Appendix G

Geotechnical monitoring schedule 2014-2018

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BGC Project Memorandum

To:	**Nyrstar**	**Doc. No.:**	
Attention:	**Johan Skoglund**	**cc:**	
From:	**Geoff Claypool**	**Date:**	**September 16, 2013**
Subject:	**2014-2018 Geotechnical Monitoring Schedule Nanisivik Mine, NU**		
Project No.:	**0255-023-04**		

Dear Johan,

As per your request, BGC Engineering Inc. (BGC) has undertaken a review of the geotechnical monitoring requirements for the now reclaimed Nanisivik Mine site. This review is being conducted in support of the application for the new Water License, which is anticipated to be in place in time for the 2014 monitoring season. This memorandum provides the following information:

- A description of the monitoring program implemented since completion of the majority of reclamation construction activities (2006 through 2012);
- A brief review of the results of the monitoring program, and their significance with respect to performance of the reclamation measures and assumptions and analyses undertaken during the development of the reclamation plan; and,
- A proposed monitoring schedule for the term of the next Water License, which is assumed to be for a five year duration (2014-2018).

As per the Nanisivik Mine Reclamation and Closure Monitoring Plan (GLL 2004)[1], the various surface reclamation covers constructed around the Nanisivik Mine site were instrumented, both pre- and post-construction, to assess the effectiveness of the reclamation measures and to validate the results of various analyses undertaken while developing the reclamation

[1] Gartner Lee Limited. 2004. Nanisivik Mine Reclamation and Closure Monitoring Plan. Prepared for CanZinco Ltd. February 2004.

plan. A conceptual monitoring plan was included in GLL (2004) outlining the monitoring schedule during the Reclamation and Closure periods. The majority of the instrumentation was installed in 2005 and the monitoring plan was implemented in 2006, although monitoring of previously installed instruments continued throughout the construction period in 2004 and 2005. Since 2009, geotechnical monitoring has been conducted as per the schedule included in the current Water License (1AR-NAN0914) which was based on the monitoring schedule proposed in BGC (2008)[2]. Most instruments have been monitored on a bi-weekly basis between June and September with additional quarterly readings obtained typically in April and December or January. The monitoring data is reviewed in an ongoing basis by BGC and a comprehensive assessment of the monitoring data, and its significance with respect to the performance of the reclamation measures, is included in the Annual Geotechnical Inspection report submitted to Nyrstar. The most recent comprehensive review of the geotechnical and geothermal monitoring data was provided in BGC (2013)[3]. This Annual Geotechnical Inspection report is subsequently submitted by Nyrstar to the Nunavut Water Board as a component of the annual report required in the Water License.

Based on the monitoring data collected since the majority of the permafrost aggradation covers were completed in 2005, the following main conclusions are drawn:

- The surface reclamation covers are performing as anticipated. The geothermal monitoring data collected to-date indicates that the covers are generally achieving their design objectives by confining the active layer within the cover and maintaining the underlying tailings in a frozen state (see Figure 1). The monitoring data indicates that performance of the covers continues to improve with time, despite the warmer than average climate conditions experienced by the site since the covers were constructed.
- Freeze-back of the Surface Cell and Test Cell taliks is occurring as expected. The monitoring data collected to-date indicates that cooling of the subsurface profile is continuing. In the Surface Cell, the upper 15 to 20 m of the subsurface profile is frozen back in most areas (see Figures 2 and 3). The monitoring data collected to date validates the results of the talik freeze-back modeling undertaken during the development of the West Twin Disposal Area (WTDA) reclamation plan (see Figure 4).
- In the Test Cell, the freeze-back is also occurring, with at least the upper 10 m of the subsurface profile frozen in the centre of the talik (see Figure 5).
- The freeze-back of the Surface Cell talik has resulted in elevated pore pressures in the centre of the talik (see Figure 6). This was expected and validates the

[2] BGC Engineering Inc. 2008. Proposed 2008-2012 Geotechnical Monitoring Schedule. Prepared for Breakwater Resources Ltd. May, 2008.
[3] BGC Engineering Inc. 2013. 2012 Annual Geotechnical Inspection, Nanisivik Mine, NU. Prepared for Nyrstar, February, 2013.

assumptions made regarding talik pore pressures in the Surface Cell during the development of the reclamation plan. The increasing pore pressures are not considered to negatively impact the stability of the West Twin Dike due to the continued downward advancement of the freezing front and the confinement of the pore pressures within the centre of the talik, away from the dike. The pore pressures remain well below trigger levels previously developed as illustrated on Figure 6. The trigger levels signify pore pressures which may be of concern with respect to dyke stability.

- The freeze-back of the Test Cell talik has resulted in only minor increases in pore pressures within the Test Cell talik (see Figure 7). The piezometric data from the Test Cell suggests hydrogeologic connection exists between the Test Cell talik and the Reservoir. This validates the assumptions made during the development of the contaminant loading model component of the WTDA reclamation plan.
- The West Twin Dike and its foundation remain in a perennially frozen state and no indications of instability have been observed (see Figure 8).
- The landfill has frozen back and the cover confines the annual active layer thaw from migrating into the underlying waste materials (see Figure 9). Similar observations with respect to freeze-back of underlying waste and backfill materials and cover performance have been noted at the Industrial Complex.
- The East Open Pit waste rock backfill has frozen back and the cover confines the annual active layer thaw from migrating into the underlying waste materials (see Figure 10). Similar observations with respect to freeze-back of underlying mine wastes and cover performance have been noted at the Oceanview and West Open Pits.

Given the encouraging results of the monitoring program and the positive performance of the reclamation measures observed to-date, it is considered appropriate to reduce the monitoring schedule for the term of the next Water License. A proposed geotechnical monitoring schedule for the term of the next Water License is provided in Table 1 and is summarized below:

- Thermistors will be monitored bi-weekly or monthly between July 1 and September 1, based on the following rationale:
  - Data will be collected bi-weekly from thermistors providing information from the active layer between July 1 and September 1.
  - Data will be collected monthly from thermistors providing information only on freeze-back of the underlying mine waste.
- Vibrating wire piezometers will be monitored on a monthly basis, between July 1 and September 1.
- Frost gauges will be monitored on a bi-weekly basis between July 1 and September 1.
- Water levels at the West Twin Outlet Wall should be recorded on a weekly basis between July 1 and September 1.

