ABANDONMENT AND RESTORATION PLAN FOR THE MUNICIPAL DUMP SITE IN RESOLUTE BAY, NUNAVUT

GN-CGS PROJECT #08-2002

May 07, 2010

Submitted to: **GOVERNMENT OF NUNAVUT – COMMUNITY AND GOVERNMENT SERVICES**

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May 07, 2010

Government of Nunavut – Community and Government Services
2nd Floor, GNO 1045
P.O. Box 379
Pond Inlet, NU, X0A 0S0

ATTENTION: Matthew Hamp

RE: ABANDONMENT AND RESTORATION PLAN FOR THE MUNICIPAL DUMP SITE IN RESOLUTE BAY, NUNAVUT (GN-CGS PROJECT #08-2002)

ARKTIS Solutions Inc. is pleased to provide Government of Nunavut, Community and Government Services with a final report for the above referenced project. We trust that the information presented in this report satisfies the requirements of the project. Please do not hesitate to contact the undersigned if there are any questions or comments.

Sincerely,

ARKTIS SOLUTIONS INC.

Jamie VanGulck, Ph.D., P.Eng.
Chief Technical Officer, ARKTIS Solutions Inc.

Letter of Transmittal

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

DRAWINGS

Drawing AR-ED–01 – Conceptual Design – Plan View and Site Location

APPENDICES

Appendix A – Geostudio Stability Analysis

Appendix B – General Terms and Conditions

1.0 INTRODUCTION

1.1 Background Information

The Hamlet of Resolute Bay currently operates a Municipal Dump Site (MDS) for disposal of solid waste. The MDS is located approximately 5 km (by road) west of the community as shown in **Drawing AR-ED-01**. The solid waste generated in the community is landfilled at the MDS, and commonly open burned to reduce waste volumes. After burning, the residues are spread over a large area and covered with soil to minimize wind-blown debris. The MDS has reached its designed capacity[1].

A new Solid Waste Disposal Facility (SWDF) is proposed for construction in 2010 within the Hamlet of Resolute Bay, Nunavut (see **Drawing AR-ED-01** for location of SWDF). The SWDF is to accommodate the permanent disposal of domestic solid waste and bulky waste, as well as, the temporarily storage of household hazardous materials generated in the community. The proposed lifespan of the SWDF is 20 years with an operational period that spans from 2010 to 2029. The existing MDS is proposed to be permanently closed and remediated after the construction and commissioning of the new SWDF.

The existing MDS was surveyed and visually assessed by ARKTIS[2] in August, 2008. A survey of the MDS was completed by ARKTIS in July 2009. The topographic relief is depicted in **Drawing-AR-ED-01** and provides an indication of the footprint of the landfilled waste at the time of the survey. Since the MDS is operational, the footprint and conditions at the landfill may differ from the 2008 and 2009 site visits.

1.2 Objectives of the Abandonment and Restoration Plan

The overall objectives of the Abandonment and Restoration (A&R) Plan of the existing MDS are:

- To establish conceptual requirements for future restoration of the existing municipal dump site to reduce risks to human health and the environment;
- To return the solid waste disposal facility area to a state of compatible with the original undisturbed conditions, and land use, giving due consideration to practical factors including aesthetics, safety and future users;
- Minimize long term maintenance and monitoring after decommissioning.

The specific objectives of the A&R Plan are:

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[1] Government of Nunavut, Department of Community & Government Services, June 2008. Request for Proposal, Project 08-2002.

[2] ARKTIS Solutions Inc. (2008). Dump Site Investigation, Hamlet of Resolute Bay, Nunavut.

- Provide a conceptual design of a cover system in accordance to recognized guidelines[3] for solid waste disposal facilities at closure and preliminary slope stability analysis;
- Provide an advanced conceptual design of the municipal dump site and associated Class D cost estimate; and,
- Provide recommendations for further considerations to support final engineering design.

1.3 Regulatory Considerations

An A&R plan is a typical water licence term and condition for solid waste disposal facilities in Nunavut. The water licence is issued by the Nunavut Water Board. The proponent for the water licence would be the Hamlet of Resolute Bay. There is no current water licence for the Hamlet of Resolute Bay. This report was developed, in part, to assist the Hamlet of Resolute in achieving the requirements of a typical water licence.

1.4 Related Studies

This A&R plan was developed with consideration given to information contained in the following document:

- **Dump Site Investigation**[2]: This report summarizes the field assessment of local dump sites in Resolute Bay, Nunavut.

2.0 ABANDONMENT AND RESTORATION

2.1 Overview of the Existing MDS

The MDS site is immediately east of the road to the cemetery and about 500 m north of the ocean shoreline, as shown in **Drawing AR-ED-01**. Based on field observations[2], it was assumed that disposal operations consisted of end dumping (area fill) from the existing road elevation onto the adjacent lower elevation ground surface. Additionally, waste was found to be open burned on-site as a means to manage waste volumes. It was also noted that there are limited, to no, controls for waste disposal, burn pits, site access, safety, or site water management at the MDS. Based on the 2009 topographic survey of the MDS, it has approximate dimensions of 165 m length and 72 m width (footprint area of 11,880 m^2).

[3] Ferguson Simek Clark (2003). Guidelines for Planning, Design, Operations and Maintenance of Modified Solid Waste Sites in the NWT.

Based on an assumed thickness of waste of about 3.5 m, the total volume of was is calculated to be 41,580 m^3.

2.2 A&R Plan Considerations

A guideline for modified solid waste sites developed in the Northwest Territories[3], which is considered to be generally applicable to Nunavut, was used to identify typical A&R planning concepts that are applicable to the MDS; these concepts include the following:

- Future land use – discussed in **Section 2.3.1**.
- Implementation schedule – discussed in **Section 2.3.3**.
- Map/description of disturbed areas, borrow materials areas, and site facilities – discussed in **Section 2.4** and depicted in **Drawing AR-ED-01**.
- Consideration of altered drainage patterns. – discussed in **Section 2.4.2**.
- Type and source of cover material - discussed in **Section 2.3.1**.
- Leachate management - – discussed in **Section 2.4.4** and **2.4.5**.
- Contaminated site remediation - The remediation of the area will be based on a cover system which is expected to limit leachate generation and wind-blown debris, protect wildlife and population from the direct contact with waste.

At the initiation of operations of the new SWDF, closure of the MDS can commence. Prior to closure of the MDS, an engineered design may be required to transform this advanced conceptual A&R plan to a level that will include all details to facilitate construction; achieve design objectives; and any regulatory requirements issued by agency such as the Nunavut Water Board. As such, the final A&R plan may include consideration of each of the above listed A&R planning concepts, which are described at a level of detail to facilitate final A&R engineering design.

2.3 Post Closure Overview of Municipal Dump Site

2.3.1 Future Land Use

Choosing an appropriate post closure use for a disposal facility is critical to important successful restoration. The post closure use should be realistically achievable in terms of site topography, geology, soil types and particularly the quantity of soils available for restoration. The financial costs involved in restoration and post closure maintenance and management needs to be considered. Further, restoration goals/objectives should consider land user desires.

