was in operation from the early 1980's until mine closure in 2002. The wastes placed in this landfill would have been similar to those placed in the Nanisivik mine landfill. A final cover for the Polaris landfill was completed in 2003. The initial temperature monitoring data reported to the Nunavut Water Board indicate that the cover is performing successfully (i.e., the waste beneath the cover remains frozen).

3.3 Preferred Approach

The preferred approach to closure of the Nanisivik landfill is to construct a thermal barrier cover of locally available, natural materials that makes use of the natural thermal regime at the mine site to achieve the reclamation objectives. This design approach has been successfully used for landfill closures at other northern mine sites in the Canadian Arctic.

Since the waste will be permanently frozen, there will be no opportunity for contaminants to migrate from the landfill. Design considerations for the cover will include the existing environmental conditions, geotechnical issues and thermal properties of the cover materials. These considerations are discussed in the following sections.

3.4 Review of Existing Reports Relevant to Landfill Closure

The most relevant report for landfill closure is the report "Engineering Design of Reclamation Covers" (BGC 2004a) (the "Covers Report"). This report also makes reference to several other reports and memorandum listed below:

- Closure and Reclamation Plan for Nanisivik Mine Plan (GLL 2002);
- Geotechnical Assessment of Cover Materials for West Twin Disposal Area Nanisivik Mine, Baffin Island, NWT (Golder Associates 1999); and
- Reclamation Cover Design for Nanisivik Mine West Twin Disposal Area Surface Cell (Appendix B to GLL 2002).

These existing reports were reviewed and key points relevant to the landfill closure plan from these reports are summarized below:

- Monitoring of the mine site will be conducted during reclamation activities and for a period of five years after completion of reclamation work. Monitoring will include water quality, ground temperatures, general reclamation and geotechnical inspections.

- For the landfill, a dry cover composed of natural materials is considered appropriate.

- Five test pad covers were constructed at the West Twin Lakes Disposal Area (WTDA) in the early 1990's. The covers generally consisted of 2 m of shale; some had internal layers of sand and gravel and others had sand and gravel caps. The maximum depth of active layer thaw ranged from 0.95 m to 1.63 m between 1993 and 1997.

- A 2.0-2.1 m thick shale cover was constructed over the sulphide rock pile at Area 14 in 1990. Two boreholes were drilled through the cover and into the waste dump and thermocouple strings were installed within the shale cover and the waste rock to a maximum depth of 6.6 m below ground surface. Based on the temperature data from the thermocouples, it was concluded that the thaw depth was consistently recorded at depths of just less than 1.4 m and at 1.7 m in the two boreholes. The borehole with 1.7 m thaw depth was considered to be more relevant to the landfill facility.

- A one-dimensional geothermal model, calibrated with the available data, predicted that an additional 0.5 m of cover material would be required under the high (i.e., worst) estimate case of global warming for a 100-year period for the proposed soil covers over unsaturated materials.

- Of the potential natural materials onsite, only two are available in sufficient quantity to be considered: Twin Lakes Sand and Gravel, and shale. Samples of each were subjected to a series of laboratory tests to determine the geotechnical durability of the material under a variety of test conditions. The shale was determined to be suitable for use as a thermal barrier but was not recommended for use as a long-term surface covering material due to potential freeze-thaw breakdown. The Twin Lakes Sand and Gravel was more durable under freeze-thaw conditions and was determined to be suitable for use as a long term surface capping material.

- Geothermal monitoring of thermistors installed in September 2002 at 2 and 5 m below ground surface at the Nanisivik Landfill during the summer of 2003 produced maximum temperatures ranging from –2 to –5 degrees C.

3.5 Final Cover Design

3.5.1 Geotechnical Design Requirements

The geotechnical issues to be addressed include:

1. cover thickness/thermal performance;
2. availability of materials;
3. infiltration;
4. durability;
5. gradation/filtration;
6. slope stability; and

7. erosion.

Cover Thickness/Thermal Performance

The cover thickness and thermal performance of the thermal barrier cover for the landfill facility was developed in and is described fully in the Covers Report. The design rationale and components are summarized as follows:

1. Shale is the most available and abundant cover material and has demonstrated adequate thermal properties; however, the better long term durability of the Twin Lakes sand & gravel suggests that this material is the most suitable to provide an erosion resistant cap on the final exposed surface;
2. Thermal modeling has demonstrated that both the shale and the Twin Lakes sand and gravel share similar thermal properties such that there is no appreciable difference in their thermal performance if in the order of 0.25 m of Twin Lakes sand & gravel is used as the capping (surface) layer of the cover;
3. Experience and observations of the shale cover at Area 14 are more relevant to the landfill facility than observations at the WTDA test cells because of the unsaturated and more permeable nature of the materials being covered in rock piles and open pits;
4. The Area 14 data indicate that 1.7 m of shale cover is sufficient to maintain freezing temperatures in the covered waste materials; and
5. The thermal modeling suggests that an additional 0.5 m of cover would be required to maintain frozen conditions in the covered waste materials under the extreme, 100-year climate warming scenario.