- No data collection is proposed to be undertaken outside the July 1 to September 1 window. Data collected from thermistors previously during this time period has shown to be consistently cooling and typically only yields geothermal information when the geothermal profile is at its coolest, especially in the upper 15 m of the depth profile. As such, it is recommended that the quarterly readings typically undertaken during December and April be discontinued.
- Thermocouples will no longer be monitored since many are malfunctioning and the data collected in recent years has been shown to be inconsistent and unreliable. This should be expected given the age of the instruments, many of which were installed more than 20 years ago. Also, the thermocouples are located in areas that have been frozen back for many years. Hence, the data collected from these sites are of limited value.
- No samples will be collected from the groundwater monitoring wells installed in the Surface Cell and Test Cell taliks. All of the monitoring wells are currently inoperable due to malfunctioning heat trace and blocked or bent well casings. Given the encouraging water quality of both the Surface Cell discharge and the outflow from the Reservoir, the water quality in the taliks is not considered to be of critical importance at this time. Should water quality in either the Surface Cell or the outflow from the Reservoir decline in the future, the need for groundwater monitoring may be re-visited.
- The air temperature probe installed on the Surface Cell in 2012 should continue to collect site specific air temperature data for the duration of the next Water License. This data will supplement climate data collected at the Arctic Bay airport.

Monitoring data will continue to be forwarded to BGC immediately after collection for review and assessment. Additionally, the reclamation measures will continue to be inspected on an annual basis throughout the remainder of the Closure Period by a qualified geotechnical engineer. The inspection observations and the monitoring data will be included in the Annual Geotechnical Monitoring Report, along with a comprehensive assessment of the significance of the data with respect to the reclamation measures.

It should be noted that the monitoring schedule proposed herein is based on the expectation that the reclamation measures will continue their current trend of good and improving performance. In the unlikely event that performance is observed to be not as expected, the monitoring schedule may be altered accordingly.

CLOSURE

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This memorandum presents a proposed geotechnical instrument monitoring schedule for the Nanisivik Mine, NU for the term of the next Water License. We trust the information provided herein meets your requirements and expectations. Should you have any questions or comments regarding the information provided herein, please contact the undersigned at your convenience.

Respectfully submitted,

BGC Engineering Inc.
Per:

Original Signed By

Geoff Claypool, M.Eng., P.Eng.
Senior Geological Engineer

Reviewed by:

Original Signed By

James W. Cassie M.Sc., P.Eng.
Vice President, Specialist Geotechnical Engineer

TABLES

Table 1 -

Recommended 2014-2018 Geothechnical and Geothermal Instrument Reading Schedule

BGC Engineering Inc.

							1-Jul	8-Jul	15-Jul	23-Jul	1-Aug	8-Aug	15-Aug	22-Aug	1-Sep
West Twin Dyke															
TC12	Thermocouple		Not functioning												
TC13A	Thermocouple		Not functioning												
TC31	Thermocouple		Not functioning												
TC32	Thermocouple		Not functioning												
TC33	Thermocouple		Not functioning												
BGC03-33	Thermistor	Monthly													
BGC03-34	Thermistor	Monthly													
BGC05-09	Thermistor	Bi-weekly													
BGC05-15	Thermistor	Bi-weekly													
BGC05-17	VW Piezo.	Monthly													
Surface Cell															
BGC02-03	Thermistor		Not functioning												
BGC03-07	Thermistor	Monthly													
BGC03-09	Thermistor	Monthly													
BGC03-10	Thermistor	Bi-weekly													
BGC03-11	Thermistor		Not functioning												
BGC03-12	Vibrating Wire Piezometer	Monthly													
BGC03-14	Vibrating Wire Piezometer	Monthly													
BGC03-15	Thermistor	Bi-weekly													
BGC03-20	Thermistor	Bi-weekly													
BGC03-21	Thermistor		Not functioning												
BGC03-32	Vibrating Wire Piezometer	Monthly													
BGC03-35	Vibrating Wire Piezometer	Monthly													
BGC03-36	Thermocouple	Monthly													
BGC03-37	Thermistor		Not functioning												
BGC05-05	Thermistor	Monthly													
BGC05-06	VW Piezo.	Monthly													
BGC05-07	VW Piezo.	Monthly													
BGC05-08	Contingency														
BGC05-10	VW Piezo.	Monthly													
BGC05-11	Monitoring Well		Not functioning												
BGC05-12	Monitoring Well		Not functioning												
BGC05-13	VW Piezo.	Monthly													
BGC05-14	Contingency														
BGC05-16	Contingency														
FG-1	Frost Gauge	Bi-weekly													
FG-2	Frost Gauge	Bi-weekly													
FG-3	Frost Gauge	Bi-weekly													
FG-4	Frost Gauge	Bi-weekly													
FG-5	Frost Gauge	Bi-weekly													
FG-6	Frost Gauge	Bi-weekly													

Weekly Reading

Monthly

Bi-Weekly Reading

Table 1 -

Recommended 2014-2018 Geothechnical and Geothermal Instrument Reading Schedule

BGC Engineering Inc.

