December 20, 2006

Wek’eezhii Land and Water Board
Violet Camsell-Blondin, Chair
Zabey Nevitt, Executive Director

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Dear: Ms Camsell-Blondin

Re: Annual Geotechnical Engineering Report — A154 Dike and North Inlet East Dike.

Please find accompanying this cover letter, DDMI’s Annual Geotechnical Engineering Reports for the A154 Dike and North Inlet East Dike, as per Part H, Items 3e, 4f, and 5f of Water Licence N7L2-1645. These reports have been prepared and stamped by Mr. Anthony Rattue with Nishi-Knton/SNC-Lavalin (NKSL).

Both inspection reports are in pdf format, readable in Adobe for your convenience, as well a hard copy has been provided.

If additional copies are required, please forward a request to Scott Wytrychowski @ 867-766-5407.

There were no major notable concerns by the geotechnical engineer during the inspections in 2006; however, there were a few minor items noted. In italics, DDMI has added comments on items that are currently within the dike-monitoring schedule, as well as items that will be addressed prior to the next annual inspection.

**A154 Dike**

- Continue dike monitoring with the measurement frequencies revised as appropriate to take into account the reliable performance of the automated reading and the evolution of various values. *This is part of the dike Standard Operating Procedure.*
• Manual readings of the vibrating wire piezometers have been reduced to once per month as a check of the automated readings for the latter are now showing reliable and consistent results. However, the reading frequency should be increased in the case of a malfunction of the automated system. Manual data will be compared to automated readings, and if the data demonstrates significant differences an investigation will be undertaken to determine why the differences and manual reading frequency will be adjusted.

• Complete the repairs to the discharge line from pump stations DPS-1 and DPS-2 and replace the pump controllers at these stations and at DPS-4 so as to permit automated pumping from the stations and providing the means to evaluate the water inflow. New piping is on order for the 2007 winter road.

• Backfill the pit at Stn. 1+540 and regrade the area downstream of island E to improve drainage, reduce the extent of ponded water and lower the water table in the spring. Re-grading of the down stream of island E was started in October and November. Till from A418 pre-stripping will be used in 2007 to improve drainage control and to direct run-off toward the DPS well to reduce the amount of ponded water within the basin.

• Ensure a periodic review by the engineering staff of the thermistor readings in marginally frozen areas. DDMI Geotechnical technicians review all dike monitoring data as per their Standard Operating Procedures (i.e., daily). DDMI’s Geotechnical Engineer reviews all dike monitoring data periodically, as well reviews a weekly summary report.

• Maintain control of blast parameters to ensure a maximum PPV of 50 mm/sec on the dike. PPV of 50 mm/sec or less will be followed.

• Reinstate blast monitoring and increased piezometer reading frequency if required by work on the upper benches. If upper bench work is required, blast monitoring and piezometer readings will be monitored, frequency of monitoring will be determined by the Mine Geotechnical department.

• Periodically check the functioning of the return valves in all pump stations. This check is part of the maintenance schedule for the DPS wells conducted by Diavik’s Site Services Department.

• Add slope protection around the intakes to the pump stations. During the re-grading around the DPS wells, additional slope protection will be added. This protection will help reduce erosion, reduce the amount of suspended solids, and moderate flows towards the DPS wells.

• Clean out the sediment traps at the intakes. Once a year this is completed, as part of the maintenance schedule for the DPS wells by Diavik’s site Services Department.
• Install survey monuments with anchors buried in the crest of the dike above and below elevation 419m to assist in better understanding the cracking phenomenon. *Monuments were added in the fall of 2006 at selected locations to monitoring the cracking phenomenon.*

• Remain vigilant despite the reduction in seepage as manifested at the dike toe. Flow is now taking place at greater depth and though overall slope stability has been enhanced by lower piezometric levels in the foundation, the high gradients may increase the potential for internal erosion. Pay particular attention to areas where dumps prevent visual observations to be made. *No comment*

**North Inlet East Dike**

• Monitor the upstream and downstream faces for wave damage and repair as necessary. *Included in the Standard Operating Procedures for the North Inlet dike monitoring.*

• Examine the crest, after the disappearance of snow and ice in the spring, for renewed cracking. *Information will be added to the notes of the inspection report of the North inlet dike.*

• Install survey monuments with anchors in the embankment above and below the working platform from which the cut-off was constructed. Continue to take readings of the thermistor strings. Excavate a shallow trench in the vicinity of the crack to determine depth. *Completed.*

• Continue to ensure that no degradation of the permafrost takes place in the two abutments. Note: that this is more of an environmental concern at this time than a potential for effects on the dike performance. *No comments.*

• Conduct a survey along the dike crest preferably on fixed monuments at two-month intervals for the next 3 to 5 years to monitor dike heave or settlement. *This is part of the Standard Operating Procedures for the North Inlet dike monitoring.*

We trust this satisfies the requirements for the 2006 Annual Geotechnical Inspection.

Sincerely,

Mike Kelly  
Vice President, Operations

Scott Wytrychowski  
Manager, Environmental

Attachment
Cc: DIAND Inspector - South Mackenzie District Office (Clint Ambrose)
DIAVIK DIAMOND MINES
WATER RETENTION DIKES

A154 DIKE

Annual Inspection and Performance Evaluation

AUGUST 2006

NISHI-KNON/SNC-LAVALIN
DIAVIK DIAMOND MINES
WATER RETENTION DIKES

A154 DIKE

Annual Inspection and Performance Evaluation

AUGUST 2006

Reviewed by: D. Lemelin, P.Eng.

NISHI-KNON/SNC-LAVALIN
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Executive Summary

The A154 dike was constructed to permit the dewatering of an area enclosing the kimberlite pipes A154N and A154S and the exploitation of the same by open pit mining methods.