The restoration goal assumed for the A&R plan of the MDS is to transform the site area from a waste disposal ground to an area that blends into the undisturbed surrounding environment. As such, the future land use was assumed to be a natural setting for recreational use. Should the future land use deviate from this assumption, this A&R plan will require updating and revisions.

2.3.2 Post Closure Site Infrastructure

In general, A&R activities may involve:

- Completion of engineering design and plans to support the development of a final A&R plan, and,
- Modification of site characteristics such as topography to facilitate post closure monitoring and maintenance.

Overall, this conceptual A&R plan considers the following modifications/additions to site infrastructure and conditions at closure:

- Re-grade site to facilitate surface water diversion, site water drainage, and to minimize erosion;
- Construct any diversion berms or ditching to facilitate surface water management;
- Consolidate any waste disposed in the vicinity of the dump site to reduce the footprint of the waste.
- Construct final cover for the site;
- Restore disturbed areas;
- Install infrastructure to accommodate water quality monitoring (if required); and,
- Install sign to inform the community that the site has been closed.

2.3.3 Implementation Schedule

A final A&R plan should be accompanied with any engineering designs and plans to support final closure of the MDS. It is estimated that this process can be completed within one construction season. Post closure A&R activities should be implemented, as-required, after the implementation of the restoration of the site.

2.4 Overview of Closure Activities

2.4.1 Final Cover for Dump Site

A final cover is to be constructed on the MDS area. Ferguson Simek Clark (2003)[3] recommended the construction of a final soil cover with minimum thickness of 600 mm (see **Drawing AR-ED-01** for typical soil cover configuration). However, the type and materials used in the cover is dependent on, but not limited to, the acceptable infiltration through the cover, and desired permafrost conditions below the cover, which should be considered in the design. Therefore, the thickness and properties of the cover should be evaluated in the engineering design stage and consider, but not be limited to, the following:

- Local total precipitation and evapotranspiration;
- Geotechnical properties of cover materials;
- Borrow material sources and availability;
- Drainage and cover material design to limit erosion;
- Permafrost regime and global warming effects;
- Slope stability; and,
- Settlement of waste and cover.

At a final stage design, consideration could be given to include geosynthetic materials in the cover system. Geosynthetics may be an option to limit infiltration into the waste through the cover, and therefore minimize potential for leachate generation.

Decomposing solid waste has the potential to generate landfill gas that can largely contain methane and carbon dioxide. An assessment of the potential for landfill gas generation and its implications (e.g., migration, venting requirements, etc.) should be considered in the final cover engineering design of the solid waste disposal cell. For example, if landfill gas generation is significant, management of landfill gas may be necessary.

The top surface of the cover should allow surface water (rain water and snow melt) to run off the cover. To limit erosion and permit surface water run-off, the cover should consider employing a 2% to 5% slopes (minimum and maximum). The final design of the geometry of the cover should consider, but not be limited to, the following:

- Volume of surface water run-off;
- Run-off to be diverted away from the waste area and towards the south side of the MDS;
- Availability of suitable soil types;

- Elements to minimize erosion such as swales and armouring of swales and berms; and,
- Construction and maintenance.

To improve the long term stability of the slopes to contain waste, the side slopes of the MDS should be flattened to about 4H:1V (slope to be confirmed in final engineering design stage). Current site conditions of the MDS have constructed side slopes of approximately 1H:1.5V. If a soil cover of 600 mm is employed, to achieve a side slope of 4H:1V, it is estimated that the cover will have maximum thickness of 1.7 m along the side slope. A conceptual cover configuration is presented in **Drawing AR-ED-01**.

2.4.1.1 Stability Analysis

A preliminary slope stability analysis was complete to evaluate the static stability of the side slopes. The static factor of safety of the south slope (equilibrium analysis) of the MDS at closure was calculated by completing stability analyses using Geostudio's Slope W software. The stability analysis report with details of the model is presented in **Appendix A**.

The stability analysis adopted a soil cover with minimum thickness of 600 mm, minimum and maximum slopes at the surface of the cover of 2 and 5% respectively, and side slope (south) with 4H:1V slopes. A typical cross section (Section A-A – **Drawing AR-ED-01**) was adopted for the stability analysis.

Two scenarios were considered in the stability analysis to partially assess the sensitivity of permafrost aggradation on slope stability. The scenarios evaluated include:

- Scenario 1: Negligible permafrost aggradation as a result of waste placement. The assumed model boundary conditions and configuration include: an active layer depth of 1.0 m below the foundation soil grade; elevation of foundation soil grade was assumed; and groundwater table elevation at the foundation soil grade.
- Scenario 2: Permafrost aggradation within the waste pile and cover. The assumed model boundary conditions and configuration include: an active layer depth of 1.5 m below the MDS cover and 1.0 m below foundation soil grade outside of the MDS area; foundation soil grade; elevation of foundation soil grade was assumed; and groundwater table elevation at the foundation soil grade outside of the MDS area.

The following soil strength parameters were adopted for the analysis:

- Soil Cover
  - Soil unit weight: 17 kN/m^3
  - Cohesion: 0 kPa

- Internal Friction Angle (Phi): 26 degrees (typical of a gravelly sand with poor to intermediate compaction)

- Waste
  - Waste unit weight[4]: 4.5 kN/m^3
  - Cohesion[5]: 5 kPa
  - Internal Friction Angle (Phi)[5]: 15 degrees
- Foundation Soil
  - Soil unit weight: 18 kN/m^3
  - Cohesion: 0 kPa
  - Internal Friction Angle (Phi): 28 degrees
- Permafrost
  - Impenetrable

The following methods were selected for the stability analysis:

- Material mode: Mohr-Coulomb;
- Side function: Interslice force function option - half-sine function;
- Pore-water pressure: Piezometric line;
- Slip surface option: grid and radius;
- Tension crack option: No tension crack;
- Factor of safety distribution calculation: constant;
- Number of slices: 50;
- Factor of safety tolerance: 0.01;
- Minimum slip surface depth: 0.1 m; and,
- Analysis type: Mongerstern-Price.

Additional information regarding modeling parameters, geometry and methods are presented in **Appendix A**.

The minimum design factor of safety (FOS) was adopted to be 1.5 (based on Canadian Dam Association[6]). Scenario 1 analysis resulted in a minimum FOS (equilibrium analysis) observed of 1.86

[4] Adapted from: Oweis, I. and Khera, R. (1990). "Geotechnology of waste management." Butter-Worths, London.

[5] Adapted from: Richardson, G.N. and Reynolds, R.D. (1991). "Geosynthetic considerations in a landfill on compressible clays." Proc., Geosynthetics '91, Industrial Fabrics Association International, St. Paul, Minn., Vol. 2.

[6] Canadian Dam Association. Dam Safety Guidelines, 2007.

(see **Figure 1**), which was considered adequate for long term stability. Scenario 2 analysis resulted in a minimum FOS (equilibrium analysis) observed of 1.92 (see Figure 2). The critical failure surfaces under this scenario are observed along the toe of the cover.

Long term stability will depend on the shear strength properties of the soils, waste, and geosynthetic components used in the cap system, if any. Additionally, the presence of water acts as a destabilizing agent in reducing the strength and increasing the destabilizing force. Long term fluctuations (dry/wet years, climate change) may affect the stability of the cover and containment berms, and should be evaluates at a final design stage.