							1-Jul	8-Jul	15-Jul	23-Jul	1-Aug	8-Aug	15-Aug	22-Aug	1-Sep
Toe of West Twin Dyke															
BGC03-18	Thermocouple		Not functioning												
BGC03-19	Thermistor	Bi-weekly													
BGC05-26	Thermistor	Bi-weekly													
Test Cell															
BGC05-04	Thermistor	Bi-weekly													
BGC05-18	VW Piezo.	Monthly													
BGC05-19	Thermistor	Bi-weekly													
BGC05-20	VW Piezo.	Monthly													
BGC05-21	Monitoring Well		Not functioning												
BGC05-22	VW Piezo.	Monthly													
BGC05-23	Monitoring Well		Not functioning												
BGC05-24	VW Piezo.	Monthly													
BGC05-25	Contingency														
FG-7	Frost Gauge	Bi-weekly													
FG-8	Frost Gauge	Bi-weekly													
Test Cell Dyke															
BGC02-09	Thermistor		Not functioning												
BGC03-22	Thermistor	Monthly													
BGC05-29	Thermistor	Bi-weekly													
Toe of Test Cell Dyke															
BGC05-27	Thermistor	Bi-weekly													
BGC05-28	VW Piezo.	Monthly													
FG-9	Frost Gauge	Bi-weekly													
FG-10	Frost Gauge	Bi-weekly													
Oceanview Pit															
BGC05-01	Thermistor	Bi-weekly													
FG-16	Frost Gauge	Bi-weekly													
East Open Pit															
BGC05-02	Thermistor	Bi-weekly													
BGC05-03	Thermistor	Bi-weekly													
FG-13	Frost Gauge	Bi-weekly													
FG-14	Frost Gauge	Bi-weekly													
Landfill															
BGC05-30	Thermistor	Bi-weekly													
FG-11	Frost Gauge	Bi-weekly													
Area 14															
TC7	Thermocouple	Monthly													
FG-15	Frost Gauge	Bi-weekly													
Upper Dump Road															
FG-17	Frost Gauge	Bi-weekly													
West Open Pit															
BGC08-01	Thermistor	Bi-weekly													
Mill Cover															
BGC08-02	Thermistor	Bi-weekly													
Water Quality / Levels															
159-4	Water Level	Weekly													
159-4	Water Quality	Bi-weekly													
Spillway Inlet	Water Quality	Bi-weekly													

Weekly Reading

Monthly Reading

Bi-Weekly Reading

FIGURES

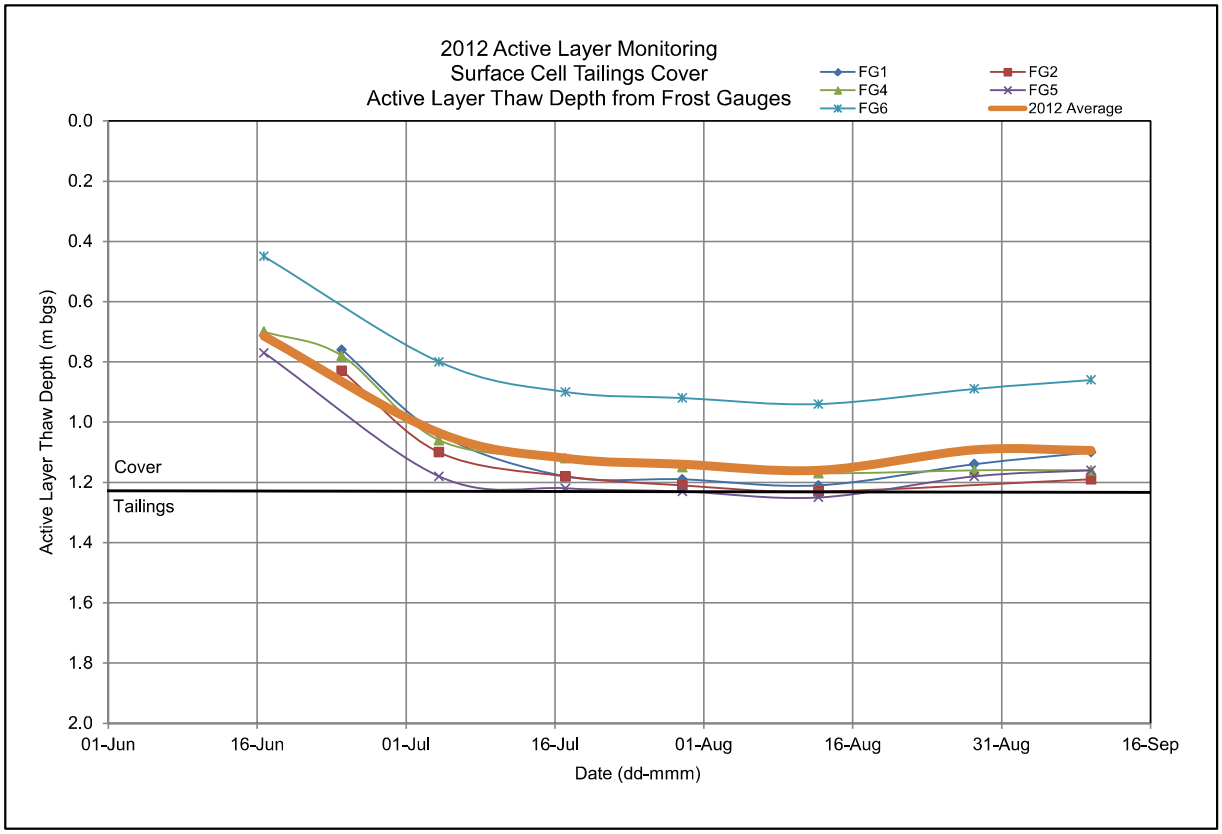

Figure 1. Cover Performance – 2012 Frost Gauge Plot from Surface Cell.