The dike consists of a zoned rock fill embankment with plastic concrete diaphragm wall in the fill and till foundation, which is continued to rock by jet grout columns. A grout curtain in the rock also contributes to reducing seepage and uplift pressures.

The dike was constructed in 2001 and 2002. The initial dewatering took place from late July to mid September of 2002. An annual inspection and performance evaluation is required and is to be carried out when steady state conditions have been established in the foundation at the downstream toe following the ground thawing. This period has now been established as being during the month of August. This report constitutes the findings of the fourth annual report.

The performance of the dike is satisfactory. Piezometric levels continue to decline as a result of the drainage of the overburden and rock within the enclosure and the deepening of the mine pit. The spring runoff caused some short term rises in the levels but these have returned to previous values. Some fluctuations are noted in the vicinity of the dike pump stations DPS-1 and DPS-2 due to problems with automated pump control.

The seepage reporting to the dike pump stations is within the design criterion but routine monitoring is not possible given the current pump operation problems.

Deformation of the dike as measured by the inclinometers and survey markers is equal to or less than the values predicted by finite element stress/strain analyses.

Temperature measurements show satisfactory performance of the thermosyphon groups. The slow but steady recovery of the permafrost conditions on the abutments is noted but small local warming trends have been observed in two areas.

As blasting for the mine takes place only at the bottom of the pit, the distances to the various sectors of the water retention dike have increased and little or no influence is detected. Blast monitoring no longer takes place on a regular basis. Any slashing of the pit walls on the upper benches would be justification to resume monitoring, at least for those blasts.
1 INTRODUCTION

1.1 Summary description of the project

The A154 dike was constructed to permit the dewatering of an area enclosing the kimberlite pipes A154N and A154S and the exploitation of the same by open pit mining methods. See plate #1 for the general arrangement.

The dike consists of a zoned rock fill embankment with plastic concrete diaphragm wall in the fill and till foundation, which is continued to rock by jet grout columns. A grout curtain in the rock also contributes to reducing seepage and uplift pressures. The central part of the embankment was constructed of 0-56mm crushed rock to permit the excavation of the diaphragm wall under bentonite slurry. The downstream shoulder is composed of 0-200mm crushed rock and the upstream shoulder of 0-900mm quarry run rock. The maximum size of particles in the downstream shoulder was required to reduce segregation and to better ensure filter compatibility with the central zone. The upstream zone is less critical in this respect and the larger size rock provides greater wave protection. The downstream shoulder is underlain by a filter blanket of 0-56mm material to protect the foundation against piping.

The foundation was dredged prior to embankment placing to remove lakebed sediments judged to be prejudicial to the dike stability.

The crest of the embankment is at elevation 421m, which provides a 5m freeboard above normal lake level and adds thermal protection to reduce the amplitude of the freeze/thaw cycles at the level of the cut-off, which extends to elevation 417.5m.

The dike foundation under the lake was originally unfrozen, whereas the on-land areas are affected by permafrost. The grout curtain could not treat the frozen rock and a potential weak zone could exist at the frozen/unfrozen boundary if degradation of the permafrost occurs. To mitigate against this possibility, thermosyphons were installed at the abutments to artificially freeze the ground and the rock, and envelope the end of the grout curtain and the diaphragm wall. In this way, some fluctuation of the boundary may take place without opening a window for seepage.

After the initial dewatering of the pit area, perforated drains were installed along the dike toe, and pump stations provided at the low spots in the profile to collect and dispose of seepage water. A total of five stations were required. These are hooked up to heat traced pipelines installed on the 419m level berm. With the current pit configuration and drainage patterns, only three pump stations are required. An additional weighting berm was added after the toe drain installation, to a height of 5m in deeper areas or to reach elevation 416m in the shallow areas.
A comprehensive set of instruments was installed in the dike and the foundation to monitor the behaviour of the dike. Several of these are connected to an automated data acquisition system, which permits readings to be made from a central location in the office complex.

1.2 Scope of present report

Nishi-Khon/SNC-Lavalin (NKSL) were involved in the design, construction and initial dewatering of the A154 dike. A renewable mandate has been given to NKSL to carry out an annual inspection and performance evaluation of the dike. The initial dewatering took place in July/August 2002 and this report presents the findings of the fourth annual inspection carried out in August 2006.

The report comprises:

· The observations and comments arising from the site inspection;

· A review of the instrumentation system;

· An analysis of the results obtained from the instruments;

· Conclusions pertaining to the dike performance;

· Recommendations for ongoing monitoring, repair and maintenance.
SITE INSPECTION

2.1 Itinerary

The inspection was carried out on August 28\textsuperscript{th} by Anthony Rattue, PEng (NKSL) in the company of Dan Guigon (Geotechnical Technician DDMI) and Eric Thiesburger (Assistant project manager A418 dike).

The inspection was carried out on foot, proceeding generally from the North-West abutment around to the South-West. The dike was divided into two sectors to facilitate the inspection. First the crest of the dike from the abutment to island E was covered on foot followed by a return at the toe level. Subsequently the sector from island E to the south-west peninsula was inspected.

The weather was cool and sunny during the inspection. Two days of dry weather preceded the inspection but heavy rain had fallen earlier. Nevertheless, conditions permitted a good appreciation of the seeps and wet areas.

2.2 Observations and Comments

As was noted in the previous report (2005) the continuing influence of the mine drainage is apparent in all sectors. The dropping piezometric levels (see section 3) are accompanied by reduced surface manifestations of seepage. Any flow, through or beneath the dike and the cutoff is reporting to the mine rather than to the dike toe drains.

The bottom of the pit is now at elevation 270 m and the lake at the time of the inspection was 415.8m thus the head difference is now greater than 145 m, an increase of about 30m since the previous year.