To maintain the designed FOS of the berms during operation of the solid waste disposal facility, the following factors should be considered:

- The diversion ditches should be maintained to be fully functional and clear of any obstruction to restrict the accumulation of water in the vicinity of the berms.
- Settlement of waste may cause differential settlement in the cover which may return in depressions in the surface of the cover where water can pond. This potential for settlement to cause water ponding should be evaluated at final design and considered in any long term maintenance program. Settlement in the waste may also impact the stability of the cover, which should be also be evaluated at final design as well.
- Water ponding is to be limited at all times in the cover the MDS to maintain the designed factor of safety.

2.4.2 Drainage and Erosion Control

To limit leachate generation and to facilitate surface water run-off, a diversion ditch will be excavated along the north, east, and west perimeter of the cover system as shown in **Drawing AR-ED-01**. The diversion ditch should aim to limit the amount of water entering the site from northern areas and allow collection and drainage of surface water off the cover system.

A typical cross section of the diversion ditch to be excavated on site is shown in **Drawing AR-ED-01**. A final ditch configuration and layout should be completed as part of final engineering design. In order to maintain the ditch operational and drainage of the site at acceptable levels, the ditch should be maintained free of blockage or dirt. The long term performance of the ditch should be evaluated with time to reflect any changes in the flow system, permafrost degradation, and blockage.

Long term degradation of the diversion ditch by erosion should be evaluated at a final design stage, where ditch armouring of the ditch should be consider as an long term management alternative.

2.4.3 Signage

A sign should be installed at the road in the vicinity of the dump site to inform MDS users that the site has been closed and will no longer accept disposal of waste material. The sign should also state the acceptable location for disposal of solid waste.

2.4.4 Post Closure Leachate Generation

There is potential for leachate to be generated from the MDS after closure of the facility. Typically, after placement of a waste final cover, leachate generation decreases compared to during site operation.. It is suggested that leachate generation is minimized post closure to reduce monitoring and management requirements. A final cover design should be completed as part of the final A&R plan for the MDS that considers minimizing leachate generation. The leachate generation prior to closure is likely to be minimal (i.e., about 0 m^3/yr), see ARKTIS Solutions Inc. (2010)[7] for calculation. As such, if snow removal from the waste cells prior to melt is practiced after closure, it is hypothesized that there will be minimal leachate generation. An estimate of the annual post-closure leachate generation volumes may be a component of the final cover design.

2.4.5 Environmental Monitoring

Inspection of the facility should be completed on a regular basis for signs of infrastructure degradation and repairs completed as required.

Long term water quality monitoring is to be completed in accordance with the Hamlet of Resolute Bay's water licence. Details pertaining to monitoring may include the location(s) and frequency for water quality sampling, requirements for select water quality parameters to analyze, and reporting requirements to the Nunavut Water Board. These environmental monitoring details will not be realized until a water licence is issued, by the Nunavut Water Board, for the closed MDS.

Drawing AR-ED-01 proposes a location for the installation of a shallow groundwater monitoring well to allow water quality sampling down-gradient of the MDS. Additional monitoring locations may be necessary after the closure of the facility and shall be evaluated during development of the final A&R design and plan. Further, the frequency of water quality sampling and parameters to analyze for each

[7] ARKTIS Solutions Inc. (2010). Solid Waste Disposal Facility Design Report for Resolute Bay, Nunavut.

sampling location should be evaluated during development of the final A&R plan and with consideration to the water licence.

If the potential to generate landfill gas is significant, it may warrant development of a landfill gas monitoring plan and associated environmental monitoring.

3.0 CLASS D COST ESTIMATE

A Class D cost estimate for the closure of the MDS has been prepared based on the concept presented in this A&R Plan. The Class D cost estimated is presented in **Table 1** and summarized below. The design and construction costs are estimated to be approximately $ 850,300 +/- 20% for contingency, therefore $850,300 +/- $154,600.

COST SUMMARY

Site Preparation	$ 80,000
Soil Cover	$ 576,000
Site Drainage	$ 25,000
Signage	$ 5,000
Environmental Monitoring	$ 2,000
Miscellaneous	$ 85,000
TOTAL	**$ 773,000**
Engineering (15%)	$ 77,300
TOTAL	**$ 850,300 +/- 20% for contingency**
Contingency (20%)	$ 154,600

4.0 LIMITATIONS OF LIABILITY

This report has been prepared for the exclusive use of the Government of Nunavut, Community and Government Services for the specific application described in Section 1.0 of this report. It has been

prepared for information purposes only. No other warranty is made, either expressed or implied. For further limitations, please refer to the General Conditions provided in **Appendix B**.

5.0 CLOSURE

We trust that this report meets your present requirements. Please contact the undersigned should there be any questions.

ARKTIS SOLUTIONS INC.

Alexandre Knop, Ph.D., P.Eng.
Geo-Environmental Engineer

Jamie VanGulck, Ph.D., P.Eng.
Chief Technical Officer

REGISTERED PROFESSIONAL ENGINEER
A. KNOP
LICENSEE
MAY 7, 2010
NWT/NU

PERMIT TO PRACTICE
ARKTIS SOLUTIONS INC.
Signature
Date May 7, 2010
PERMIT NUMBER: P 598
The Association of Professional Engineers, Geologists and Geophysicists of NWT/NU

Table 1. Class D cost estimate.

	Quantity	Unit	Unit Cost	Total Cost
1. SITE PREPARATION				
General Mob/Demob	1	unit	$40,000	$40,000
Waste grading and consolidation of waste	16000	m2	$2.50	$40,000
			Item Total	$80,000
2. SOIL COVER				
Granular material for cover (exploration of quarry, screening, hauling, placing, compacting)	12,800	m3	$45	$576,000
			Item Total	$576,000
3. SITE DRAINAGE				
Excavation of Diversion Ditch and transport of cut material off the site	300	m	$50	$15,000
Allowance for culverts and finishig drainage activities	1	allowance	$10,000	$10,000
			Item Total	$25,000
4. SIGNAGE				
Site signage - CLOSED SITE	1	unit	$5,000	$5,000
			Item Total	$5,000
9. ENVIRONMENTAL MONITORING				
Shallow Monitoring wells (full supply and installation)	1	unit	$2,000	$2,000
			Item Total	$2,000
10. MISCELANEOUS				
As-built Survey of site	1	unit	$5,000	$5,000
Permanent Site Cleaning (construction waste, snow removal)	1	allowance	$10,000	$10,000
General Requirements and Accommodations	1	allowance	$70,000	$70,000
			Item Total	$85,000
			SUBTOTAL	**$773,000**
			Engineering (10%)	$77,300
			TOTAL COSTS WITHOUT CONTINGENCY	**$850,300 +/- 20%**
			Contingency (20%)	$154,600