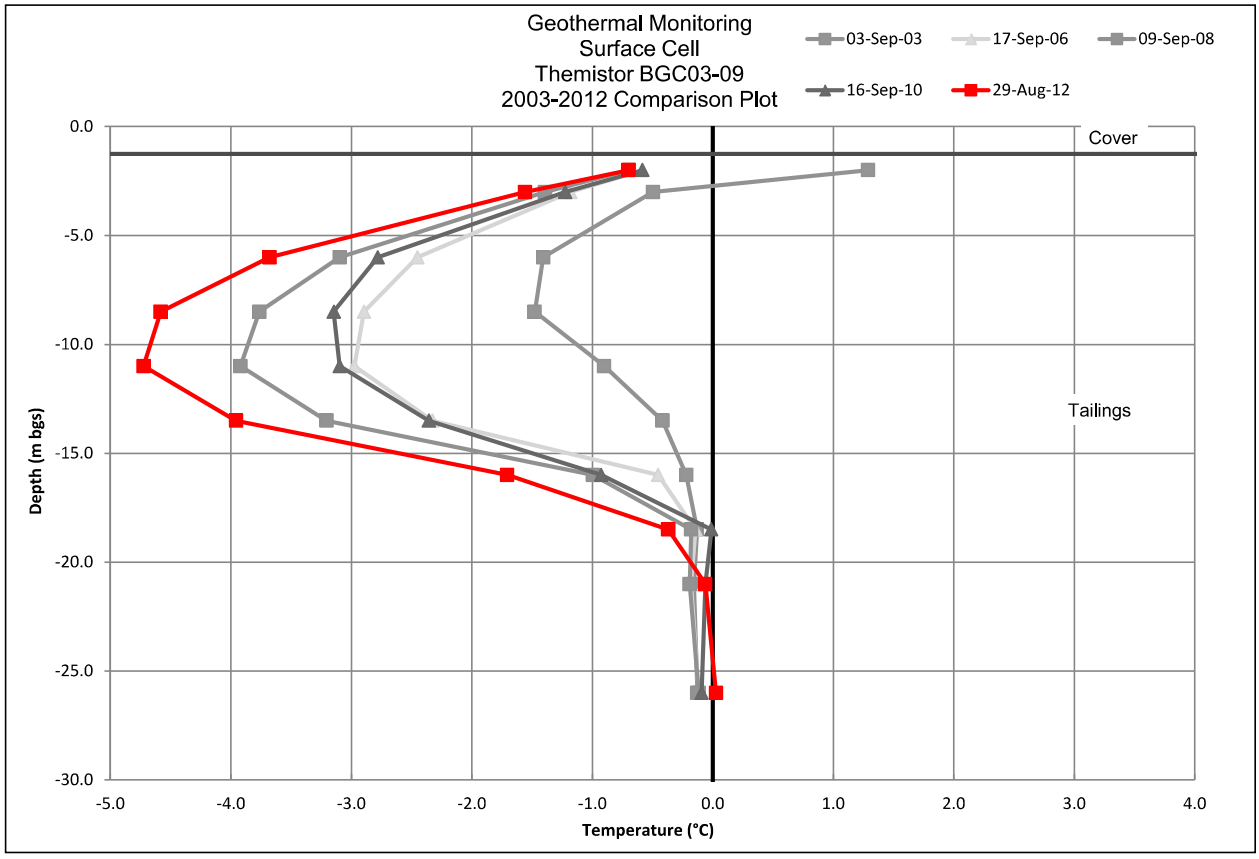

Figure 2. Surface Cell Talik Freeze-back – Thermistor 05-05 near Centre of Surface Cell Talik.

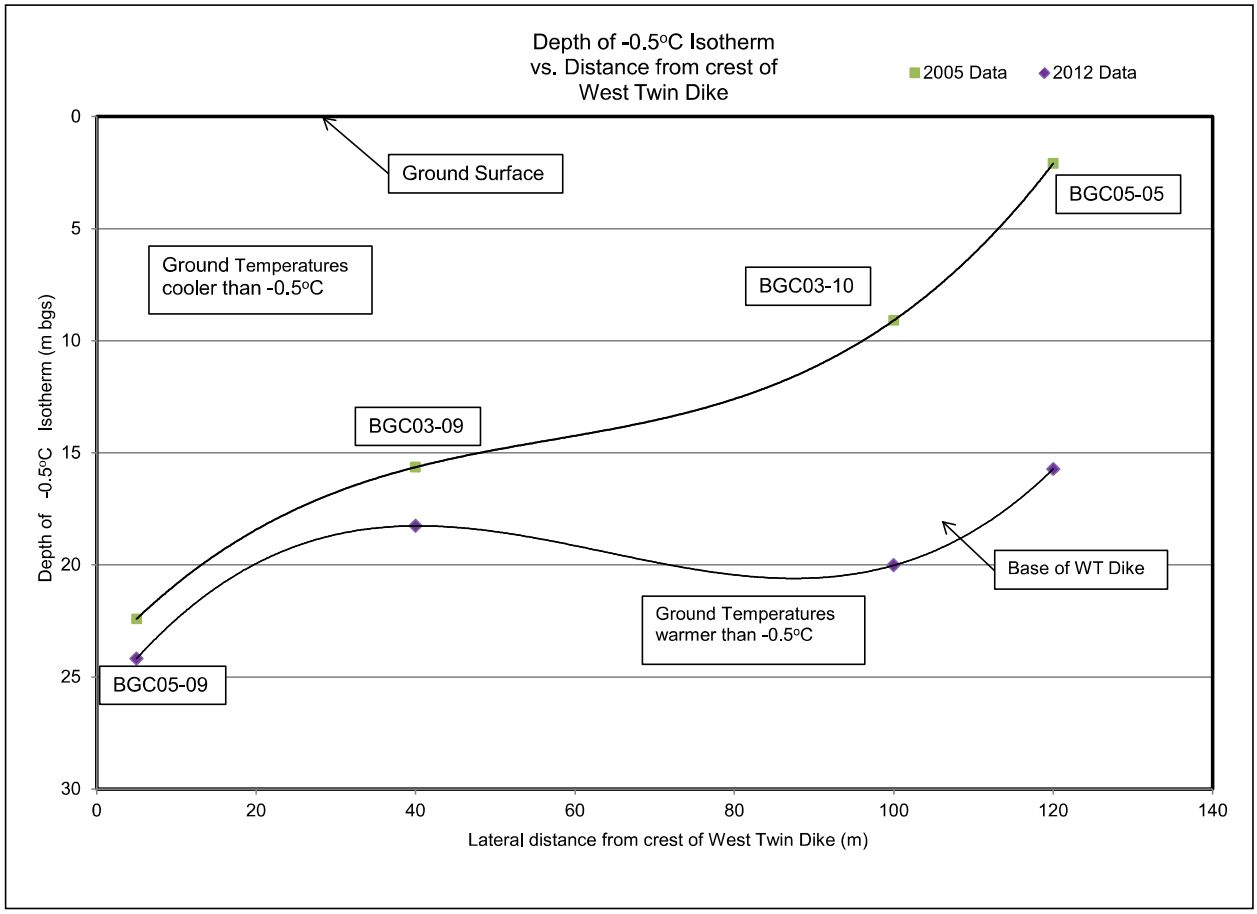

Figure 3. Surface Cell Talik Freeze-back – Downward progression of freeze-back with time and proximity to West Twin Dyke.