The overall layout of the dike is shown on plate # 1. The stations advance from the NW abutment, continue along the dike and terminate at the SW abutment. The following comments are presented in order of increasing station.

Northern sector (NW abutment to Island E)

The sector comprises three distinct catchment areas. The first is bounded by the dike and dump # 7 (photo #1) and the runoff reports either to pump stations DPS-1 and DPS-2 or seeps into the ground to be ultimately handled by the mine pumps. The second area from Stn. 1+000 to Stn.
1+500 drains directly to the pit area, and the third from Stn. 1+500 to island E drains along the valley between dump #8 and the dike to finally disappear into sinkholes before reaching the DPS 4 pump station.

Water emanates from the toe of the downstream berm at station 0+228 (photo #2). The base flow rate has remained below 0.1 l/s but snow melt and rainfall can raise the flow to measured values exceeding 0.5 l/s. The flow at the time of the inspection was somewhat higher due to the rain three days previously. The water was flowing clear and there was no evidence of boils or other sign that the flow was anything other than groundwater flow unrelated to Lac de Gras. This same flow had been monitored during the initial dewatering and, at that time, its origin could be traced to a stream downstream of and beyond the limits of the dike with a source situated above the lake elevation, which flowed parallel to the dike before entering the embankment fill at around station 0+150. After flowing within the embankment the flow exited at station 0+228.

At DPS-1 (Stn 0+380), the intake was submerged (photo #3). The source of the problem is a faulty pump controller which necessitates manual operation of the pumps. This has led to intermittent operation and the accumulation of water in this area.

The influence of a higher water table is also manifested at Stn. 0+470 where a small pool of water persists (photo #4). The water was turbid but run-off from recent rains have probably contributed to the sediment in suspension. No flow was observed.

At DPS-2, station 0+620, a small inflow of water could be seen at the inlet. The total flow was less than 1.0 l/s. The excavated face in front of the intake still requires better slope protection to minimize the quantity of material washed down by rain or snowmelt.

The depression between Stns 0+725 and 0+740 was virtually dry. As noted in 2005, complete thawing of the ground is necessary to make a reliable appreciation of the water accumulation in these depressions.

Between Stns. 1+040 and 1+200, the only water visible was in the drain at Stn. 1+040 (photo #6). Little flow was observed at this location and rain water run-off may be responsible. The vegetation in the general area was quite luxuriant (photo #7) but, as mentioned, no surface water was visible. The upper bench of the pit wall is dry (photo #8), water appearing only on the second bench.

As noted in 2005, water was backed up into the drain outfall at Stn. 1+435 by a roadway constructed to access a drill pad. No flow was visible downstream of this roadway, only damp ground.
The pit excavated at Stn 1+540 and mentioned in the previous report, was again filled with water. It should be backfilled.

The downstream slope of the main embankment in this sector (0+000 to 1+500) is generally planar. No areas requiring maintenance were noted.

Some investigation of the crack between stations 0+282 and 0+303 has been made. Cement grout was poured into the crack and allowed to set prior to excavation. The crack could be traced down to a depth of 1.5m (from the crest at el.421m). At elevation 419m, the crushed stone material was visibly contaminated with grout return from the jet grout treatment of the central portion of the dike. It had been surmised that the aquiclude created by this material prevented free drainage and allowed ice accumulation which jacked the ground surface and opened the cracks. The cracking phenomenon is therefore deemed to be superficial and has no effect on dike performance.

The crackmeters at stations 0+645 and 1+225 have not been disturbed and a cyclical movement of about 5-6mm was recorded in the 2005-2006 period.

The upstream face of the dike is composed of quarry run rock fill with a maximum size of 900 mm. The design did not call for rip-rap as the dike will be under year round surveillance and mine equipment is available to undertake repairs as and when necessary. Several areas have been affected by wave action since the construction, particularly on the more exposed northern and north-eastern sectors. It should be noted that the material eroded from the face has formed a beach which tends to break the waves prior to impact. The annual lake level variation is rarely more than 0.5m and the face of the dike will not be affected at other elevations. The rock fill comprising the slope is uncompacted and some slope movement combined with washing of the finer fraction into voids could create depressions in the slope and result in a retrogressive displacement reaching the edge of the crest. At this point the survey markers may be affected by local displacement and the true record of dike deformation may be lost. Dike integrity is not in jeopardy but the repair of the more extensively eroded areas was deemed desirable. This work was carried out in the winter of 2005-2006 (photos #9 and #10). This period with ice cover was chosen so as not to release any rock dust into the lake. Unfortunately, the presence of snow did not permit the various areas to be fully observed and repaired. Missed areas in this sector include the following:

- 0+728 to 0+735;
- 0+752 to 0+764;
- 0+920 to 0+930;
- 1+120 to 1+125.

DDMI is being diligent in the respect of the water license conditions but at times this can impede the execution of good quality work.
During the visit, particular attention was paid to the area between Stn. 0+920 and Stn. 0+970, which had been noted during the previous inspection as having the most serious erosion. As noted above, the first 10m were missed in the repair and will require extra work. The current condition can be appreciated from photo #10. The recommendation that well graded 0-200 or 0-300 rock be placed against the faces before adding coarse rock protection was not adopted. Energy dissipation by the large rocks is the primary objective of a rip rap and the absence of a transition may lead to some particle rearrangement but large scale movements are not anticipated.

The leaking welded joint in the HDPE discharge pipeline at the pump station DPS-1 has not yet been properly repaired as can be seen in photos #11 and #12. No significant damage is being caused to the dike but this and the intermittent pump operation may prevent timely recognition of changes in the seepage regime.