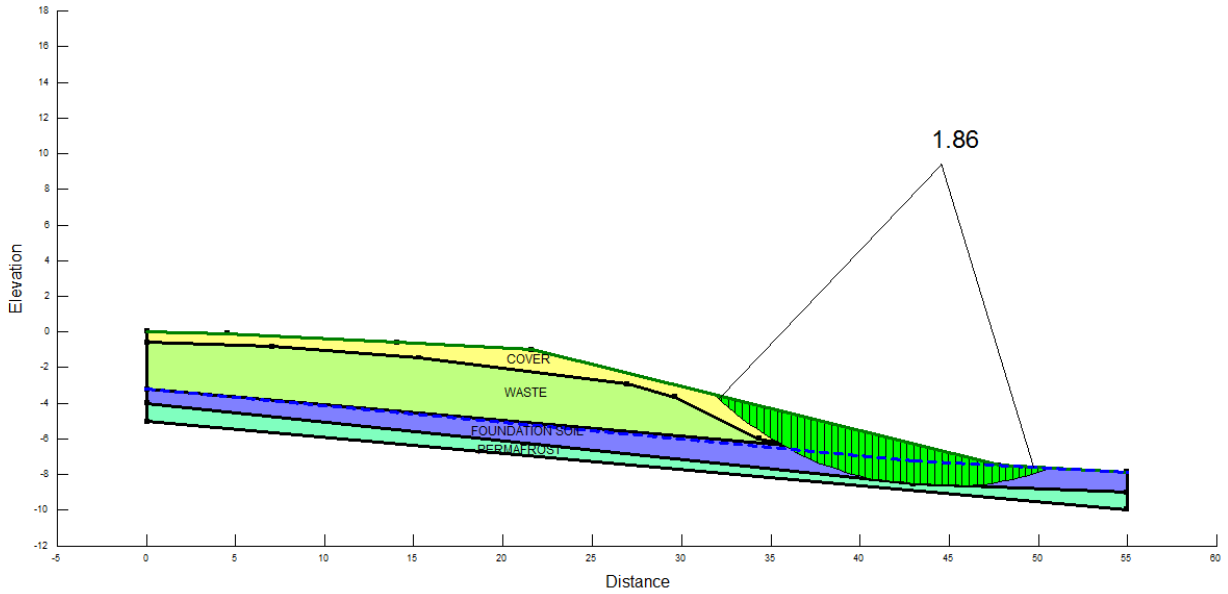


Figure 1. Scenario 1 slope stability analysis critical failure surface.

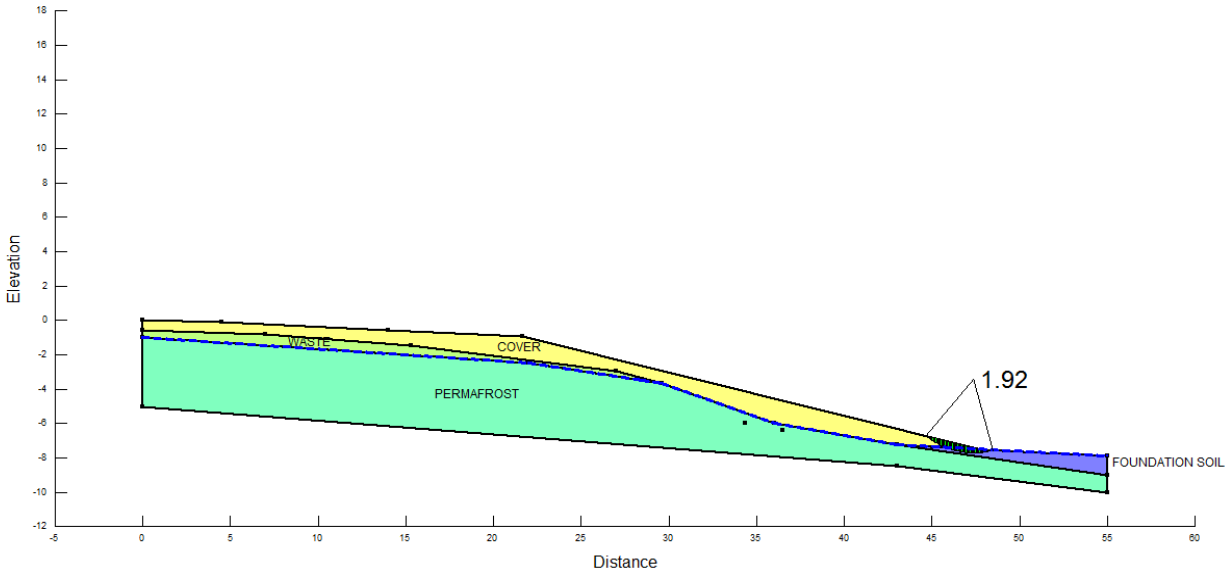
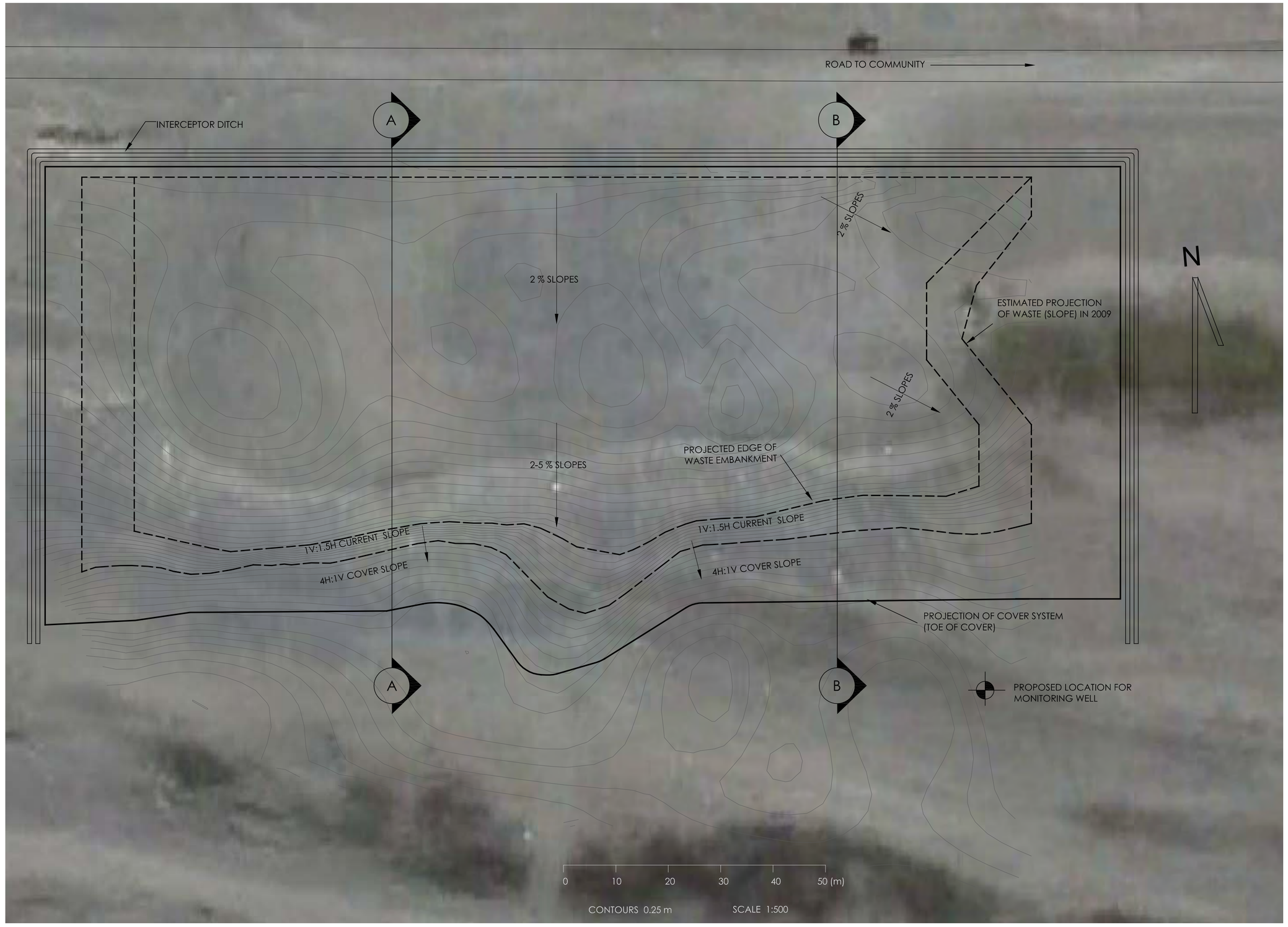
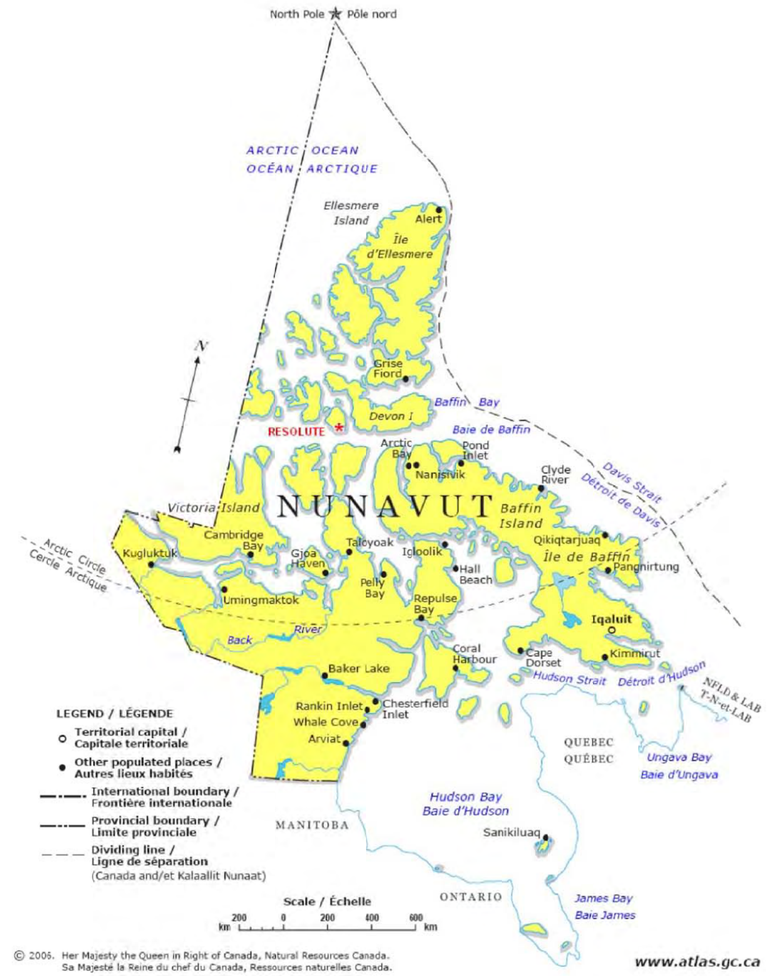