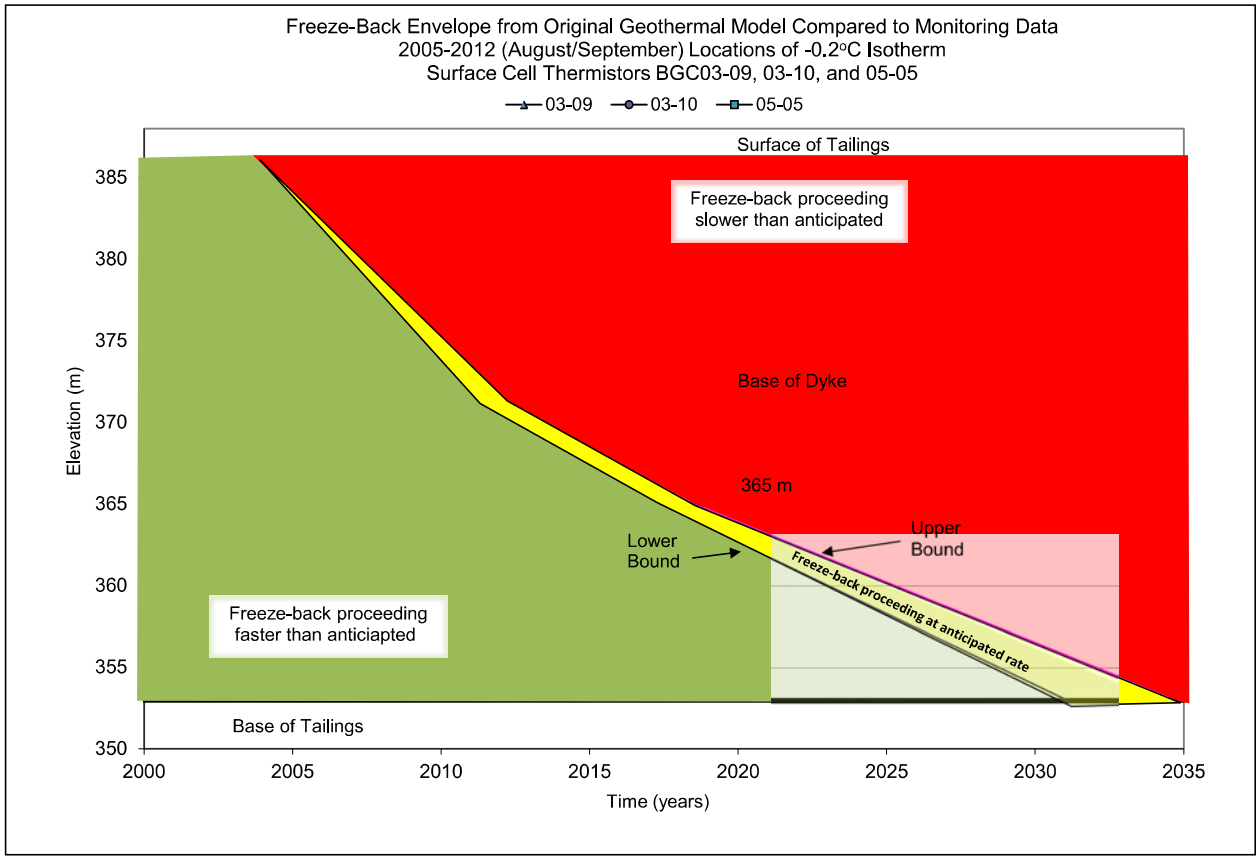

Figure 4. Surface Cell Talik Freeze-back – Comparison of observed freeze-back with previous model results.

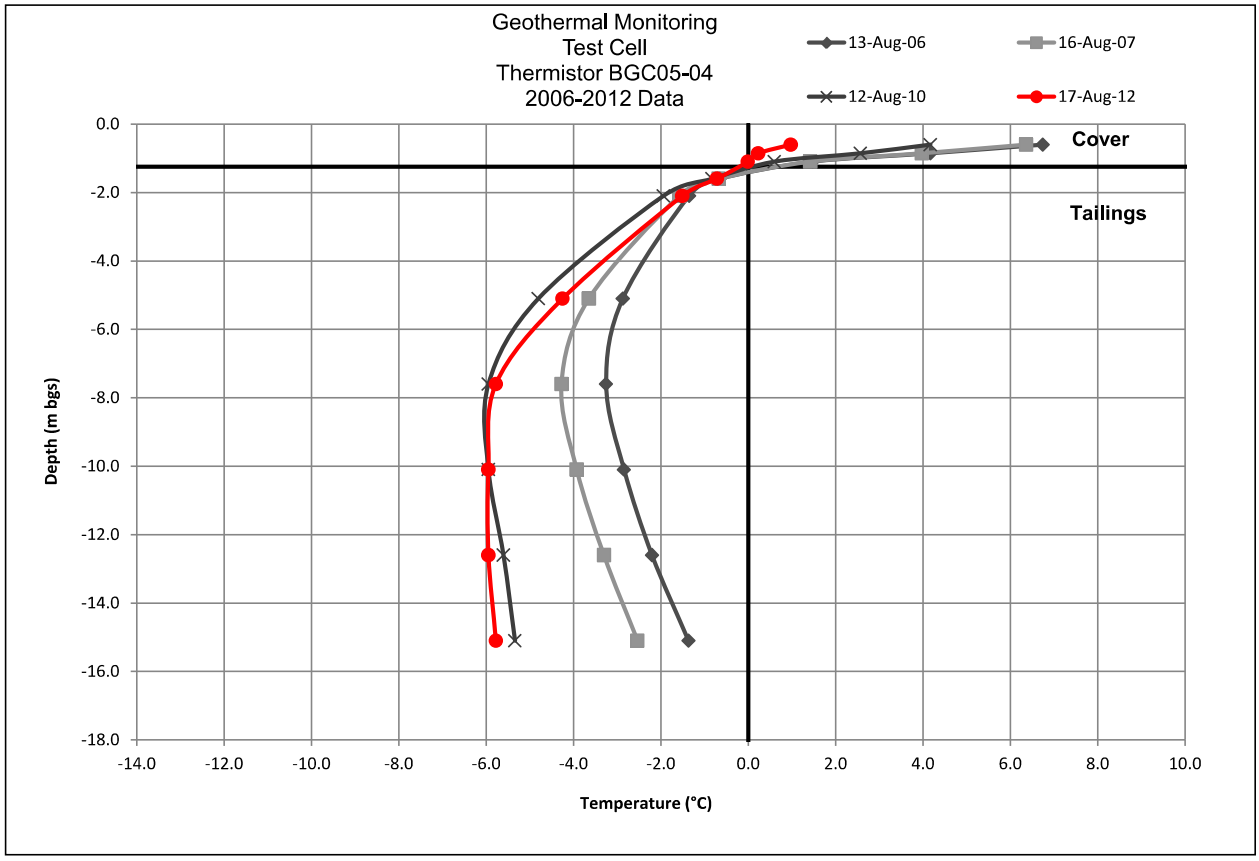

Figure 5. Test Cell Talik Freeze-back – Thermistor 05-19 near Centre of Test Cell Talik.