**Eastern Sector (Island E to Island D)**

The drainage basin downstream of island E that is shown in photo #13 has not been touched since the previous inspection and consequently some local ponding in the spring or after rain still occurs. Subsequently the water infiltrates the ground. Even the catchment basin at DPS-3 that fills with melt water drains down into the rock during the summer period. However, the distance to the mine pit face is at its greatest at this point. The seepage measuring pipe at Stn. 2+180 was dry.

The discharge line from pump station DPS-3 has been re-connected.

The upstream slope was repaired during the winter but again, the presence of snow hampered the work and additional rockfill is required between stations 2+230 and 2+240.

**Island D**

Seepage was noted to be emanating from the pit side slope of Island D during the initial dewatering. Some was attributed to drainage of the terrain and some to thawing of ice and snow buried in fill outside the dike limits. Presently, only minor seeps are noted such as those at stations 2+275 and 2+290 immediately upstream of the toe access road. Close attention is still being paid to the seepage, as one explanation for it’s occurrence is a talik beneath island D. The northern tip of the island is quite narrow and the permafrost may pinch out at depth. The thermosyphon group was located according to the position of the vertical permafrost boundary at the end of the island. Additional thermistor strings have been installed to monitor the situation. This subject is also treated in section 3.7 of this report.
Run-off from the platform downstream of the dike in the center of the island contributes to the moisture content of the natural ground at the scarp shown in photo #14. Some erosion of fines continues to take place but the slope is generally stable.

The seepage from the entire area is collected at the flow pipe 2+485 (photo # 15) from whence the flow disappears down sinkholes as in the small pool shown in photo #16.

**Southern Sector (Island D to SW Peninsula)**

At the pump station DPS-4, a small flow is monitored in the channel leading away from the station (photo # 17). However, this flow also disappears a short distance downstream. Pump operation is intermittent and controlled manually.

The seep at Stn. 2+870 persists and is measured by a flow pipe. The flow is minor and the water runs clear.

The dike toe between stations 2+800 and 3+000 was dry as were the depressions further downstream (photo #18).

The downstream face of the dike is generally planar and no signs of erosion or deformation were noted.

No cracking has been observed on the crest in this segment of the dike. A small sinkhole has been noted in the crest at Stn. 2+626 and is likely the result of the road topping material being washed down into the coarse zone 3 rockfill.

The upstream face is in the lee of the prevailing wind and little wave induced erosion has been noted. No repair was required in this area.

**South-west Peninsula**

The south-west peninsula is a zone of permafrost, though only marginally frozen at the neck (station 3+700 to station 3+800), and little or no seepage was anticipated or in fact has been observed. The small seep originally noted at Stn 3+130, has been covered since two years by the dump #8 (photo #19) and can no longer be checked. A small increase in the piezometric levels is noted as discussed in chapter 3.
Some housekeeping is still in order on the downstream slope area above the haul roads but there is nothing evidently prejudicial to dike integrity.

No significant observations were made concerning the crest and upstream slope in this area.

**Instrumentation**

Other than reports of interference between the PED (Personnel Emergency Device) antenna and the instrument grounding system, no other problems with instrumentation have been noted. The reliability continues to be excellent and the coverage adequate to define the behavior of the dike.

**Miscellaneous**

Bracing is still required for the thermosyphon radiators as oscillation in high winds may continue to be a risk for damage. The installations for the A418 dike have this feature.

**Daily Reports**

The geotechnicians file daily reports that include notes on the instrument readings, visual observations, mine blasting, construction/maintenance activities and any other pertinent incidents.

**Weekly Visual Inspection**

A comprehensive visual inspection is carried out during the summer months by the dike surveillance team on a weekly basis. The findings are transcribed onto standard forms which permit subsequent inspections to be easily carried out by the same or other technician. Winter conditions and snow accumulation do not permit such detailed inspections but the surveillance team makes daily visits to the dike throughout the year.
3 ANALYSIS OF INSTRUMENTATION READINGS

3.1 Generalities

The analysis of the instrument readings is presented in two sections. In the first section a general description of the instrument system is given, followed by a review of the results.

3.2 Instrumentation system

A comprehensive instrumentation system was installed in the A154 dike to take into account the initial dewatering, which was carried out essentially blind as the downstream toe was not accessible, and the fact that visual observation is impossible for much of the year.

Instruments installed as part of the original construction include:

135 vibrating wire piezometers distributed at 59 locations along the dike alignment;

59 Casagrande piezometers installed at 31 locations;

8 inclinometers 6 of which are installed in the cutoff wall at selected locations and 2 are located in the embankment downstream from the cutoff axis;

17 extensometers, 5 of which are installed in the cutoff, 5 in the embankment from the dike crest within the thermosyphon clusters and 7 near the downstream toe of the dike;

84 thermistor strings, 7 of which are installed in the cutoff, 70 in the dike fill and foundation downstream of the dike axis and 7 near the dike toe;

76 survey markers on the dike crest and the toe berm;

84 survey pins at the top of the cutoff wall;

4 survey reference monuments;

10 flow meters installed in the pump stations;
3 portable seismographs.

A data acquisition system consisting of 7 data loggers was located on the dike crest to automatically take readings of all the vibrating wire piezometers as well as the thermistor strings and extensometers installed in the vital cutoff wall.

The instrument layout is illustrated on plate #2.

Subsequent to the first year of monitoring with the mine in operation, additional instruments were installed and include:

- 9 vibrating wire piezometers;
- 4 inclinometers;
- 1 deep string of thermistors in island D;
- Several survey markers and reference stations.

The piezometers and inclinometers were located on the stretch of dike where the set back from the pit wall is a minimum and effects of blasting were recorded.

### 3.3 Records consulted

The records of most manual readings are archived in dedicated Microsoft Excel based computer files. The software Grapher is also used to facilitate the graphical presentation of these results. The primary treatment of the automated readings is done with Geonet, a proprietary software package from Geomation, the acquisition equipment manufacturer. The results consulted for the preparation of this report were up to date as of August 2006.