Figure 2. Scenario 2 slope stability analysis critical failure surface.

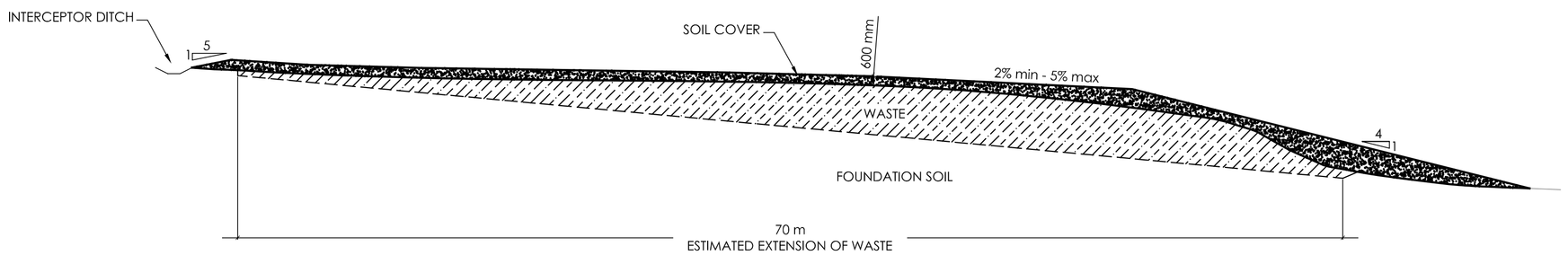


EXISTING DUMP SITE - PLAN VIEW

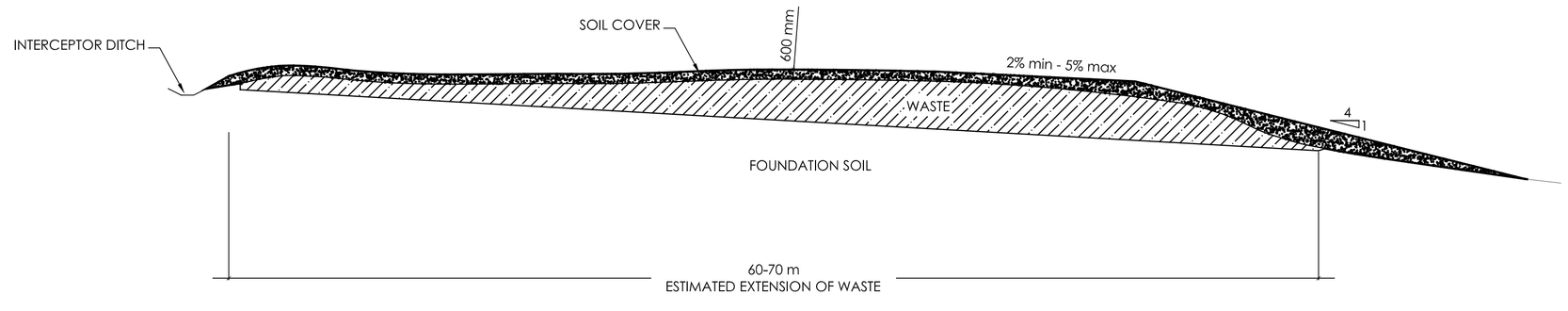


RESOLUTE BAY, NUNAVUT

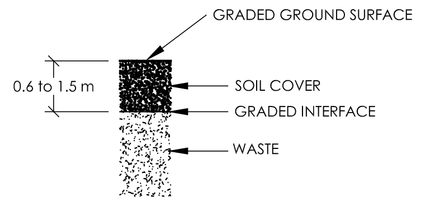
EXISTING DUMP SITE LOCATION



SECTION A-A

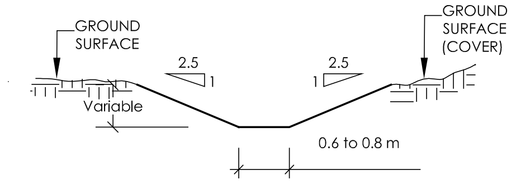


SECTION B-B



- MINIMUM SOIL COVER 0.6 m AS RECOMMENDED BY GUIDELINES (REFERENCE 3 OF A&R REPORT)
- THICKER SOIL COVER IS REQUIRED TO RETURN TO 4H:1V SLOPES
- THICKNESS OF SOIL COVER TO BE CONFIRMED AT FINAL DESIGN