Availability of Natural Materials

The availability of sufficient quantities of shale and East Twin Sand & Gravel has been investigated as documented in the report "Quarry Development and Reclamation Plan" (BGC 2004b) (the "Quarries Report").

The Quarries Report includes details regarding development, operation and reclamation of the borrow areas to be used.

Infiltration

The cover will consist of granular materials and will be permeable. It is anticipated that precipitation and snowmelt will infiltrate into the cover during the spring/summer and will become frozen within the waste pile. Over time, it is expected that this process will generate an ice rich layer within the cover. Observations and test data described in the Covers Report for the WTDA Test Cells and for the Area 14 rock pile cover confirm the general expectation that an ice rich layer will form in the base of the cover materials at the depth of the active thaw layer. This is due to the infiltration of runoff water to the base of the active layer where the water freezes. Once frozen, the latent heat of ice maintains the frozen condition. In fact, the depth of thaw in the WTDA Test Cells decreased over time due to the progressive accumulation of frozen infiltration water.

In the case of covering the Nanisivik landfill facility with shale, the formation of an ice rich layer at the depth of the active thaw zone is anticipated to occur more slowly than the cover over tailings. This is because the (assumed) unsaturated void spaces within the waste materials may allow infiltrating water to initially migrate into the waste pile before the sub-zero temperatures cause the water to freeze in place. Hence, aggradation of the ice rich layer may begin at some depth within the waste materials and propagate upwards. Ultimately, infiltrating water will remain within the cover material and there will be no anticipated infiltration into the waste.

Durability

The durability of the proposed cover materials is not an issue at the top portion of the landfill due to the relatively flat slope in the range of 2 to 5% grade. However, along the steeper sideslopes of the landfill with slopes up to 33% (i.e. 3H:1V), there is a risk that fines from the shale cover material could possibly be washed through the capping material at the base. If the shale cover material is non-durable and breaks down, this process could result in significant erosion or a decrease in its internal friction angle, reducing slope stability.

The durability of the cover materials to weathering and physical breakdown has been assessed as documented in the Covers Report. Samples of the potential cover materials underwent laboratory tests including relative absorption, Los Angeles abrasion, slake durability, and freeze-thaw cycles. A petrographic analysis on the Twin Lakes sand and gravel was also completed.

The Twin Lakes sand and gravel was determined to be very durable (0.1% loss) under freeze-thaw conditions. Since the Twin Lakes sand and gravel is not subject to physical breakdown, it is well suited for the erosion-resistant capping layer. The samples of shale had higher losses in the freeze-thaw and Los Angeles abrasion tests and are not recommended for the capping layer. However, the shale is suitable as a thermal barrier layer underlying the surface cap.

The durability of the shale is not as critical as for the capping layer. However, the material within the sideslope cover should be durable enough so that loss of fines subject to seepage pressures does not result in loss of cover integrity. One sample (five sub-samples) of the Twin Lakes shale and the Mt. Fuji shale were tested for freeze-thaw durability. The Twin Lakes shale had an average loss of 2.3% (the range of loss was from 0.3% to 11.1%) after 25 freeze-thaw cycles and the Mt. Fuji sample had an average loss of 19.7% (range from 1.2% to 46.3%). However, Golder (1999), noted that this loss would have been 6.1% if the Mt. Fuji sample did not split along a bedding plane (large pieces that spalled off the sample had to be counted as lost material under the test protocols). Therefore, this freeze-thaw test result appears to overpredict the loss of material under freeze-thaw conditions by a large degree.

Samples collected in 2003 from the West Twin Disposal Area test cell cover are also relevant. The cover on Test Cell no. 1 was constructed in 1991 and consisted of 2 m thick layer of Mt. Fuji shale. Two samples of the shale were collected from 0.6 m and 1.3 m depth and submitted for grain size analyses. The grain size analyses indicated that both samples consisted of moderately well-graded gravel with some sand and only 3-5% fines. These results suggest that the Mt. Fuji shale, which has been subject to freeze-thaw cycles for 12 years in the field, is durable.

In summary, the laboratory freeze-thaw tests and field trial generally indicate that the shale at the site is durable with the possible exception of the one Mt. Fuji sample, which was reported to be suspect and likely not representative of the material or standard test conditions. The laboratory tests also indicate that there may be some variability between the Mt. Fuji shale and the Twin Lakes shale. Therefore, quality control measures should be taken with respect to material durability when constructing the sloped section of the cover. Both freeze-thaw tests and local field experience should be used to assess and confirm the durability of the shale material placed in the sideslopes of the landfill cover, as described in Section 3.6.

Gradation/Filtration

For the proposed two-layer cover system, the adjacent materials should be filter compatible with respect to grain size distribution. There are two requirements to be met:

1. The upper material (in this case, Twin Lakes sand and gravel) should not fall into the voids of the lower material; and
2. The lower material (in this case, shale) should not wash through the voids of the upper material at the steeper sideslope portions of the cover where lateral flow of infiltrating water through the cover materials may occur.