### 3.4 Pore pressures

#### 3.4.1 Casagrande Piezometers

In general, the readings continue to show a steady decline in piezometric levels. This is consistent with continued drainage of the terrain exposed by dewatering and the influence of the
deepening mine pit. At the time of the review, the elevation of the sump was around 270 m, that is about 30 m lower than the corresponding period in 2005.

In June, runoff from snow melt initiated an increase in the readings of most instruments and because the winter levels are lower than in previous years, the short term increases are more noticeable.

In the northern sector the intermittent operation of the pump stations has resulted in pressures which have not declined to their winter levels. This is the case for the piezometers C0401 and C0491.

At the southern part of the dike before the peninsula area, the instruments in the overburden beneath the dike (C3032 and C3172) are showing a gradual increase since the spring of 2005. In contrast, the rock pressure levels remain low. The dump #8 affects surface drainage in the area and may be contributory. The piezometric levels are not prejudicial to dike stability but the presence of the dump precludes visual observation of the toe.

3.4.2 Vibrating Wire Piezometers

Comments similar to those for the Casagrande piezometers can be made. In general, the lack of groundwater recharge from rainfall during the winter and the influence of the mining have resulted in progressive declines in the piezometric values. The piezometric levels in the overburden, and in certain areas also in the rock, rose by up to 6m at the time of the spring snow melt. This rise was exacerbated by the reliance on manual start-up of the pump stations. The pressures subsequently declined as the ground drained and less frequent pump operation was required.

3.4.3 Discussion relating to piezometric levels

In general it is anticipated that the efficiency of the cut-off is greatest for the plastic concrete diaphragm wall, almost as great in the jet grout treatment of the overburden and lowest in the grout curtain. The grout curtain was taken down to a depth in rock of 3/4 of the water head or a minimum of 10m. The transmission of lake pressure through the rock is highly likely and the piezometric records were examined for excessive residual artesian pressures under the dike and particularly at the dike toe.

A variety of different conditions exist with regard to the direction and magnitude of hydraulic gradients. A selection of graphs showing current piezometric levels and the evolution of the levels over time is included in figures 3.1 to 3.31 to illustrate the points discussed. On the cross-sections, the water level indicated by the large triangle is the alert level and often is equivalent to
the historical high since the initial dewatering whereas the small triangles with numerical values denote the most recent reading.

In general, on the higher ground the gradients are downward. In the depressions, the artesian pressure in the rock produces an upward gradient. Some of the piezometers at the higher elevations are now dry and at the toe of the berm where the ground cover is shallow, the ground in the vicinity of the instrument is frozen.

At station 0+340 (figures 3.1 and 3.2), all five piezometers indicated water levels below their installation levels (dry) during the winter period. As runoff resumed in the spring, the piezometers V0341 in the rock under the dike, V0344 and V0345 at the toe were the only ones to respond and by greater amounts than in 2005 due to the pump operation. The pressures have not, as yet, declined to their pre-freshet levels. The pressures are not prejudicial to dike behavior but the situation could prevent the timely detection of real changes in the groundwater regime.

The lowest area of dike foundation is to be found around station 0+700. As the till cover over the bedrock is relatively thin, the presence of artesian pressure could be of concern. The situation at station 0+640 is shown in figure 3.4. An upward gradient is noted under the dike. At the toe, the thermistor in the instrument V0645 indicates an ingress of freezing and it is no longer possible to determine if a hydraulic gradient exists in this area, the piezometric value no longer being reliable. However, the rock piezometric level at the toe does not exceed the ground level even during the spring freshet and the till level instrument (V0642) also shows a level within the foundation. It is to be noted that all piezometric measurements are made at a discrete point and conditions between instruments may vary, but the trends are sufficiently consistent to give confidence that a situation which could lead to piping in the foundation does not exist.

As noted in previous reports, the water level in the relief well RW4 can be compared with the V0641 pressure reading. The piezometer is sealed in the rock with bentonite occupying the space in the borehole above the sand pocket in which the instrument is located. The wells are designed to relieve water pressure in the rock by allowing water to enter the well by the lower screen and exit via an upper screen into the embankment. The relief well drill hole was backfilled with granular material and water may escape not only through the well riser pipe but also through this annular backfill. The water level is now below ground level and coincides with that recorded by V0642 located in the till, indicating that little flow is being produced by this well. The fact that the pressure recorded by V0641 remains higher than the relief well level gives credence to the conclusion that the rock conductivity is generally low.

At station 0+940 (figures 3.7 and 3.8), little or no gradient is noted at the toe and a downward gradient is apparent under the dike. This is due to some extent by the pressure recorded at V0943 which has not yet recovered to August 2005 levels.
At station 0+940 and at stations 0+600 (figure 3.3) and 0+880 (figure 3.6) piezometers were installed in the upstream shell or in the till foundation upstream of the cut-off. In all cases, the piezometric level is lower than lake level which indicates that a measurable downward hydraulic gradient in the region upstream of the cut-off has been created by the pit dewatering. Note that the alarm levels are set below the current levels as a drop in pressure would indicate erosion of the seepage path downstream of these instruments.

At station 1+040 (figure 3.9), a downward gradient both below the dike and at the toe is still being observed. The piezometers are mainly dry and a spring time reaction is noted only at V1041, V1042 and V1043. This section was one of the primary areas of interest for the blast monitoring as the pit wall is relatively close (100 m ±). The upstream piezometer (V1046) indicates a general continuing decline in the pore pressure in the till upstream of the wall. The seepage likely takes place through the rock as V1042 is dry. As noted in the inspection report section, there is a reduction in the amount of seepage visible on the face of the pit slope but the gradient between the lake and the bottom of the pit is increasing.

