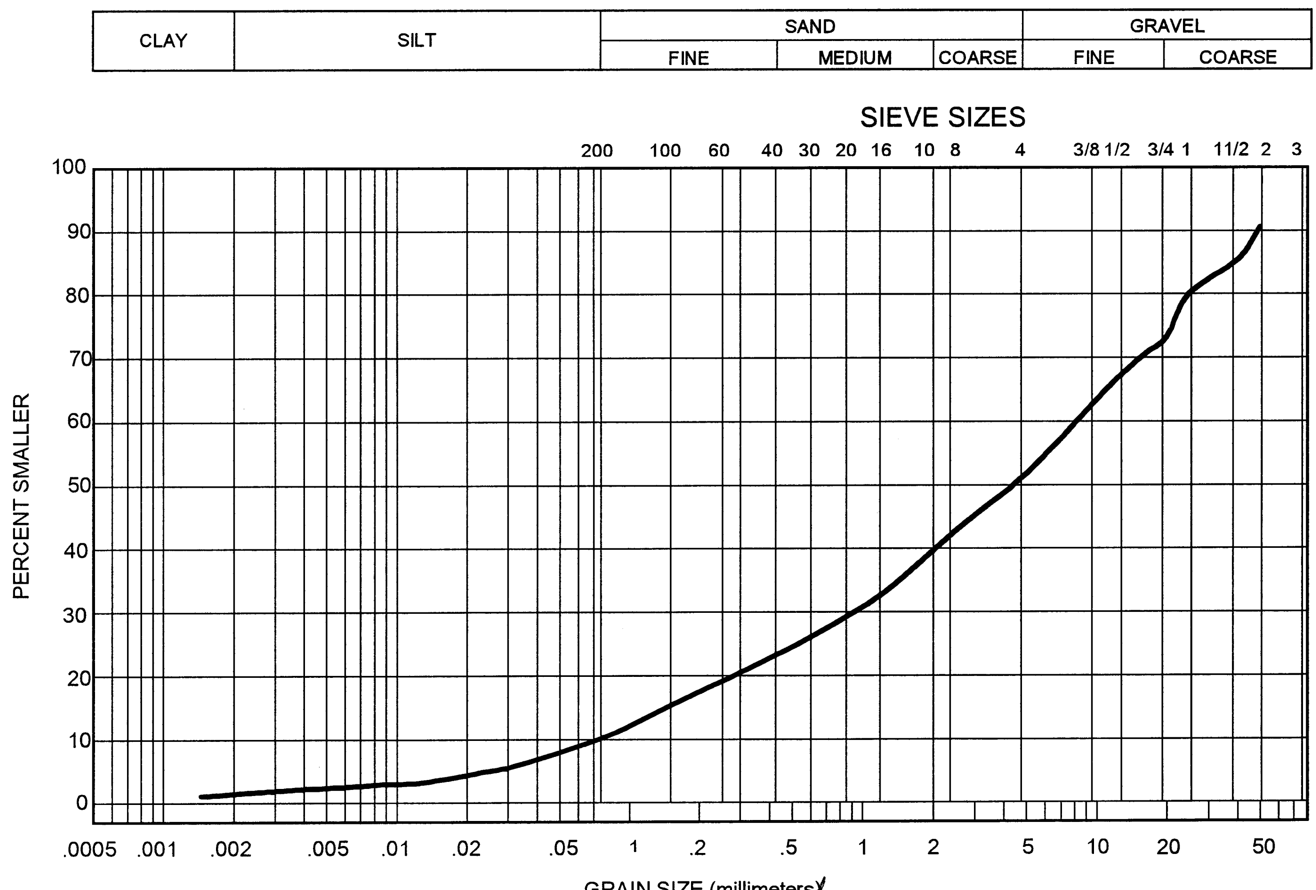
Soil Description: GRAVEL and SAND, trace silt, trace clay

Natural Moisture Content: 3.9%

Remarks: Soil contents trace of peat and grass roots

Nonplastic fines

SIEVE	PERCENTAGE PASSING
50	91
40	85
25	80
20	73
16	70
12.5	67
10	63
5	52
2.5	43
1.25	33
0.63	26
0.315	21
0.16	16
0.08	11



Reviewed By:____________ P.Eng.