The Twin Lakes sand & gravel is a well-graded material that is coarser than the shale, which is also well-graded. Since the shale is well-graded (contains about 35% sand based on Unified Soil Classification system), the voids between the shale particles that would allow migration of fines to pass will likely be approximately equal to the D_{10} size, which is 0.4 mm. Based on the available grain size data, 96% of the Twin Lakes sand and gravel is larger than 0.4 mm, which would mean that only 4% of the particles could potentially migrate through the shale. However, because it is well-graded, the fine particles within the sand and gravel will likely be interlocked with larger particles and will not be mobile. Even if some of the fines did migrate into the shale, it is likely that the volume would be insignificant and would not result in any loss of the cover thickness. Therefore, the first requirement will be met for the proposed cover.

For the second requirement, the proposed cover materials were verified against a conservative filter criteria that was developed for drains used for seepage control (Craig 1983) as follows:

a) $(D_{15})_f / (D_{85})_s < 4\text{-}5$

b) $(D_{15})_f / (D_{15})_s > 4\text{-}5$

c) $(D_{50})_f / (D_{50})_s < 25$

where D_{15} = the particle size at which 15% of the soil is finer,

D_{50} = the particle size at which 50% of the soil is finer,

D_{85} = the particle size at which 85% of the soil is finer,

f = the filter soil, East Twin sand and gravel

s = the soil to be retained, shale

Using the grain size data presented by Golder (1999), the following effective sizes are:

$(D_{15})_f = 4.0$ mm $(D_{50})_f = 20$ mm

$(D_{15})_s = 1.0$ mm $(D_{50})_s = 9.3$ mm $(D_{85})_s = 22.5$ mm

and a) $(D_{15})_f / (D_{85})_s = 0.18$, which is <4-5

b) $(D_{15})_f / (D_{15})_s = 4$, which is on the boundary of this criteria and marginally acceptable

c) $(D_{50})_f / (D_{50})_s = 2.15$, which is <25.

Criterion b) ensures that the flow capacity of the filter is greater than the flow capacity of the soil to be retained and is not considered to be as important as criteria a) or c). Therefore, the above filter criteria are met for the proposed two layer cover system.

Figure 14 of the Covers Report shows five grain size distribution curves for the Twin Lakes sand and gravel. The sample analyzed by Golder (1999) was selected as the coarsest material with the highest percentage of gravel and it is expected to have the largest void spaces and the poorest capability to retain fines. Assuming that this sample is the worst case scenario for the Twin Lakes sand and gravel with respect to filtering the underlying shale, the grain size specification for the shale to be retained by the Twin Lakes sand and gravel can be calculated. Based on a fixed gradation of the Twin Lakes sand and gravel, the shale could range from a well-graded gravel to a fine to medium sand and meet the filter criteria. A target grain size specification for the shale is as follows:

Particle Size	Sieve Number	Percent Passing
300 mm	-	100
75 mm	-	85-100
20 mm	-	50-100
4.75 mm	4	30-100
2 mm	10	22-100
0.84 mm	20	15-50
0.42 mm	40	10-27
0.25 mm	60	6-20
0.15 mm	100	4-15
0.075 mm	200	1-10

The above grain size specification is presented as a guide only and does not represent a "must meet condition". The grain size specification presented above is similar to that presented in Figure 29 of the Covers Report. The specification provided here allows for more sand and less fine to medium gravel compared to the specification on Figure 29 of the Covers report. It is expected that the Twin Lakes sand and gravel will vary in the field and the above specification can be modified to ensure that the filter criteria are met. Any modification would be part of a construction quality control program, which is discussed in Section 3.6.

Slope Stability

The waste beneath the cover will be frozen and a slide within the frozen waste is considered to be unlikely. The only potential stability issue is within the cover. The proposed final slope for the cover is a maximum of 3H:1V, which is 18 degrees or 33%. However, as previously discussed, the shale is expected to be durable based on the field trial; therefore, degradation of the material is not expected to be significant. In the short-term, the internal friction angle of the shale is expected to be a minimum of 30 degrees, taking into account its grain size distribution and angular particles. It is unlikely that the cover would become saturated with unfrozen water due to several factors including the permeability of the cover material, the available void space within the cover and the relatively low maximum expected precipitation event for this location. Hence, pore water pressure is not likely to be a factor and the factor of safety against sliding in the short-term is likely a minimum of 1.7, which is considered very stable. In the long-term, potential physical breakdown (due to freeze-thaw cycles) of the particles is expected to reduce the internal friction angle slightly. It is estimated that the reduction in the internal friction angle in the long-term could be approximately 24 degrees. The potential reduction in friction angle is expected to be partially offset by the aggradation of ice within the cover, which would provide cohesive strength to the cover. Therefore, the resulting in a factor of safety against sliding in the long-term is expected to be greater than 1.5.

Erosion

Substantial erosion of the cover could allow the active thaw layer to reach the waste, thawing the surface of the waste materials. A large portion of the landfill surface will have very shallow slopes (e.g. 2 or 3 °), which are considered to be erosion resistant. The proposed maximum sideslope of the landfill final cover will be 18 ° (3H:1V).