TYPICAL COVER



TYPICAL DITCH SECTION

Nunavut

1. THIS DRAWING IS NOT TO BE SCALED.
2. ALL PARTIES USING THESE DRAWINGS SHALL REVIEW THEM PRIOR TO QUOTING AND CONSTRUCTION OF ANY AND ALL ASPECTS OF THE WORK AND REPORT ANY ERRORS, OMISSIONS AND/OR DEFICIENCIES IMMEDIATELY TO ARKTIS SOLUTIONS INC.

01	05/05/10	A&R PLAN
No.	DATE:	REVISION:

ARKTIS SOLUTIONS
117 LOUTIT STREET, YELLOWKNIFE, NT, X1A 3M2
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DRAWN BY:	AK	DESIGNED BY:	AK
DATE:	MAY 05, 2010	CHECKED BY:	JVG
SCALE:	AS NOTED	PLOT DATE:	MAY 05, 2010

PROJECT:

ABANDONMENT AND RESTORATION PLAN
MUNICIPAL DISPOSAL SITE - MDS -

RESOLUTE BAY, NUNAVUT

DRAWING NAME:

CONCEPTUAL DESIGN PLAN VIEW AND SITE LOCATION

DRAWING NO.:

AR-ED-01

APPENDIX A - GEOSTUDIO SLOPE W MODELING RESULTS

SLOPE/W Analysis: SCENARIO 1

SLOPE/W Analysis

File Information

Revision Number: 25
Date: 5/4/2010
Time: 12:08:04 AM
File Name: Resolute_Existing_MDS.gsz
Directory: C:\ARKTIS\RESOLUTE\2010\A&R OLD DUMP\Geoslope Analysis\
Last Solved Date: 5/4/2010
Last Solved Time: 12:09:20 AM

Project Settings

Length(L) Units: meters
Time(t) Units: Seconds
Force(F) Units: kN
Pressure(p) Units: kPa
Strength Units: kPa
Unit Weight of Water: 9.807 kN/m³
View: 2D

Analysis Settings

SLOPE/W Analysis

Kind: SLOPE/W
Method: Morgenstern-Price
Settings
Apply Phreatic Correction: No
Side Function
Interslice force function option: Half-Sine
PWP Conditions Source: Piezometric Line
Use Staged Rapid Drawdown: No
Slip Surface
Direction of movement: Left to Right
Use Passive Mode: No
Slip Surface Option: Grid and Radius
Critical slip surfaces saved: 1
Optimize Critical Slip Surface Location: No
Tension Crack
Tension Crack Option: (none)
FOS Distribution
FOS Calculation Option: Constant
Advanced
Number of Slices: 50
Optimization Tolerance: 0.01
Minimum Slip Surface Depth: 0.1 m
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 16
Complete Passes per Insertion: 1
Driving Side Maximum Convex Angle: 5 °
Resisting Side Maximum Convex Angle: 1 °

Materials

Cover_Soil

Model: Mohr-Coulomb
Unit Weight: 17 kN/m³
Cohesion: 0 kPa
Phi: 26 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Waste

Model: Mohr-Coulomb
Unit Weight: 4.5 kN/m³
Cohesion: 5 kPa
Phi: 15 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Foundation Soil

Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 0 kPa
Phi: 28 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Permafrost

Model: Bedrock (Impenetrable)
Pore Water Pressure
Piezometric Line: 1

Slip Surface Grid

Upper Left: (24, 49) m
Lower Left: (16, 3) m
Lower Right: (76, -11) m

Grid Horizontal Increment: 50
Grid Vertical Increment: 50
Left Projection Angle: 0 °
Right Projection Angle: 0 °

Slip Surface Radius

Upper Left Coordinate: (14.824773, 0.993261) m
Upper Right Coordinate: (55.997406, -9.505912) m
Lower Left Coordinate: (6.002065, -5.006267) m
Lower Right Coordinate: (54.526954, -17.005322) m
Number of Increments: 30
Left Projection: No
Left Projection Angle: 135 °
Right Projection: No
Right Projection Angle: 45 °

Slip Surface Limits

Left Coordinate: (0, 0) m
Right Coordinate: (55, -7.9) m

Piezometric Lines

Coordinates

X (m)	Y (m)
0	-3.2
43	-7.25
55	-7.9

Regions

	Material	Points	Area (m²)
Region 1	Waste	1,2,6,7,8,9,10,11	90.69
Region 2	Foundation Soil	1,2,4,5,3,16,18,17	63.35
Region 3	Cover Soil	12,13,14,15,5,4,2,6,7,8,9,10,11	44.19
Region 4	Permafrost	17,18,16,20,19	38.75

Points

	X (m)	Y (m)
Point 1	0	-3.2
Point 2	36.5	-6.4
Point 3	55	-7.9
Point 4	43	-7.25
Point 5	47.81	-7.5
Point 6	34.35	-6
Point 7	29.6	-3.66
Point 8	27	-2.92
Point 9	15.32	-1.45
Point 10	7	-0.8
Point 11	0	-0.57
Point 12	0	0
Point 13	4.5	-0.12
Point 14	14	-0.58
Point 15	21.65	-0.96
Point 16	55	-9
Point 17	0	-4
Point 18	43	-8.5
Point 19	0	-5
Point 20	55	-10

Critical Slip Surfaces

	Slip Surface	FOS	Center (m)	Radius (m)	Entry (m)	Exit (m)
1	22827	1.867	(44.64, 9.72)	18.409	(31.8346, -3.50615)	(50.7067, -7.66115)