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EBA Engineering Consultants Ltd.

GRAIN SIZE DISTRIBUTION

Project: Geotechnical Evaluation for Municipal Waste Facilities

Project Number: 1700219

Client: Earth Tech (Canada) Inc.

Attention: Mr. Ken Johnson, P.Eng.

Date Tested: October 12, 2006

Sample Location: n/a

Depth: n/a

Sample ID: S'F'

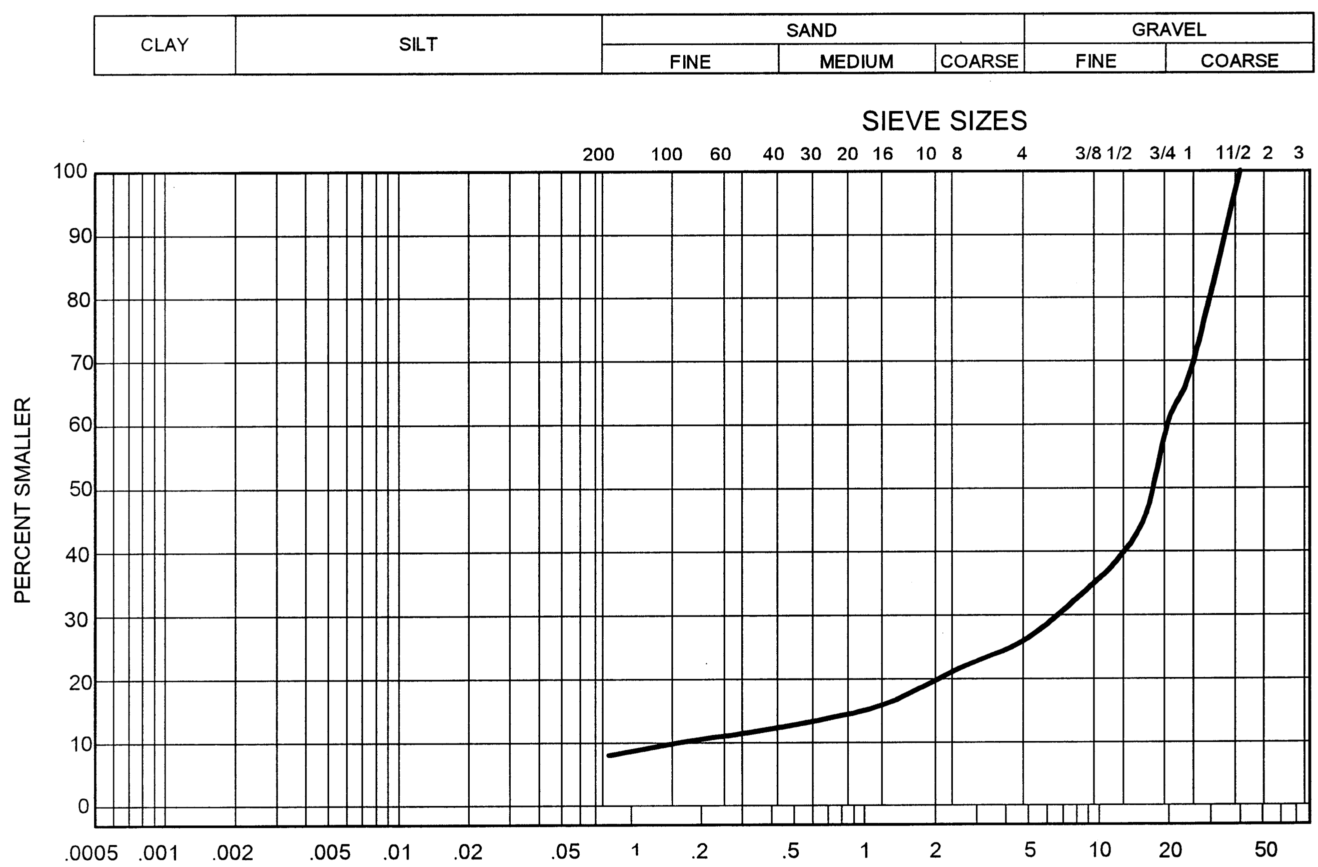
Lab Number: 4332-13

Soil Description: GRAVEL, some sand, trace silt