The selection of East Twin sand & gravel as the surface capping layer was based on the acceptable durability of this material as compared to the shale. Also, the well-graded grain size distribution of the material will also allow particles to interlock, reducing erosion potential.

The monitoring program includes inspections by qualified engineers of the physical stability of the covers. If erosion occurs, the cover would be repaired.

3.5.2 Proposed Final Cover Design

Based on the geotechnical design requirements discussed in the preceding sections, the proposed design of the cover for the landfill facility is as follows:

5. The top slope of the final landfill surface will be about 2 ° and the maximum sideslope of the landfill will be 18 °;
6. A two-layer thermal cover with a total thickness of 2.20 m will be placed above the landfill waste;
7. The upper erosion-resistant capping layer shall consist of a durable (percentage loss under freeze-thaw is in the order of or less than 1%), erosion resistant material with a thickness of 0.25 m. The selected material is the Twin Lakes sand and gravel;
8. The underlying layer will be shale with a minimum thickness of 1.95 m to provide a minimum total thermal cover thickness (in combination with the surface layer) of 2.20 m. This material should not migrate through the upper layer at the base of the landfill and should meet filtration requirements. A grain size guideline (grain size distribution ranging from well-graded gravel to fine to medium sand) has been provided in Section 3.5.1. It is recommended that the shale material be durable under freeze-thaw conditions on steeper slopes, as determined in the field by qualified professionals experienced in working with shale on the site or working under the direction of an experienced engineer.

3.6 Proposed Closure Activities

Activities to be completed as part of the landfill closure are outlined below.

1. Relocate soil in the landfarm cell that exceeds the remedial objectives for petroleum hydrocarbons to the underground mine according to the Underground Mine Waste Disposal Plan;

2. Implement a construction quality control program, to include material testing, survey control, and construction monitoring as described below;
3. Grade the existing surface according to the design drawings to prepare a reclamation surface that does not exceed 4H:1V slope;
4. Construct the lower (shale) layer of the final cover;
5. Construct the upper (Twin Lakes sand and gravel) layer of the cover over the shale and groom the final surface to avoid potential surface channelization of runoff water. The berm at the base of the landfill should also be groomed to match local contours; and
6. Prepare an as-built report.

Each of these tasks is discussed in more detail the following sections.

3.6.1 Relocation of Hydrocarbon Contaminated Soil

Soil that was excavated from the area around the Carpenter Shop as part of the response to a fuel spill in 2000 was placed in an isolated landfarm cell on the upper surface of the landfill facility. The Phase 2 and 3 ESA programs completed in 2002 and 2003 identified that some of this soil continues to contain hydrocarbons in excess of the remediation objectives.

The soil that exceeds the remediation objectives for hydrocarbons, as identified in the Phase 3 ESA report, will be excavated and placed in the underground mine following the procedures described in the Underground Mine Waste Disposal Plan.

The Phase 3 ESA Report states that a portion of the landfarm soil is not contaminated. Therefore, the uncontaminated soil may remain at the landfill facility and be incorporated into the general contouring and covering work, provided that it can be identified and isolated with confidence.

3.6.2 Implement a Construction Quality Control Program

A quality control program will be implemented, as described here, to ensure that cover materials meet the design specifications and are constructed in accordance with the design drawings. This program will include survey control, materials testing, construction monitoring and documentation.

Survey Control

Survey control is necessary to ensure that the cover is constructed to the grades shown on the drawings and to allow preparation of as-built drawings. Topographic surveys will be conducted at three stages of construction: after grading of the existing surface; after placement/compaction of the shale layer; and after placement/compaction of the capping layer. The survey will be completed using a 20 m grid on the upper surface and a 15 m grid on the sideslopes, such that accurate 0.5 m vertical contour intervals can be resolved from the data. Where the sideslope length is less than 30 m, a minimum of three points should be collected (top, mid-point of slope and base of slope).

Materials Testing

Materials testing will be required to provide confirmation that specified grain size and durability criteria have been met. Grain size distribution can be determined on site but freeze-thaw durability testing requires more than a month to complete at a specialized laboratory off-site. Grain size analysis for each material should be completed at a regular frequency (e.g. one test for every 2,000 m^3 of material placed or a frequency determined by the supervising engineer). The frequency of testing will depend on the expected uniformity of the material. The selection of durable shale material for the lower half of the sideslopes of the cover will require field judgement on the part of the on site engineering staff to minimize the risk of inadvertent use of non-durable material. A limited number of samples of the shale used in this part of the sideslope will be obtained and subsequently subjected to freeze-thaw durability testing to confirm its durability. Since the freeze-thaw tests require a significant time to complete, consideration should be given to completing these tests prior to construction of the 3H:1V sloped section of the lower cover layer.