Mainly dry foundation conditions are also reported at station 1+450 (figure 3.11). This year, no influence of ponded water at the time of the spring runoff was noted in the bedrock at piezometer V1351. However, the piezometric levels at V1451 and V1452 rose to peak annual values of 410.7 m and 411.7 m respectively in June 2006, which was slightly higher than the equivalent values for 2005. A partial decline has subsequently been noted. An improvement in the drainage conditions in this area would probably lead to a reduction in the spikes noted each year.

No significant hydraulic gradients have been noted between island E and island D.

At station 2+010 (figure 3.13), the water levels at the toe are controlled by the level in the intake basin for the pump station DPS-3 and whether or not the pumps have been used. The effect of intermittent pumping while testing the line in 2005 can be seen for V2014 on figure 3.14. Natural drainage down into the bedrock takes place during the summer period but a shallow residual pool was noted at the time of the inspection. The piezometric levels have remained high as a consequence. Monitoring of the evolution of these instruments is warranted but the dike is of low height in this area.

At station 2+100, the time history shows all piezometers to be dry during the winter (figure 3.16). The spring freshet in 2005 again caused a sharp rise in V2103 to 409 m on June 1st and the reading had reduced to 407.5 at the time of the inspection. A smaller rise in V2101 had dissipated.

Piezometer 61461, installed in the till foundation upstream at station 2+109, shows a negligible loss of pressure below the lake bed and thus indicates a low permeability foundation.
The greatest artesian pressures were previously recorded along the southern sector of the dike. However, as illustrated by the results from stations 2+710, 2+730, 2+750, 3+000 and 3+030, an upward gradient from the rock only exists in the Casagrande piezometer at station 2+750. Even at station 3+000, the pressure recorded at instrument V3034 is below the rock elevation. The pool level at the downstream toe has dropped and, with the exception of the flow at station 2+870, no springs are to be found in the area exposed to view.

At station 3+130, the typical situation observed for the high ground areas is again in evidence. The gradient is downwards and piezometric levels are contained within the foundation and are similar to the levels recorded in 2005. Piezometer V3133 shows a continuous steady rise since the spring of 2005 similar to the adjacent Casagrande piezometer mentioned earlier. The level exceeds the alert level but by less than 1m. The equivalent instrument at the toe is indicated as being frozen, so the hypothesis of infiel drainage being affected by the dump #8 cannot be easily verified. The dike is shallow in this area but continued monitoring is required.

A similar situation is apparent at station 3+220. That is to say; rising piezometric levels in the till (V3222 and V3223) and a continued decline in the rock as at V3221.

The dissipation of pressure head upstream of the cut-off as recorded by the piezometer 60466 at Stn 3+133 (figure 3.28) has remained essentially constant over the period since the previous inspection. This instrument, situated at an offset of –4m in the foundation till, records a level of 412.7m. The alarm level could be lowered to slightly below the previous low of 412.5m.

To summarize, as a consequence of the continuing decline in groundwater levels, and except for the situations such as the ones mentioned above, the till will cease to be saturated and the potential susceptibility to blast induced pore pressures will also diminish.

The foundation beneath the upstream part of the dike, while further from the blasts, will remain saturated and monitoring for deformation of the structure must be maintained.

Continued monitoring is essential and the piezometer readings should be analyzed along with the temperature measurements in the same instruments in order to identify, in a timely manner, any changes in the current regime. It is to be hoped that the pump station operation will be resolved as soon as possible to permit the re-establishment of equilibrium conditions.

### 3.5 Inflows

Each of the pump stations is equipped with flow meters on the inflow from the toe drains. However, the flow rates are small and fall on the lower end of the flow meter range, such that the accuracy leaves something to be desired. Consequently, this feature has not been used to
monitor the evolution of the inflows. Previously, the automated pump operation monitoring permitted the calculation of the flow rate from the operating cycle times. The irregular manual operation has removed this tool.

The previously mentioned stream which exits the embankment fill at 0+228 has a base flow at about 0.1 l/s but rainfall raised the most recent value to 0.4 l/s.

There are persistent seeps on the upstream side of the toe access road at stations 2+275 and 2+290 but the values are only of the order of 1 l/min. This area is on the land side of the island D North thermosyphon group where a talik at depth is suspected. There does not appear to have been any deterioration during the previous 12 month period. Inflow to the sector downstream of island D is collected and measured by the flow pipe at station 2+485. In August the flow rate prior to the rain was less than 0.1 l/s.

As the DPS-4 pump station only operates on an intermittent basis and as the infield area drains down to rock, a small flow from the pump station area to the infield has established itself and is monitored by the flowpipe at station 2+740. A flow of around 4 l/min is recorded.

At stations 2+870 and at 2+971, the base flows have decreased to negligible values.

The design criteria for the dike was 1.8 l/min/m which, for a wetted length of about 2500m, would translate to 75 l/s. The total measured seepage flow is well within this value but the current mode of operation of the pump stations does not permit a reliable estimate of the rate at which water is pumped. As noted in the previous reports, this is not to say that the total flow passing through and beneath the dike has diminished. In fact, quite the contrary, the increase in hydraulic gradient has led to greater flow being pumped from the principal sump in the mine. Careful monitoring of piezometric levels is still required to detect disproportionate changes and fluctuations.

### 3.6 Deformation

#### 3.6.1 Inclinometers

As mentioned earlier, of the original complement of inclinometers, six are located in the plastic concrete cut-off wall to monitor the deflection of this element during dewatering and mine operations. The first group of comments apply to these installations. The attached figures 3.32 to 3.43 show the displacement profiles in the A and B directions which are perpendicular and parallel to the dike axis respectively. Only selected profiles are shown to improve clarity. Attention is paid particularly to the A axis.
IN044  The maximum horizontal deformation is about 70mm which represents an increase of a little over 10mm in the last three years. The yearly change is steady or declining. The deflection in the cutoff (depth 4.8m and lower) is somewhat less.