Natural Moisture Content: 9.8%

Remarks: Soil contents trace of peat and grass roots

SIEVE	PERCENTAGE PASSING
50	
40	100
25	69
20	61
16	46
12.5	39
10	36
5	26
2.5	22
1.25	16
0.63	13
0.315	12
0.16	10
0.08	8



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EBA Engineering Consultants Ltd.

CONSTANT HEAD PERMEABILITY TEST **MUNICIPAL WASTE FACILITIES**

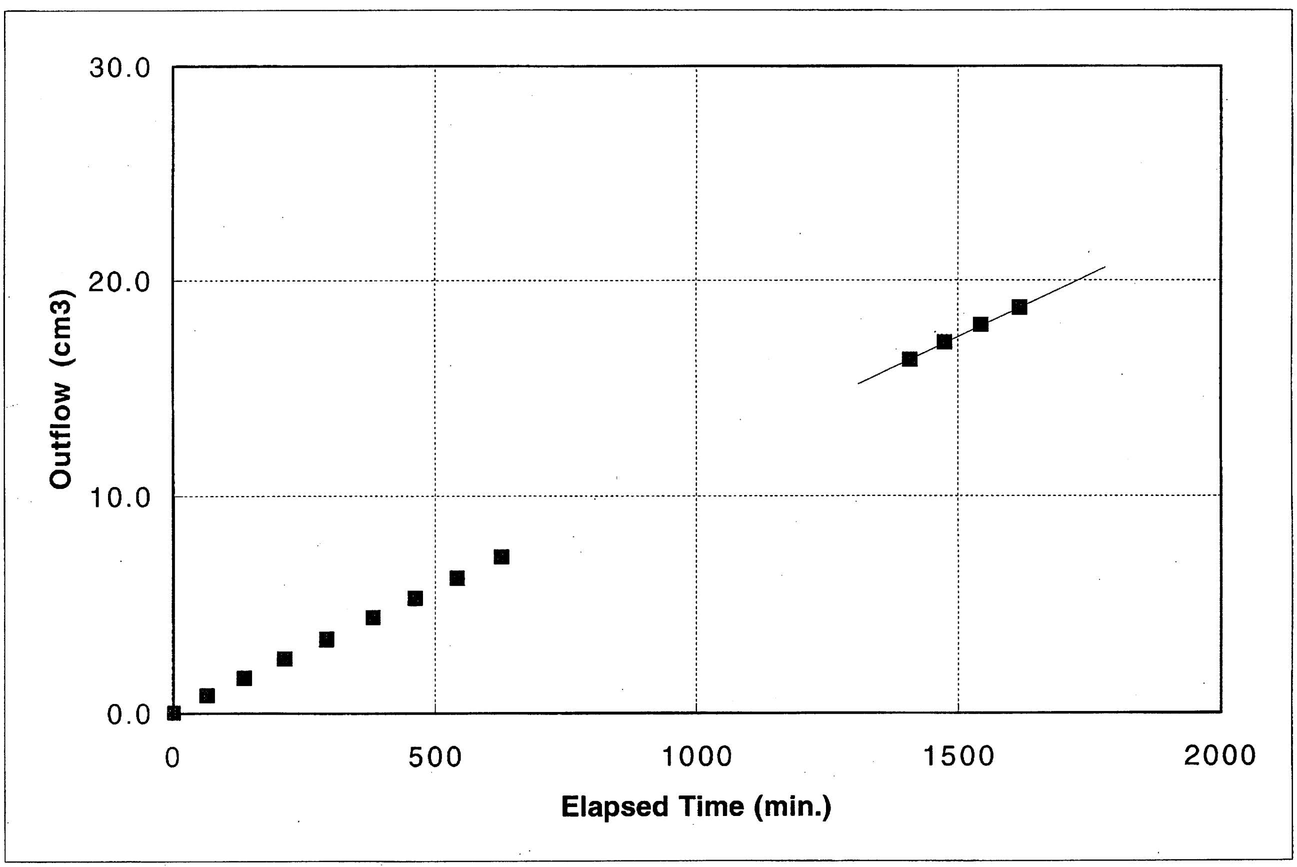
Job Number: 1700219
Sample No.: 4332-4 Location: BA6