Construction Monitoring

Construction monitoring is required as part of the quality control program to verify that the work is completed in accordance with the design. Specifically, a trained (geotechnical) engineering technician will monitor construction works in the field to ensure that material is placed in the prescribed lift thickness, conduct sampling and testing and arrange for or conduct survey control. This person should work under the direction of or be a qualified engineer.

Documentation

All test results, field inspections, and surveying at the site will be documented by the site (geotechnical) engineering technician. The documentation will also include discussions with the operations foreman/contractor, deviations from acceptable laboratory results or specifications, reasons for accepting deviations, and any adjustments made to the design. Photographs will also be collected over the course of construction to generate a photographic record.

3.6.3 Landfill Surface Regrading

The existing ground surface is currently sloped between 3% and 10% on the upper surface of the landfill and is steeper at the edges. There are several low points where water may pool at various locations. Prior to construction of the final landfill cover, it will be necessary to regrade the landfill to a more uniform surface for safe and efficient cover construction. An alternative to the proposed regrading of the current surface would be to utilize increased quantities of fill materials to create the desired final surface. However, this approach would be substantially more costly and would not provide any substantial benefits.

The final slopes for the landfill cover were selected to meet the geotechnical considerations or issues previously discussed. The design objective is to maintain a minimum grade of 2% on the upper surface to ensure positive drainage. The design objective for the sideslope areas is to reduce the slope angles to a maximum of 3H:1V.

The proposed regraded landfill surface, as shown on Figure 4, has a uniform 3H:1V slope. Accurate estimate of total cut and fill volumes from the regrading have not been estimated at this time; however, it is expected that the cut and fill volumes be balanced. If there is any excess cut material, it may be uniformly spread along the slope or the top portion of the landfill. There may be small amount of waste located at the southeast quadrant of the landfill (the exact waste boundary is not known). If present, this waste should be moved to the top of the landfill and graded.

The proposed final landfill surface is shown on Figure 5. Cross sections of the cut/fill areas are shown on Figures 6-9. To preclude loss of cover layer integrity, it is important that the final surface of the regraded landfill be free of visible open voids.

3.6.4 Construction of Lower Layer of the Thermal Cover

Once the regraded surface has been surveyed and approved (meets design grades), the lower layer of the cover may be constructed. As shown on Figure 6, the shale layer is 1.95 m thick. The cover material will be placed in not less than three lifts of 0.65 m maximum thickness.

The required compaction effort is consistent with that specified in the Covers Report (BGC 2003). The compaction process will be performance based and will consist of a number of passes from the proposed construction equipment (i.e., Bulldozer and loaded haulage trucks). Other criteria for the compaction operation, subject to field verification, will consist of the following general guidelines:

- Compaction of each layer of fill shall proceed in a systematic and continuous manner so that each portion of the layer receives an equal amount of compactive effort;
- The method of changing direction of the equipment shall result in uniform compaction;
- Overlap should occur between the various passes of the construction equipment;
- It is expected that the upper surface will be free from ruts or any uneven surface. If any are noted, relevelling and/or additional passes will be required; and
- Any oversized particle sizes will be removed from the fill before proceeding with compactive effort.

The total thickness of the shale layer shall be within 100 mm of the design thickness. The completed layer shall be surveyed for the as-built drawing and to verify that the total thickness of this layer is in accordance with the design.

The volume of the lower layer of cover is estimated to be 61,000 m^3, excluding contingency.

3.6.5 Construction of Upper Layer of the Thermal Cover

After construction of the lower layer and verification that it meets the design requirements, the upper capping layer of the cover may be constructed. As shown on Figure 6, the upper layer is 0.25 m thick. The material (Twin Lakes sand and gravel) may be placed in a single lift. After the material has been placed, it should be groomed smooth (to avoid leaving any peaks or troughs) to meet the final design grades. The compaction specification, consistent with the Covers Report, is to achieve a firm and tight final surface to the satisfaction of the engineer.

After placement and compaction of the top layer of the cover, it should be surveyed to verify that the design grades and thickness of the capping layer have been achieved.

The volume of the upper layer of cover is estimated to be 8,000 m^3, excluding contingency.

3.6.6 Surface Water Management

Surface water runoff in the area upgradient of the landfill will continue to be diverted around the landfill via the existing diversion berm. This diversion berm is not considered to be a critical long term design component given that an ice rich layer is anticipated to form in the cover such that seepage flows into the covered waste will be reduced to near zero over time.

3.6.7 Generate As-built Drawings

After completion of the construction of the landfill cover that meets the design specifications, as-built drawings should be generated under the direction of the qualified engineer responsible for the project.

3.7 Performance Monitoring

3.7.1 Overview

The main objective of the performance monitoring program is to monitor the reclamation cover's performance under three areas (seepage water quality, ground temperature, and physical stability) and to report the results, as described below. The program is to be conducted during the 2-year reclamation period and the 5-year closure period, as outlined in the Water Licence.

The monitoring program will complement the monitoring requirements of other areas of the mine site. The compiled monitoring requirements for the entire mine site are compiled and presented in the report, Nanisivik Mine Reclamation and Closure Monitoring Plan.