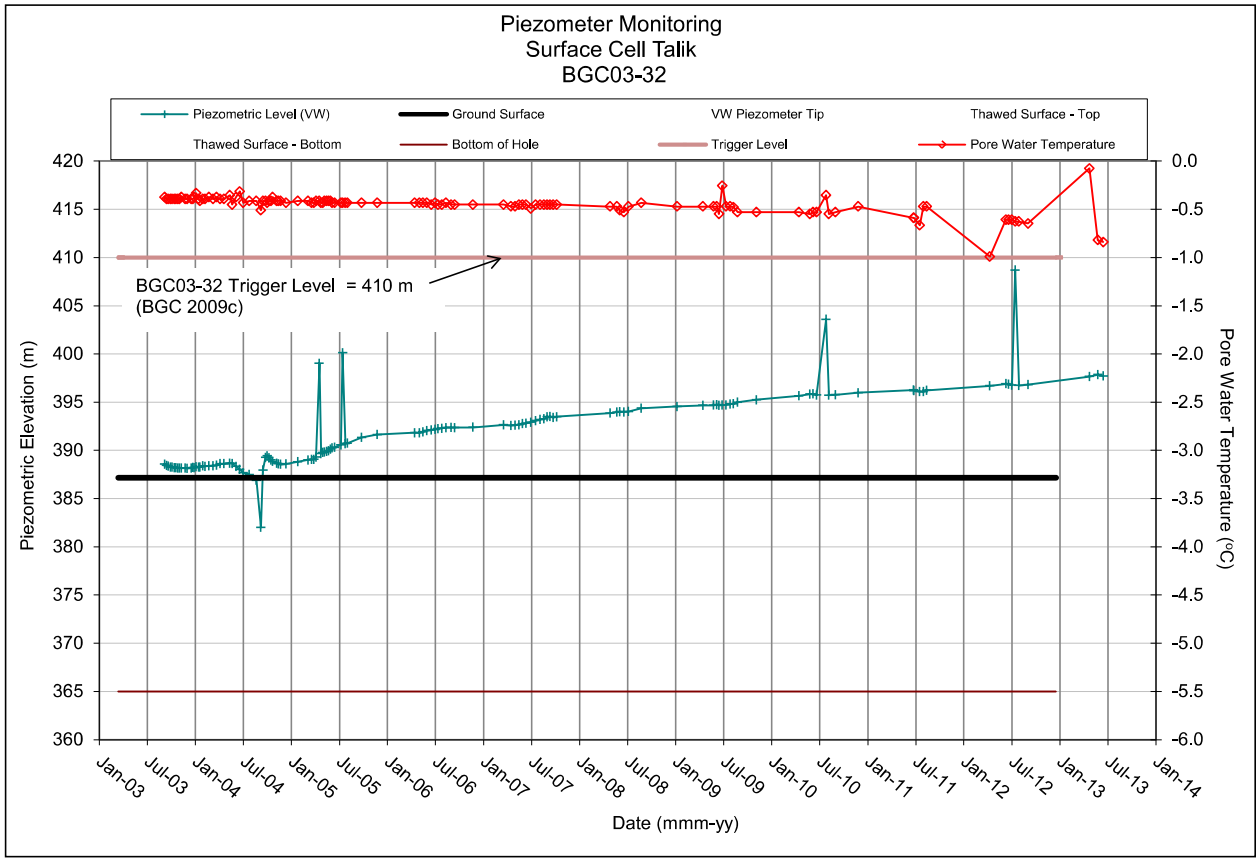

Figure 6. Pore Pressures in Surface Cell Talik.