Date: 06-11-04
Test No: P-1

Time	Buret (cc)	Elap. (min)	Outflow (cc)
6:58	12.3	0	0.0
8:02	13.1	64	0.8
9:13	13.9	135	1.6
10:31	14.8	213	2.5
11:50	15.7	292	3.4
13:18	16.7	380	4.4
14:40	17.6	462	5.3
16:01	18.5	543	6.2
17:25	19.5	627	7.2
6:28	10.4	1410	16.3
7:34	9.6	1476	17.1
8:43	8.8	1545	17.9
9:56	8.0	1618	18.7

Diameter=	70.94	mm
Height=	50.86	mm
Volume=	201.02	cm^3
Head Diff.=	1	psi
Q=	0.00019	cm^3/sec
i=	13.83	
A=	39.53	cm^2

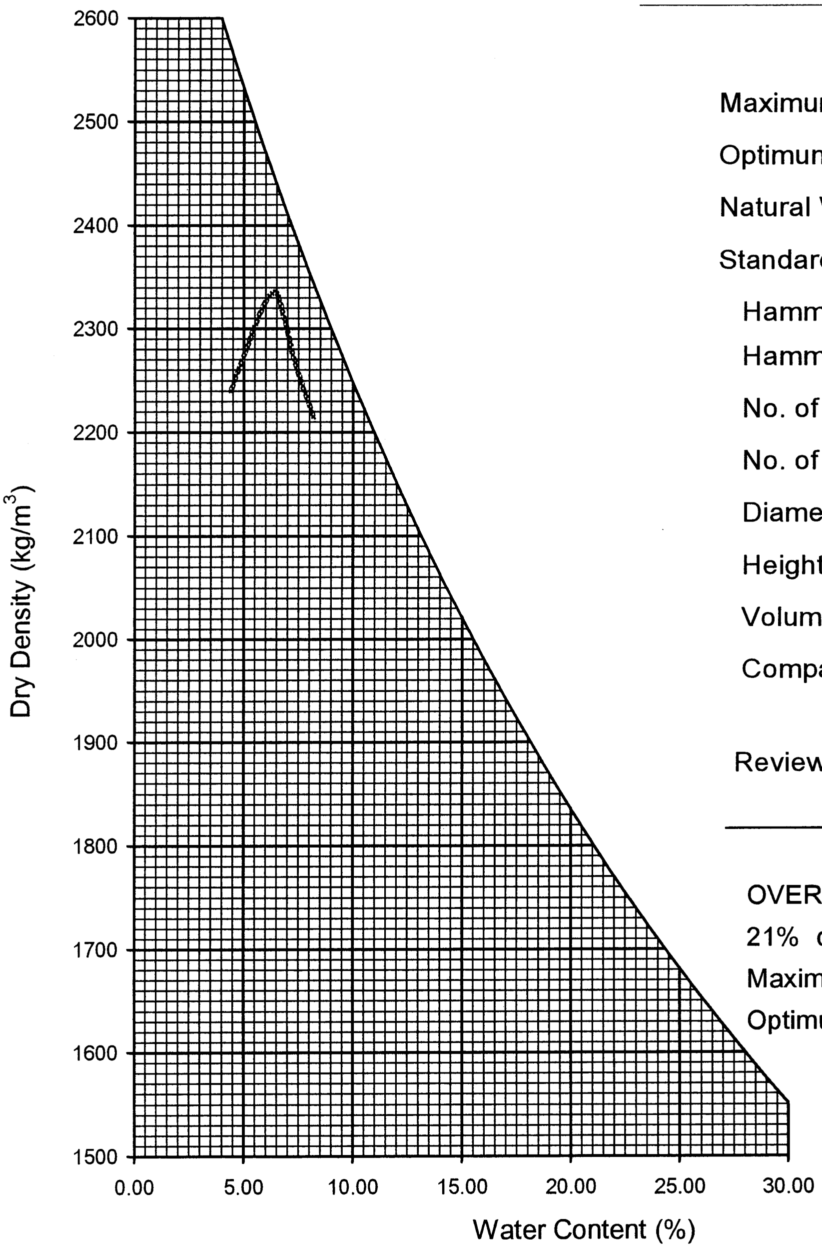
K= 3.52E-07 cm/sec



EBA Engineering Consultants Ltd.

MOISTURE-DENSITY RELATIONSHIP

Project:	Municipal Waste Facilities	Sample No.:	4332-1
Address:	Cambridge Bay, NU	Date Sampled:	n/a
		Sample Location:	BA 1
Project No.:	1700219		
Date Tested:	16-Oct-06 By: JB	Sample Description:	GRAVEL - sandy, silty