3.7.2 Seepage Water Quality

Water samples will be collected from surface sampling location NML-26 and subsurface locations TP02-95, TP02-97, TP02-100, TP02-101, TP02-102, TP03-387 and LF-SEEP (from the ESA program) for analysis of a full suite of metals and petroleum hydrocarbon parameters. Analyses will be conducted at an accredited off-site laboratory.

During the 2-year reclamation period, sampling of surface locations NML-26, NML-29 and NML-30 is recommended on a 2-week schedule through the summer season (anticipated June through September). Sampling of the subsurface monitoring locations listed above will be conducted twice per year (June and August/September). Samples will be collected using accepted field protocols including filtering of samples for dissolved parameters and addition of preservatives in the field. Shipment to the laboratory should be as quickly as possible with sample collection timed to coincide with flights departing site.

During the 5-year closure period and depending on water quality results, sampling of surface locations NML-26, NML-29 and NML-30 will be conducted on a minimum once per year basis during freshet (June) or a maximum twice per year basis during June and August/September. Subsurface monitoring locations will be sampled once per year at the time of maximum thaw depth (August/September).

3.7.3 Geothermal Conditions

The temperatures experienced within the final cover will be measured by installing thermistors at two locations and frost gauges at two locations. The thermistor boreholes will be drilled through the waste materials to bedrock and will be located on the upper surface of the landfill and approximately midslope on a sidelope area. Thermistor nodes will be regularly spaced through the boreholes at a 1 m interval or as determined by the responsible engineer after construction is complete. The frost gauges will be installed on the upper surface of the landfill and on a sideslope.

During the 2-year reclamation period, the instruments will be read on a monthly basis. During the 5-year closure monitoring period and depending on results to date, the instruments will be read a minimum four times per year, quarterly with emphasis on including early summer (June) and maximum thaw depth (August/September).

3.7.4 Physical Stability

Inspections are to be completed through the Reclamation and Closure Periods by a qualified geotechnical engineer in conjunction with inspections of other aspects of the mine site. A frequency of once per year during late summer is recommended.

The inspection should include observations of signs of erosion, cracking, slumping, movement or other deformations of the cover. If there are any indications of erosion or slope instability, mitigative measures should be implemented as soon as possible.

3.7.5 Review and Reporting of Monitoring Results

The data collected from the monitoring should be reviewed by qualified technical personnel on a regular basis and as soon as practical following receipt of data. The technical personnel should report any findings or recommendations directly to CanZinco on a timely basis.

A formal report on the monitoring data that includes recommendations for any amendments to the schedule or other aspects of the program should be prepared at the end of each year of the reclamation and closure periods.

3.8 Contingency Plan

In the event that the cover does not perform as expected, then some or all items of the contingency plan should be implemented. Contingency actions are also described in the Covers Report. The components to the contingency plan that should be considered for implementation depending on the specific circumstances include:

- increased frequency of sampling/monitoring and data review by the technical professional;
- repair any erosion of the cover;
- place additional cover material to increase the cover thickness; and
- extend the period of performance monitoring.

The risk that contaminated leachate will be observed at the reclaimed landfill facility is considered to be small based on the information presented in this report. Nonetheless, in the unlikely event that leachate is observed and confirmed by increased sampling and other investigations, the mitigative measures that would be considered would include: increasing the cover thickness over all or parts of the facility; passive treatment along the seepage flowpath; installation of a geosynthetic or GCL liner over all or portions of the facility; relocation of portions of the waste materials; and, ultimately, installation and operation of a leachate collection system.