Slices of Slip Surface: 22827

	Slip Surface	X (m)	Y (m)	PWP (kPa)	Base Normal Stress (kPa)	Frictional Strength (kPa)	Cohesive Strength (kPa)
1	22827	32.03	-3.69	-24.77	1.84	0.90	0
2	22827	32.42	-4.05	-21.60	5.37	2.62	0
3	22827	32.82	-4.39	-18.63	8.62	4.20	0
4	22827	33.21	-4.71	-15.85	11.62	5.67	0
5	22827	33.61	-5.01	-13.23	14.41	7.03	0
6	22827	34.00	-5.30	-10.78	16.99	8.29	0
7	22827	34.40	-5.57	-8.48	19.40	9.463	0
8	22827	34.79	-5.83	-6.33	21.65	10.56	0
9	22827	35.18	-6.07	-4.31	23.75	11.58	0
10	22827	35.49	-6.26	-2.81	24.96	6.69	5
11	22827	35.87	-6.46	-1.14	26.32	13.99	0
12	22827	36.31	-6.70	0.76	29.02	15.02	0
13	22827	36.69	-6.88	2.23	31.00	15.30	0
14	22827	37.07	-7.06	3.61	32.66	15.45	0
15	22827	37.48	-7.22	4.88	34.18	15.58	0
16	22827	37.83	-7.38	6.06	35.58	15.69	0
17	22827	38.20	-7.53	7.15	36.85	15.79	0
18	22827	38.58	-7.66	8.14	38.01	15.88	0
19	22827	38.96	-7.79	9.04	39.04	15.95	0
20	22827	39.34	-7.91	9.85	39.96	16.01	0
21	22827	39.72	-8.02	10.57	40.75	16.05	0
22	22827	40.10	-8.12	11.21	41.42	16.06	0
23	22827	40.48	-8.21	11.76	41.96	16.05	0
24	22827	40.86	-8.28	12.04	44.17	17.08	0
25	22827	41.251	-8.32	12.08	43.32	16.61	0
26	22827	41.64	-8.36	12.12	42.46	16.13	0
27	22827	42.03	-8.40	12.16	41.58	15.64	0
28	22827	42.42	-8.44	12.20	40.69	15.15	0
29	22827	42.81	-8.48	12.24	39.79	14.65	0
30	22827	43.19	-8.51	12.23	39.83	14.67	0
31	22827	43.58	-8.52	12.19	38.40	13.93	0
32	22827	43.97	-8.54	12.14	36.96	13.19	0
33	22827	44.36	-8.56	12.09	35.49	12.44	0

	Slip Surface	X (m)	Y (m)	PWP (kPa)	Base Normal Stress (kPa)	Frictional Strength (kPa)	Cohesive Strength (kPa)
34	22827	44.75	-8.57	12.04	34.03	11.69	0
35	22827	45.144	-8.58	11.99	32.56	10.93	0
36	22827	45.53	-8.60	11.95	31.078	10.17	0
37	22827	45.92	-8.62	11.90	29.60	9.41	0
38	22827	46.33	-8.61	11.57	28.93	9.23	0
39	22827	46.75	-8.57	10.92	26.13	8.09	0
40	22827	47.17	-8.51	10.16	23.09	6.87	0
41	22827	47.60	-8.45	9.31	19.80	5.57	0
42	22827	47.99	-8.38	8.44	17.23	4.67	0
43	22827	48.35	-8.31	7.56	15.41	4.17	0
44	22827	48.71	-8.24	6.61	13.43	3.63	0
45	22827	49.07	-8.15	5.58	11.31	3.05	0
46	22827	49.43	-8.05	4.47	9.04	2.43	0
47	22827	49.79	-7.95	3.29	6.64	1.78	0
48	22827	50.15	-7.84	2.03	4.11	1.11	0
49	22827	50.51	-7.73	0.69	1.47	0.41	0
50	22827	50.70	-7.66	-0.03	0.06	0.03	0

SLOPE/W Analysis: SCENARIO 2

File Information
- Revision Number: 32
- Date: 5/4/2010
- Time: 9:41:00 AM
- File Name: Resolute_Existing_MDS.gsz
- Directory: C:\ARKTIS\RESOLUTE\2010\A&R EXISTING DUMP\Geoslope Analysis\
- Last Solved Date: 5/4/2010
- Last Solved Time: 9:42:16 AM

Project Settings
- Length(L) Units: meters
- Time(t) Units: Seconds
- Force(F) Units: kN
- Pressure(p) Units: kPa
- Strength Units: kPa
- Unit Weight of Water: 9.807 kN/m³
- View: 2D

Analysis Settings

SLOPE/W Analysis
- Kind: SLOPE/W
- Method: Morgenstern-Price
- Settings
  - Apply Phreatic Correction: No
  - Side Function
    - Interslice force function option: Half-Sine
  - PWP Conditions Source: Piezometric Line
  - Use Staged Rapid Drawdown: No
- Slip Surface
  - Direction of movement: Left to Right
  - Use Passive Mode: No
  - Slip Surface Option: Grid and Radius
  - Critical slip surfaces saved: 1
  - Optimize Critical Slip Surface Location: No
  - Tension Crack
    - Tension Crack Option: (none)
- FOS Distribution
  - FOS Calculation Option: Constant
- Advanced
  - Number of Slices: 50
  - Optimization Tolerance: 0.01
  - Minimum Slip Surface Depth: 0.1 m
  - Optimization Maximum Iterations: 2000
  - Optimization Convergence Tolerance: 1e-007
  - Starting Optimization Points: 8
  - Ending Optimization Points: 16
  - Complete Passes per Insertion: 1
  - Driving Side Maximum Convex Angle: 5 °
  - Resisting Side Maximum Convex Angle: 1 °

Materials

Cover_Soil
- Model: Mohr-Coulomb
- Unit Weight: 17 kN/m³
- Cohesion: 0 kPa
- Phi: 26 °
- Phi-B: 0 °
- Pore Water Pressure
  - Piezometric Line: 1

Waste
- Model: Mohr-Coulomb
- Unit Weight: 4.5 kN/m³
- Cohesion: 5 kPa
- Phi: 15 °
- Phi-B: 0 °
- Pore Water Pressure
  - Piezometric Line: 1

Foundation Soil
- Model: Mohr-Coulomb
- Unit Weight: 18 kN/m³
- Cohesion: 0 kPa
- Phi: 28 °
- Phi-B: 0 °
- Pore Water Pressure
  - Piezometric Line: 1

Permafrost
- Model: Bedrock (Impenetrable)
- Pore Water Pressure
  - Piezometric Line: 1

Slip Surface Grid
- Upper Left: (24, 49) m
- Lower Left: (16, 3) m
- Lower Right: (76, -11) m
- Grid Horizontal Increment: 50
- Grid Vertical Increment: 50
- Left Projection Angle: 0 °
- Right Projection Angle: 0 °

Slip Surface Radius

Upper Left Coordinate: (14.824773, 0.993261) m
Upper Right Coordinate: (55.997406, -9.505912) m
Lower Left Coordinate: (6.002065, -5.006267) m
Lower Right Coordinate: (54.526954, -17.005322) m
Number of Increments: 30
Left Projection: No
Left Projection Angle: 135 °
Right Projection: No
Right Projection Angle: 45 °

Slip Surface Limits

Left Coordinate: (0, 0) m
Right Coordinate: (55, -7.9) m

Piezometric Lines

Coordinates

X (m)	Y (m)
0	-1
22	-.2.5
28.5	-3.5
29.6	-3.66
36	-6
43	-7.25
55	-7.9

Regions

	Material	Points	Area (m²)
Region 1	Waste	1,20,21,7,8,9,10,11	13.71
Region 2	Foundation Soil	4,5,3,16	6.66
Region 3	Cover Soil	12,13,14,15,5,4,22,7,8,9,10,11	40.85
Region 4	Permafrost	1,20,21,7,22,4,16,19,17,18	164.52