Client:	Earth Tech (Canada) Inc.	Note: Oversize correction applied	
Attention:	Mr. Ken Johnson, P. Eng.	according to: AASHTO T 224-86 (1993)	



Maximum Dry Density:	2330 kg/m^3
Optimum Water Content:	6.5%
Natural Water Content:	N/A
Standard Proctor (ASTM D 698) Part D	
Hammer Weight:	2.5 kg
Hammer Drop:	305 mm
No. of Layers:	3
No. of Blows / Layer:	56
Diameter of Mould:	152 mm
Height of Mould:	116 mm
Volume Mould:	2124 cm^3
Compactive Effort:	600 kJ/m^3

Reviewed By:

________________ P. Eng.

OVERSIZE CORRECTION

21% oversize, Bulk Sp.Gr.: 2.65 (assumed)

Maximum Dry Density: 2370 kg/m^3

Optimum Moisture Content: 5.0 %

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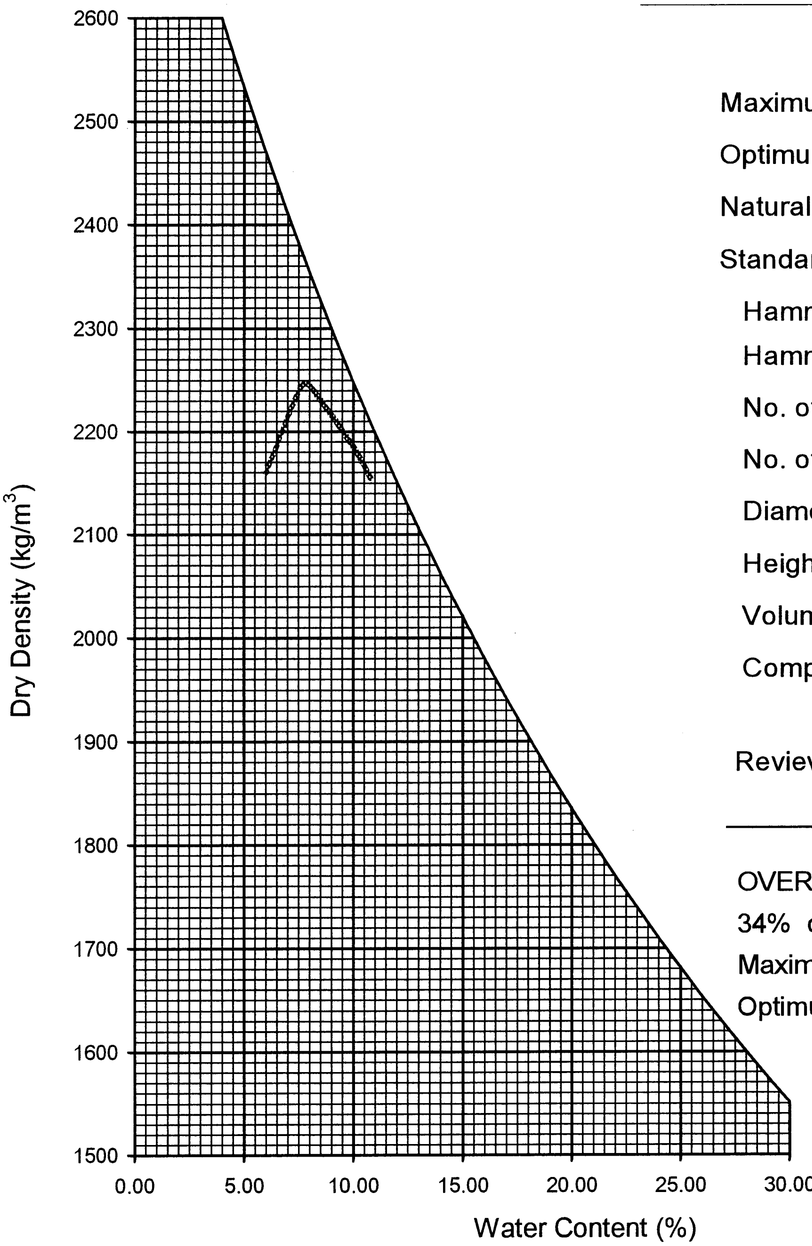
EBA Engineering Consultants Ltd.