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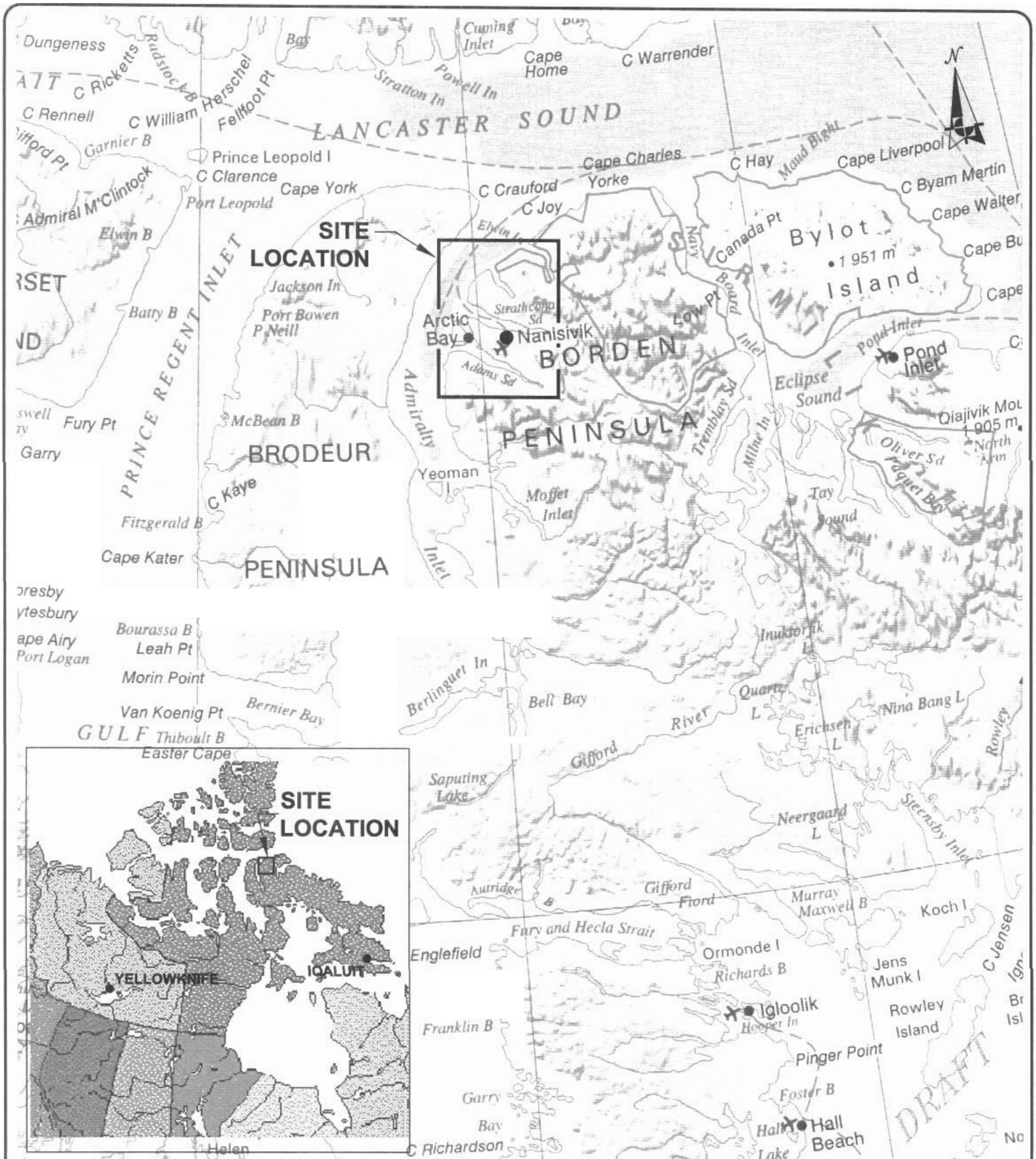
Nanisivik Mine, Phase II Environmental Site Assessment, Nanisivik Landfill Site, November 30, 2000.

Figures



0 15 30 60 90 120 150 Km

Scale 1:3,000,000

SOURCE OF FIGURE:
REFERENCE MAP BY NATURAL RESOURCES CANADA
"YUKON TERRITORIES, NORTHWEST TERRITORIES AND NUNAVUT"
DATE: 2000
(LAMBERT CONFORMAL CONIC PROJECTION)

DRAWING INFORMATION:	
REVIEWED BY:	EJD
DRAWN BY:	CCL
DATE ISSUED:	FEB 2004
PROJECT NUMBER:	23-635
FILE NAME:	23635-6F-08.DWG
REVISION:	0

KEY PLAN

Project: LANDFILL CLOSURE PLAN
Location: NANISIVIK MINE, NUNAVUT
Client: CanZinco Ltd.

Gartner Lee Limited

CanZinco Ltd.

Figure No. 1

LEGEND:

SITE LOCATION

SOURCE OF DRAWING:

LANDSAT ORTHOIMAGE
PRODUCT_ID – 036008_0100_000802_L7
PRODUCT_DATE – 2003/02/27
EDITION – 01
VERSION – 00
DATUM – NAD83 (CSRS)
PROJECTION – UTM
UTM_ZONE – 16
HORIZONTAL POSITIONAL ACCURACY VALUE – 20m
ORIGINATOR – GEOMATICS CANADA, CENTRE FOR TOPOGRAPHIC INFORMATION