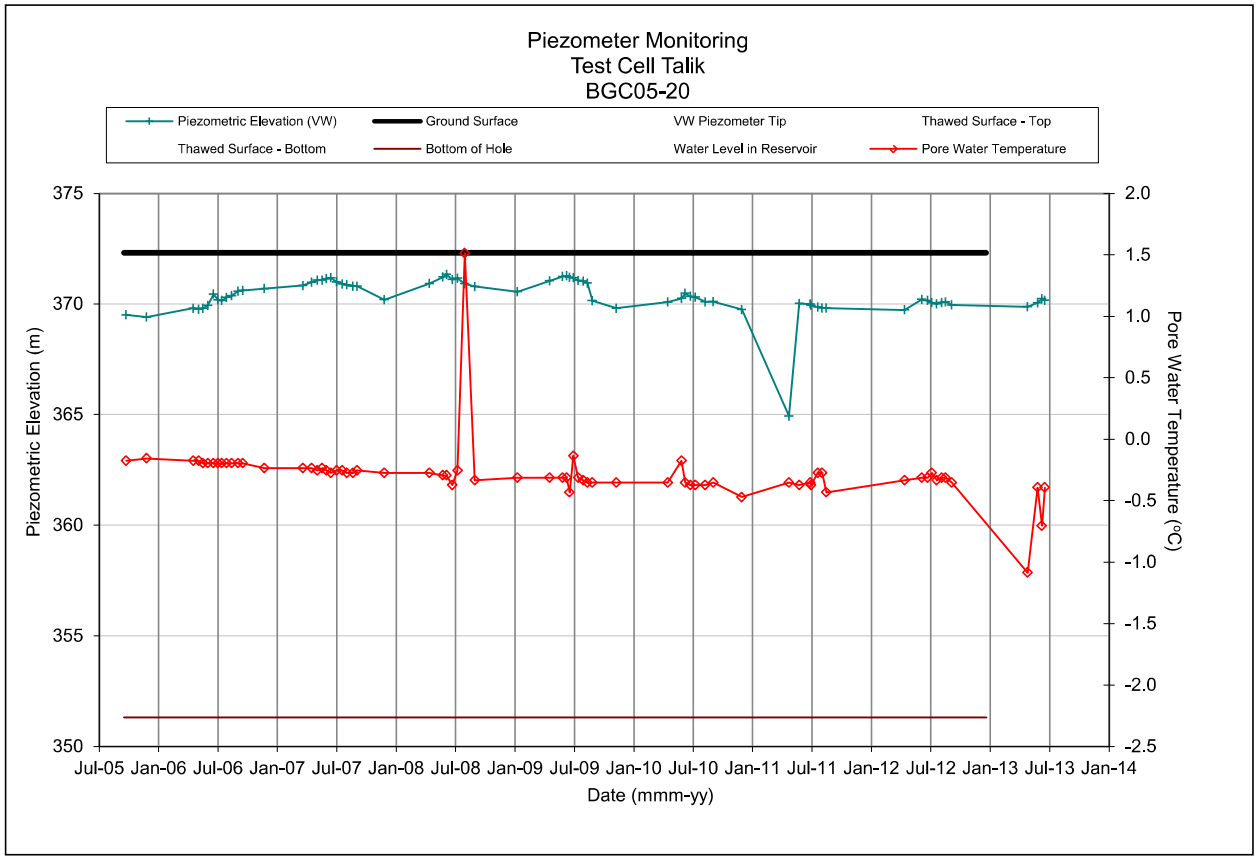

Figure 7. Pore Pressures in Test Cell Talik.

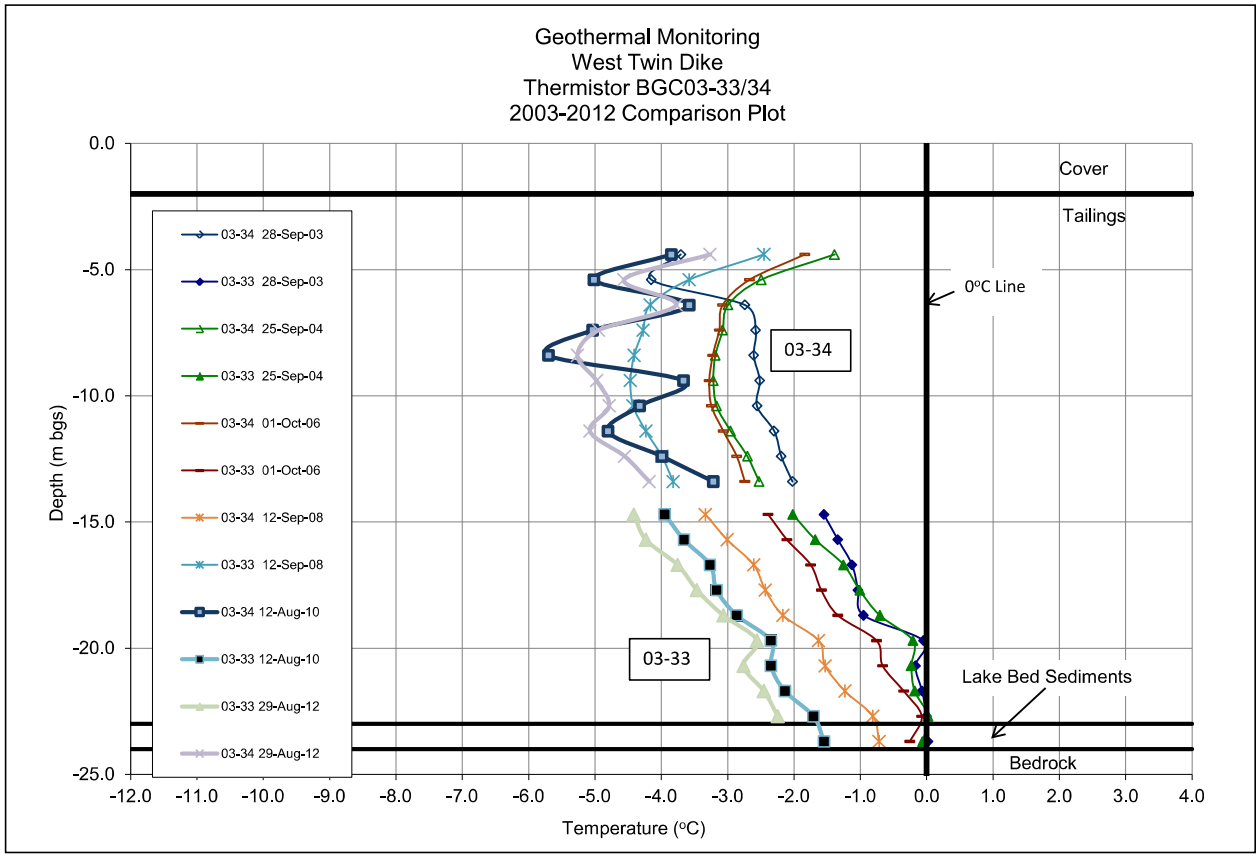

Figure 8. Freeze-back of West Twin Dyke Foundation – Thermistor 03-33/34.