Points

	X (m)	Y (m)
Point 1	0	-1
Point 2	36.5	-6.4
Point 3	55	-7.9
Point 4	43	-7.25
Point 5	47.81	-7.5
Point 6	34.35	-6
Point 7	29.6	-3.66
Point 8	27	-2.92
Point 9	15.32	-1.45
Point 10	7	-0.8
Point 11	0	-0.57
Point 12	0	0
Point 13	4.5	-0.12
Point 14	14	-0.58
Point 15	21.65	-0.96
Point 16	55	-9
Point 17	43	--8.5
Point 18	0	-5
Point 19	55	-10
Point 20	22	-2.5
Point 21	28.5	-3.5
Point 22	36	-6

Critical Slip Surfaces

	Slip Surface	FOS	Center (m)	Radius (m)	Entry (m)	Exit (m)
1	2390	1.925	(47.36, 3.36)	4.335	(44.59, -6.695)	(48.5133, -7.53912)

Slices of Slip Surface: 2390

	Slip Surface	X (m)	Y (m)	PWP (kPa)	Base Normal Stress (kPa)	Frictional Strength (kPa)	Cohesive Strength (kPa)
1	2390	44.63	-6.73	-5.99	0.31	0.15	0
2	2390	44.71	-6.79	-5.42	0.90	0.44	0
3	2390	44.79	-6.85	-4.88	1.46	0.71	0
4	2390	44.86	-6.90	-4.37	1.97	0.96	0
5	2390	44.94	-6.96	-3.88	2.45	1.20	0
6	2390	45.02	-7.01	-3.41	2.90	1.41	0
7	2390	45.10	-7.06	-2.97	3.32	1.62	0
8	2390	45.18	-7.11	-2.55	3.71	1.81	0
9	2390	45.26	-7.15	-2.16	4.07	1.99	0
10	2390	45.34	-7.19	-1.78	4.42	2.15	0
11	2390	45.42	-7.23	-1.43	4.74	2.31	0
12	2390	45.50	-7.27	-1.09	5.03	2.46	0
13	2390	45.57	-7.31	-0.77	5.31	2.59	0
14	2390	45.65	-7.34	-0.47	5.57	2.72	0
15	2390	45.73	-7.38	-0.19	5.82	2.84	0
16	2390	45.78	-7.40	-0.03	5.94	3.16	0
17	2390	45.83	-7.42	0.12	6.09	3.17	0
18	2390	45.91	-7.44	0.36	6.32	3.17	0
19	2390	45.98	-7.47	0.58	6.53	3.16	0
20	2390	46.06	-7.50	0.79	6.71	3.15	0
21	2390	46.14	-7.52	0.98	6.87	3.13	0
22	2390	46.22	-7.54	1.15	7.00	3.11	0
23	2390	46.29	-7.56	1.31	7.1155167	3.08	0
24	2390	46.37	-7.58	1.46	7.2028365	3.05	0
25	2390	46.45	-7.60	1.59	7.2651528	3.02	0
26	2390	46.53	-7.61	1.70	7.3014223	2.98	0
27	2390	46.61	-7.63	1.80	7.3106352	2.93	0
28	2390	46.68	-7.64	1.89	7.2919493	2.87	0
29	2390	46.76	-7.65	1.96	7.2441781	2.81	0
30	2390	46.84	-7.66	2.02	7.1661727	2.74	0
31	2390	46.92	-7.67	2.06	7.0569558	2.65	0
32	2390	46.99	-7.68	2.09	6.9154652	2.56	0
33	2390	47.07	-7.68	2.11	6.7405568	2.46	0
34	2390	47.15	-7.69	2.11	6.5317804	2.35	0

	Slip Surface	X (m)	Y (m)	PWP (kPa)	Base Normal Stress (kPa)	Frictional Strength (kPa)	Cohesive Strength (kPa)
35	2390	47.22736	-7.69	2.10	6.2880968	2.22	0
36	2390	47.305045	-7.69	2.07	6.009167	2.09	0
37	2390	47.38273	-7.69	2.04	5.6947102	1.94	0
38	2390	47.460415	-7.69	1.98	5.3447672	1.79	0
39	2390	47.5381	-7.69	1.92	4.9593123	1.61	0
40	2390	47.61	-7.69	1.84	4.5391557	1.43	0
41	2390	47.69	-7.68	1.75	4.08	1.24	0
42	2390	47.77	-7.67	1.64	3.60	1.04	0
43	2390	47.85	-7.67	1.52	3.22	0.90	0
44	2390	47.92	-7.66	1.39	2.96	0.84	0
45	2390	48.00	-7.65	1.25	2.68	0.76	0
46	2390	48.07	-7.64	1.09	2.36	0.67	0
47	2390	48.15	-7.62	0.92	2.02	0.58	0
48	2390	48.22	-7.61	0.74	1.65	0.48	0
49	2390	48.30	-7.59	0.55	1.26	0.38	0
50	2390	48.37	-7.57	0.34	0.85	0.27	0
51	2390	48.45	-7.56	0.11	0.41	0.16	0
52	2390	48.50	-7.54	-0.05	0.09	0.05	0

APPENDIX B – GENERAL TERMS AND CONDITIONS

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

USE OF REPORT

This 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 those to which it refers. Any variation from the site or proposed development would necessitate a supplementary investigation and assessment.

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

LIMITATIONS OF REPORT

This report is based solely on the conditions which existed on site at the time of ARKTIS' investigation. The client, and any other parties using this report with the express written consent of the clients and ARKTIS, acknowledge that conditions affecting the environmental assessment of the site can vary with time and that the conclusions and recommendations set out in this report are time sensitive.

The client, and any other party using this report with the express written consent of the client and ARKTIS, also acknowledge that the conclusions and recommendations set out in this report are based on limited observations and testing on the subject site and that conditions may vary across the site which, in turn, could affect the conclusions and recommendations made.

The client acknowledges that ARKTIS is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the client.

During the performance of the work and the preparation of this report, ARKTIS may have relied on the information provided by persons other than the client. While ARKTIS endeavors to verify the accuracy of such information when instructed to do so by the client, ARKTIS accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

LIMITATIONS OF LIABILITY

The client recognizes that property containing contaminants and hazardous wastes creates a high risk of claims brought by third parties arising out of the presence of those materials. In consideration of these risks, and in consideration of ARKTIS providing the services requested, the client agrees that ARKTIS' liability to the client, with respect to any issues relating to contaminants or other hazardous wastes located on the subject site shall be limited as follows:

a. With respect to any claims brought against ARKTIS by the client arising out of the provisions or failure to provide services hereunder shall be limited to the amount of fees paid by the client to ARKTIS under this Agreement, whether the action is based on breach of contract or tort;

b. With respect to claims brought by third parties arising out of the presence of contaminants or hazardous wastes on the subject site, the client agrees to indemnify, defend and hold harmless ARKTIS from and against any and all claim or claims, action or actions, demands, damages, penalties, fines, losses, costs and expenses of every nature and kind whatsoever, including solicitor-client costs, arising or alleged to arise either in whole or part out of services provided by ARKTIS, whether the claim be brought against ARKTIS for breach of contract or tort.

STANDARD OF CARE

Services performed by ARKTIS for this report have been conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and financial and physical constraints applicable to the services. Engineering judgment 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.

ALTERNATE REPORT FORMAT

Where ARKTIS submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed 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 ARKTIS 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 ARKTIS shall be deemed to be the overall original for the Project.

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