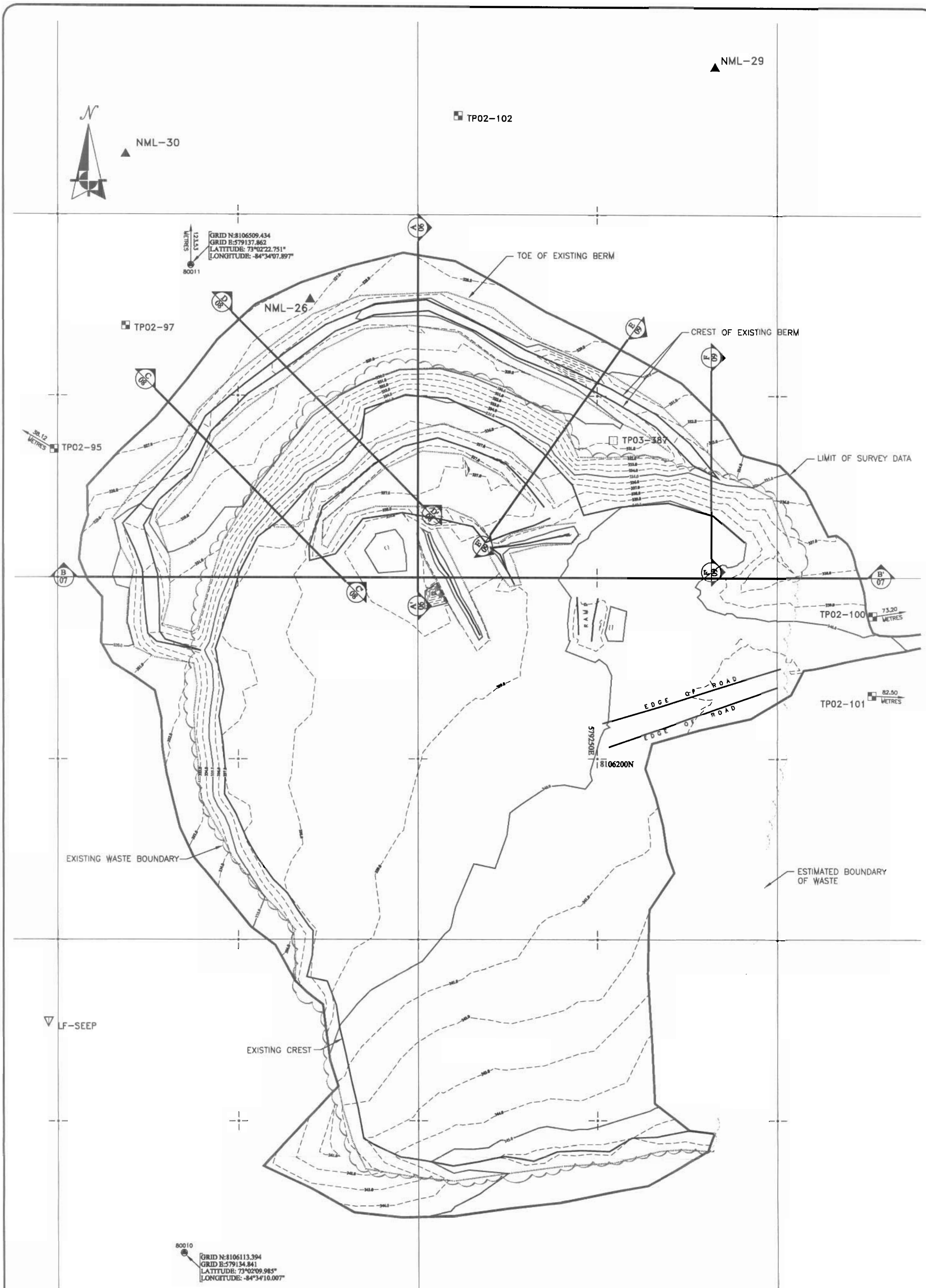
DRAWING INFORMATION:	
REVIEWED BY:	HCC
DRAWN BY:	CCL
DATE ISSUED:	FEB 2004
PROJECT NUMBER:	23-635
FILE NAME:	23635-6F-09.DWG
REVISION:	0

Project: LANDFILL CLOSURE PLAN
Location: NANISIVIK MINE, NUNAVUT
Client: CanZinco Ltd.

LANDFILL SITE
LOCATION PLAN

Gartner Lee

Figure No. 2



NOTES:

GROUND SURFACE DERIVED FROM TOPOGRAPHIC DATA PROVIDED BY SUB-ARCTIC SURVEYS LTD., DATED AUGUST 28th–29th, 2003.

CONTOURS ARE AT 1 METRE INTERVALS. COORDINATES ARE UNIVERSAL TRANSVERSE MERCATOR (UTM) COORDINATES ZONE 16 (NAD83). ELEVATIONS ARE GEODETIC AND REFFERED TO NANASIVIK CONTROL 871011 (ELEVATION = 299.606) AND ADJUSTED +3.22 METRES TO FIT LOCAL MAPPING.

0 5 10 20 30 Metres

SCALE 1:1000

LEGEND:

- LIMIT OF SURVEY
- SECTION LINE
- BOUNDARY OF WASTE
- BOUNDARY OF WASTE (INFERRED)
- CONTOUR – MAJOR (m)
- CONTOUR – MINOR (m)
- EXISTING CREST
- EXISTING TOE
- TESTPIT (2002)
- TESTPIT (2003)
- SEEP SAMPLE
- SURFACE WATER SAMPLE
- SURVEY CONTROL

SOURCE OF DRAWING:

–

REVIEWED BY:	EJD
DRAWN BY:	CCL
DATE ISSUED:	FEB 2004
PROJECT NUMBER:	23-635
FILE NAME:	23635-6F-01.DWG
REVISION:	0

Project: LANDFILL CLOSURE PLAN
Location: NANISIVIK MINE, NUNAVUT
Client: CanZinco Ltd.

EXISTING LANDFILL GROUND SURFACE

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FIGURE NO. 3