IN064  Little change has taken place in the period since the previous report and the maximum deformation is 85mm. The profile is uniform.

IN094  A steady maximum deformation of 75 mm is noted. A few kinks developed in the profile at the 4th reading in August 2002 but the profile has been consistent since that time. The trend is to diminishing deflection in the downstream direction i.e. a tendency to move upstream. The lakebed in this area is basically horizontal but the rock surface dips to the upstream. Consolidation of the thicker deposit on the upstream side may explain the trend.

IN219  The maximum deformation has reached 19mm and there is an apparent movement from 2005 of the order of 7mm. The movement at the crest is about 5mm. The deflection is small but additional readings to verify the trend are advised.

IN270  The deformation recorded is around 38mm and thus only a couple of millimeters more than in 2005.

IN320  The deflection recorded for the upper 10m of the profile is apparently decreasing. The maximum deformation is less than 10mm. The irregular profile suggests some influence of the telescopic joints, build up of frost, or other extraneous influence.

Other inclinometers were installed to address specific questions.

IN055  This instrument was installed in a deep borehole which intercepted a geological feature identified by high grout takes. A possible shear plane was hypothesized though the core recovered from an adjacent drill hole indicated an intrusive contact zone. The inclinometer was installed to check for any deep seated movement particularly during mining. With a reference date of November 2002, about 15mm of movement is indicated at the dike crest but no movement of significance is indicated at depth.

IN088  Incidents of high overbreak occurred during the cut-off wall panel excavation in deep till. A borehole was put down at an offset of 2.6m from centerline to intercept the bulb of plastic concrete. A short length was encountered and an
inclinometer was installed in the hole to determine if deformation would be more pronounced because of the disturbed ground. For the length corresponding to the cutoff wall depth, the profile is uniform. Of the total of 35mm, an increase of 4mm is noted since July 2005. A movement of the same order of magnitude was noted in 2004 and 2005. It should be noted that the dike sits on a downstream sloping foundation in this area and settlement of the downstream embankment fill may contribute to the observed movements.

As part of the additional effort to monitor the effect of blasting, four new inclinometers were installed in an area of concern. The installations were made at 2.5m downstream of the dike centerline to avoid damaging the wall and are located at stations 1+020, 1+120, 1+210 and 1+440.

IN102 With the initial reading being taken in August 2003, three years of results are available. The graph shows readings at approximately twelve month intervals. About 18mm of movement has been detected in direction ‘A’, an increase of 5mm since 2005 and occurring primarily above elevation 412m (depth 10m). Note that the bedrock is located at a depth of around 25m.

IN112 A maximum deflection of about 13mm has been recorded at this instrument. No particular reason for the curve in the profile at a depth of 10 m has yet been found but it should be noted that the berm elevation here is also at around this position.

IN121 This instrument is installed in a relatively shallow section of the dike with rock elevation at about elevation 411 m and till at 414 m. There is therefore only a limited head at the point but nearby piezometers had reacted to blasting. A maximum deflection of 10mm is recorded and the movement occurs over the full profile from the rock surface.

IN144 A sharp but small deviation has occurred in the fill above the filter blanket but the movements are stable and no changes over the preceding 12 months are noted. The maximum deflection is of the order of 6mm.

The horizontal deformations recorded by the inclinometers are in the range of values determined by finite element stress/strain analyses carried out in the design phase. The performance is therefore deemed satisfactory.
3.6.2  Extensometers

Extensometers were installed in the fill downstream of the cut-off, in the cut-off itself, and in the fill and foundation at the toe. These instruments had as objective, the measurement of settlement of the embankment fill but primarily the monitoring of the potential for heave as a result of the expansion of water due to freezing and the growth of ice lenses either in the plastic concrete or in the till foundation. The results obtained from the extensometers suffer from the inherent precision which is of the same order of magnitude as the deformations. As the apparent movements were small, the readings have been discontinued.

3.6.3  Survey markers

As indicated in the previous reports, additional monuments were installed, new survey equipment acquired and the techniques have been changed with a view to achieving greater accuracy.

The Baseline was established as September 24th, 2003. The readings indicate the following:

Settlements up to 28 mm situated primarily along the northern sector and on the upstream side of the crest. This is an increase of 10 mm over the twelve month period.

This magnitude of settlement is noted at two locations. One is in the area of maximum embankment height, between stations 0+625 and 0+725. The other is at station 1+025 where the dike has a height of 18 m, but is the area of maximum combination of till depth and embankment load.

Settlements on the line of the downstream row of monuments are up to 15 mm and the maximum values were measured at stations 1+025 and 1+471. However it should be noted that both rows are situated on the crest at elevation 421 and a 6 m wide berm at elevation 419 separates the downstream set from the outside slope.

The upstream monuments could be affected locally by movements related to slope erosion but this is likely to be sporadic rather than general. It should also be noted that the rockfill of the upstream shoulder is zone 3, which is a quarry run material with particle sizes up to 900 mm whereas the downstream shoulder is zone 2 with a maximum particle size of 200 mm. The latter would be more prone to settlement. The overall slope of the upstream face is also steeper and more subject to creep.
Horizontal deformation is up to 31mm which occurs essentially in the same areas as the maximum settlement. The following table shows the greatest movements.