MOISTURE-DENSITY RELATIONSHIP

Project:	Municipal Waste Facilities	Sample No.:	4332-4
Address:	Cambridge Bay, NU	Date Sampled:	n/a
		Sample Location:	BA 6
Project No.:	1700219		
Date Tested:	16-Oct-06 By: JB	Sample Description:	Gravel, sandy, silty
Client:	Earth Tech (Canada) Inc.	Note: Oversize correction applied	
Attention:	Mr. Ken Johnson, P. Eng.	according to: AASHTO T 224-86 (1993)	



Maximum Dry Density: 2250 kg/m^3

Optimum Water Content: 8.0%

Natural Water Content: N/A

Standard Proctor (ASTM D 698) Part D

Hammer Weight:	2.5 kg
Hammer Drop:	305 mm
No. of Layers:	3
No. of Blows / Layer:	56
Diameter of Mould:	152 mm
Height of Mould:	116 mm
Volume Mould:	2124 cm^3
Compactive Effort:	600 kJ/m^3

Reviewed By:

_______________ P. Eng.

OVERSIZE CORRECTION

34% oversize, Bulk Sp.Gr.: 2.65 (assumed)

Maximum Dry Density: 2320 kg/m^3

Optimum Moisture Content: 5.5 %

eba

APPENDIX

APPENDIX C GENERAL CONSTRUCTION GUIDELINES

CONSTRUCTION EXCAVATIONS

Construction should be in accordance with good practice and comply with the requirements of the responsible regulatory agencies.

All excavations greater than 1.5 m deep should be sloped or shored for worker protection.

Shallow excavations up to about 3 m depth may use temporary sideslopes of 1H:1V. A flatter slope of 2H:1V should be used if groundwater is encountered. Localized sloughing can be expected from these slopes.

Deep excavations or trenches may require temporary support if space limitations or economic considerations preclude the use of sloped excavations.

For excavations greater than 3 m depth, temporary support should be designed by a qualified geotechnical engineer. The design and proposed installation and construction procedures should be submitted to EBA for review.

The construction of a temporary support system should be monitored. Detailed records should be taken of installation methods, materials, in situ conditions and the movement of the system. If anchors are used, they should be load tested. EBA can provide further information on monitoring and testing procedures if required.

Attention should be paid to structures or buried service lines close to the excavation. For structures, a general guideline is that if a line projected down, at 45 degrees from the horizontal from the base of foundations of adjacent structures intersects the extent of the proposed excavation, these structures may require underpinning or special shoring techniques to avoid damaging earth movements. The need for any underpinning or special shoring techniques and the scope of monitoring required can be determined when details of the service ducts and vaults, foundation configuration of existing buildings and final design excavation levels are known.