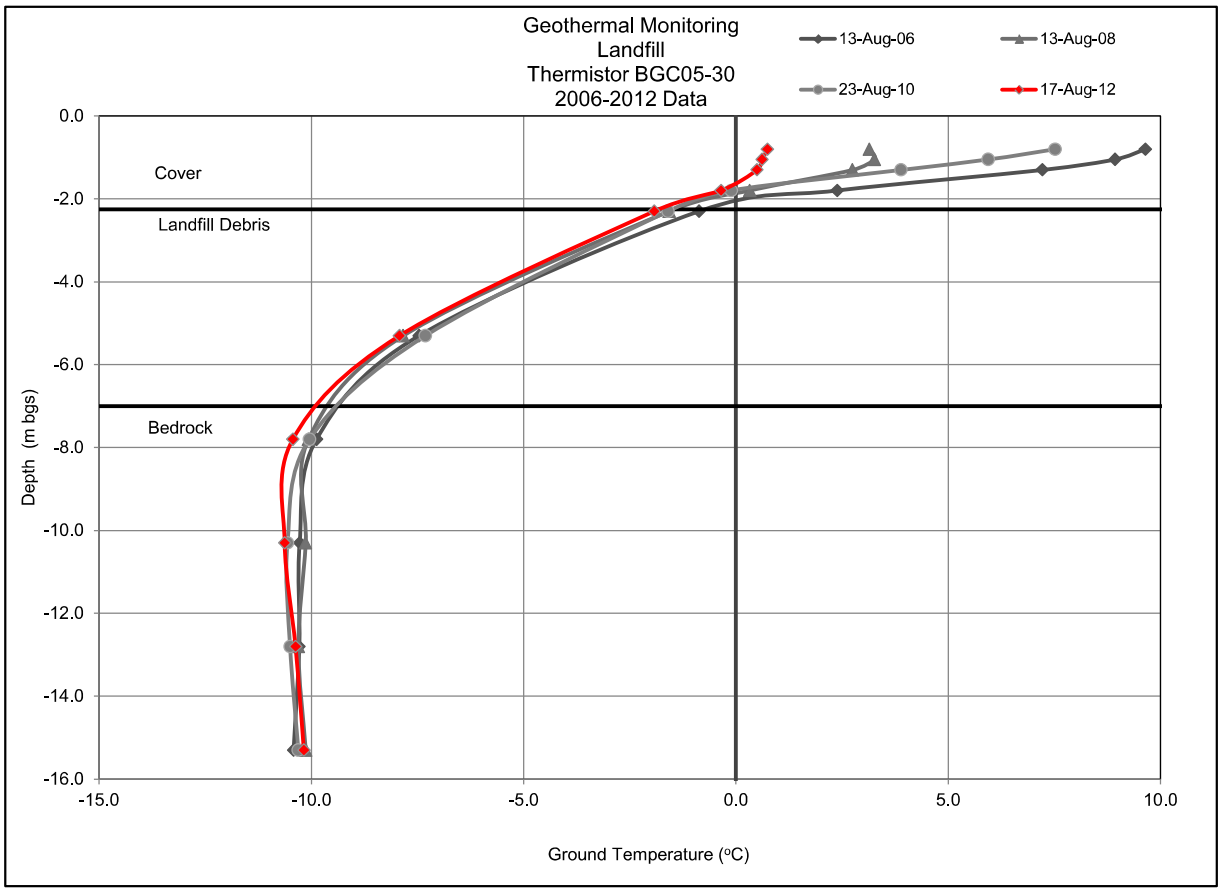

Figure 9. Freeze-back of Landfill – Thermistor 05-30.

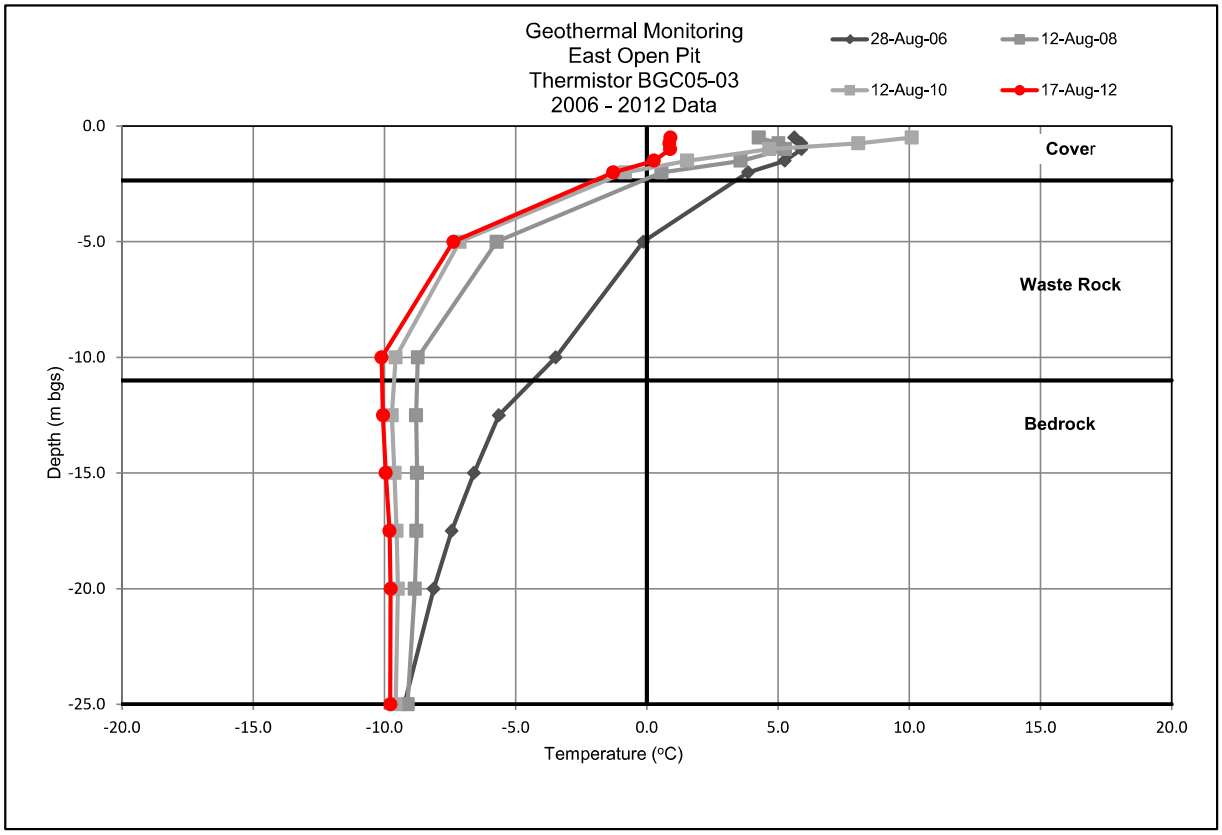

Figure 10. Freeze-back of East Open Pit Waste Rock Backfill – Thermistor 05-03.