No surface surcharges should be placed closer to the edge of the excavation than a distance equal to the depth of the excavation, unless the excavation support system has been designed to accommodate such surcharge.

BACKFILL MATERIALS AND COMPACTION

Maximum density as used in this section means Standard Proctor Maximum Dry Density (ASTM Test Method D698) unless specifically noted otherwise. Optimum moisture content is as defined in this test.

'General engineered fill' materials should comprise clean, well-graded granular soils or inorganic low plastic clay soils. Fill materials should be placed in layers of 150 millimetres compacted thickness. General engineered fills should be compacted to a minimum of 98 percent of maximum density.

Granular soils used for general engineered fills should consist of relatively clean, well graded mixture of sand and gravel (maximum size 75 mm).

Low plastic clay with the following range of Atterberg limits is generally considered suitable for use as engineered fill.

Liquid Limit:	less than 30%
Plasticity Index:	greater than 4

Clay fill material should be compacted at or slightly above the optimum moisture content.

'Structural fill' materials should comprise clean, well-graded inorganic granular soils. Such fill should be placed in compacted lifts not exceeding 150 mm and compacted to not less than 100 percent of maximum density, at a moisture content at or slightly above optimum.

'Landscape fill' material may comprise soils without regard to engineering quality. Such soils should be placed in compacted lifts not exceeding 300 mm in thickness and compacted to a density of not less than 90 percent of maximum density.

Backfill adjacent to and above footings, abutment walls, basement walls, grade beams, and pile caps or below highway, street, or parking lot pavement sections and base courses should comprise 'general engineered fill' materials as defined above.

Backfill supporting structural loads should comprise 'structural fill' materials as defined above.

Backfill adjacent to exterior footings, foundation walls, grade beams, and pile caps and within 300 mm of final grade should comprise inorganic low plastic clay 'general engineered' fill as defined above. Such backfill should provide a relatively impervious surface layer to reduce seepage into the subsoil.

Backfill should not be placed against a foundation structure until the structure has sufficient strength to withstand the earth pressures resulting from placement and compaction. During compaction, careful observation of the foundation wall for deflection should be carried out continuously. Where deflections are apparent, the compactive effort should be reduced accordingly.

In order to reduce potential compaction induced stresses, only hand held compaction equipment should be used in the compaction of fill within 500 mm of retaining walls or basement walls.

Backfill materials should not be placed in a frozen state, or placed on a frozen subgrade. All lumps of materials should be broken down during placement.

Where the size of the largest particles in any backfill material exceeds half of the minimum dimension of the cross-section to be backfilled, such particles should be removed and placed at other, more suitable, locations on-site or screened off prior to delivery to site.

Bonding should be provided between backfill lifts, if the previous lift has become desiccated. For fine-grained materials the previous lift should be scarified to the base of the desiccated layer, properly moisture-conditioned and recompacted and bonded thoroughly to the succeeding lift. For granular materials, the surface of the previous lift should be scarified to about a 75 mm depth followed by proper moisture-conditioning and recompaction.

Recommendations for specifications for various backfill types are presented below.

'Pit-Run gravel' should conform to the following grading:

TABLE 1: PIT-RUN GRAVEL GRADING STANDARDS

Sieve Size	Percent Passing by Mass
75.0 mm	100
5.0 mm	25 – 50
0.08 mm	3 – 8

The percent of material passing the 0.08 mm sieve should not exceed 2/3 of the material passing the 0.4 mm sieve. The Pit-Run gravel should be free of any form of coating and any gravel containing clay, loam or other deleterious materials should be rejected. No oversize material should be tolerated. Any gravel containing deleterious material should be rejected.

Twenty mm and 50 mm crushed gravel should be hard, clean, well graded, crushed aggregate, free of organics, coal, clay lumps, coatings of clay, silt and other deleterious materials. The aggregates should conform to the following gradation requirement when tested in accordance with ASTM C136:

TABLE 2: ASTM C136 CRUSHED GRAVEL GRADATIONS		
Sieve Size	**Percent Passing by Mass**	
	20 mm Minus Crush	**50 mm Minus Crush**
50 mm	--	100
20 mm	100	65 – 95
12.5 mm	60 – 95	50 – 75
5.0 mm	40 – 65	30 – 55
1.25 mm	20 – 40	20 – 40
0.315 mm	10 – 25	10 – 25
0.08 mm	2 – 8	2 – 8

A minimum of 60 percent of the material retained on the 5 mm sieve for the 20 mm crushed gravel should have at least two freshly crushed faces. Not less than 40 percent of the material retained on the 5 mm sieve for the 50 mm crushed gravel should have at least two freshly crushed faces.

The 20 mm granular course should be compacted in lifts not exceeding 150 millimetres to 100 percent of Standard Proctor maximum dry density.

'Coarse gravel' for bedding and drainage should conform to the following grading:

TABLE 3: COARSE GRAVEL GRADATION		
Sieve Size	**Percent Passing by Mass (Nominal Gravel Size)**	
	50 mm	40 mm
50 mm	100	-
40 mm	90 – 100	100
25 mm	-	95 - 100
20 mm	35 – 70	-
12.5 mm	-	25 - 60
10 mm	10 – 30	-
5 mm	0 – 5	0 - 10
2.5mm	-	0 - 5

'Coarse sand' for bedding and drainage should conform to the following grading:

TABLE 4: COARSE SAND GRADATION	
Sieve Size (Square Openings)	**Percent Passing By Mass**
10 mm	100
5 mm	95 – 100
2.5 mm	80 – 100
1.25 mm	50 - 85
0.63 mm	30 - 65
0.315 mm	10 - 30
0.160 mm	2 - 10

'Lean-mix concrete' for nonshrink backfill or high density fill should have a minimum 28-day compressive strength of 3.5 MPa.

PROOF-ROLLING

Proof-rolling is a method of detecting soft areas in an 'as-excavated' subgrade for fill, pavement, floor or foundations or detecting non-uniformity of compacted embankment. The intent is to detect soft areas or areas of low shear strength not otherwise revealed by means of testholes, density testing, or visual examination of the site surface and to check that any fill placed or subgrade meets the necessary design strength requirements.

Proof-rolling should be observed by qualified geotechnical personnel.

Proof-rolling is generally accomplished by the use of a heavy (15 to 16 tonne) rubber-tired roller having 4 wheels abreast on independent axles with high contact wheel pressures (inflation pressures ranging from 550 kPa (80 psi) up to 1030 kPa (150 psi)).

A heavily loaded tandem axel gravel truck may be used in lieu of the equipment described in the paragraph above. The truck should be loaded to approximately 10 tonnes per axel and a minimum tire pressure of 550 kPa (80 psi).

Ground speed – maximum 8 km/hr, recommended 4 km/hr.

The recommended procedure is two complete coverages with the proof-rolling equipment in one direction and a second series of two coverages made at right angles to the first series; one 'coverage' means that every point of the proof-rolled surface has been subjected to the tire pressure of a loaded wheel. Less rigorous procedures may be acceptable under certain conditions subject to the approval of an engineer.

Any areas of soft, rutted, or displaced materials detected should be either recompacted with additional fill or the existing material removed and replaced with general engineered fill, or properly moisture conditioned as necessary.

The surface of the grade under the action of the proof-roller should be observed, noting; visible deflection and rebound of the surface, formation of a crack pattern in the compacted surface or shear failure in the surface of granular soils as ridging between wheel tracks.

If any part of an area indicates significantly more distress than other parts, the cause should be investigated, by, for example, shallow auger holes.

In the case of granular subgrades, distress will generally consist of either compression due to insufficient compaction or shearing under the tires. In the first case, rolling should be continued until no further compression occurs. In the second case, the tire pressure should be reduced to a point where the subgrade can carry the load without significant deflection and subsequently gradually increased to its specified pressure as the subgrade increases in shear strength under this compaction.