<table>
<thead>
<tr>
<th>Marker number</th>
<th>August 2005 movement (mm)</th>
<th>August 2006 movement (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>625</td>
<td>18</td>
<td>27</td>
</tr>
<tr>
<td>702</td>
<td>-20</td>
<td>-26</td>
</tr>
<tr>
<td>752</td>
<td>-22</td>
<td>-28</td>
</tr>
<tr>
<td>1025</td>
<td>17</td>
<td>21</td>
</tr>
<tr>
<td>1102</td>
<td>-23</td>
<td>-31</td>
</tr>
<tr>
<td>1152</td>
<td>-16</td>
<td>-24</td>
</tr>
</tbody>
</table>

Notes: Marker number derived from station, odd numbers on lake side, even numbers on pit side. Positive movement towards lake, negative movement towards pit.

It is interesting to note that the movements continue to indicate a spreading of the crest (upstream monuments to upstream and downstream monuments to downstream). The average displacement is towards the pit i.e. in the direction of the hydrostatic thrust, as would be expected. The deformation measured by the survey monuments is of greater of magnitude than that recorded by the inclinometers which are installed in the cut-off or slightly downstream thereof. The average movement is consistent with the inclinometer movements. Blast induced pore pressures are low but continuing creep of the foundation and the rockfill of the embankment is the likely mechanism for the spreading movement. It would be of interest to survey the top of the inclinometer tubes or alternatively compare the dike movement with deformation of the pit wall to determine rock movement as compared to dike crest movement.

### 3.6.4 Crack monitoring

The cracks which have manifested themselves on the crest of the northern sector of the dike are monitored not only by visual observation but also by simple crack meters. The latter continue to show an annual cycle of 5mm to 6mm opening but recovery each summer is not complete and the crack does not necessarily close. This is consistent with the crest spreading noted in paragraph 3.6.3.

An inspection trench was excavated in the crest of the dike at station 0+290. The crack width diminished with depth and could no longer be traced below a depth of 1.5m to 2m. As suspected, finer materials were encountered at the elevation of the working platform from which the cut-off was constructed. This confirms that the cracking is likely related to the formation of ice lenses in the granular fill of the crest where the presence of bentonite and other materials has blocked the drainage of the fill above elevation 419m.
3.7 Temperature

The measurement of temperature at the Diavik site has significance because of the presence of permafrost. Where frozen ground is relied upon for the water barrier in the abutments, the integrity of this barrier is monitored by temperature measurements. The overlap between the cut-off wall in the unfrozen embankment and foundation, and the frozen ground of the abutments was achieved by ground freezing after construction of the cut-off. The maintenance of this overlap by active or passive operation of the thermosyphons is monitored by several thermistor strings.

A selection of temperature readings are included in the attached figures. The following comments summarize the present situation.

3.7.1 Thermosyphon Groups

The location of the thermosyphon groups and the layout of the group at the north abutment of island D are shown in figure 3.44. Figure 3.45 illustrates the typical installations at the NW abutment, West of island E and at the SW abutment (shown), while installations at island D, North and South are shown on figures 3.44 and 3.50. Extra thermosyphons were included at island D because of the less well defined natural permafrost boundary and the potentially more erodable silty sands of which the island is comprised.

South Approach

The temperature evolution and the general functioning of the thermosyphons is illustrated by examining the same selection of the records as was presented in the 2004 and 2005 reports. The thermistor readings at the South approach are shown in figures 3.47 to 3.49. Their locations and those of the thermosyphons are shown in figures 3.45 and 3.46. Thermistor T324 was installed in the cut-off between the last two pairs of thermosyphons on the peninsula, T3241 was installed in naturally frozen ground on the pit (dry) side of the cut-off and T3232 was installed in previously unfrozen ground on the lake side of the cut-off.

Two graphs are presented for each thermistor string:

1. Temperature versus elevation for various dates (for clarity only a selection of dates since installation are included);

2. Temperature versus time for various beads. Lowest bead number at the top and highest number at the bottom of the string.
Note that the records shown start just prior to the dewatering whereas the thermosyphons had been in operation since May 2002.

At the location of T324, the foundation elevation is about 413m, the bedrock is at 405m and the bottom of the thermosyphon is at 394m (figure 3.46). More rapid cooling is obtained in the rock due to the lower water content. Bead #1 at elevation 416m is primarily influenced directly by surface air temperature and the cooling did not begin until late October 2002. The influence of the cooling is apparent beyond the depth of the thermosyphons as shown by the gradual decrease in temperature at bead #16 (elevation 386m) with the latest temperature being about –4°C (figure 3.47).

The cycles of temperature contain both active and passive cooling periods interspersed with warming by heat exchange with the surrounding ground.

Active and passive cooling periods are as follows:

<table>
<thead>
<tr>
<th>Active</th>
<th>Passive</th>
</tr>
</thead>
<tbody>
<tr>
<td>May – October 2002</td>
<td>January – May 2003</td>
</tr>
<tr>
<td>June – September 2003</td>
<td>December 2003 – April 2004</td>
</tr>
<tr>
<td>July – October 2004</td>
<td>December 2004 – March 2005</td>
</tr>
<tr>
<td>July – August 2006</td>
<td></td>
</tr>
</tbody>
</table>

The reduced effectiveness of the passive operation during the milder winter of 2005-2006 is immediately apparent from observation of the temperature change during these cycles.

The graph for T3241 shows a similar response to T324 (figure 3.49).

As for T3232 (figure 3.48), its position just beyond the thermosyphon group and the use of insulated thermosyphon tubes in the embankment is reflected in the minimum temperatures attained but the cyclic trends are the same.

The duration of active thermosyphon operation may probably be decreased as the general trend is to temperatures colder than required to ensure a watertight barrier. At most groups, the minimum temperature is around –20°C. However, the compressors should be run for a brief period each year to check for possible malfunction.
North Approach

All readings in the vicinity are below zero. The evolution (not shown) follows a similar pattern to the examples above.

West Island E

Satisfactory operation was again in evidence. A warming of about 5°C was noted before initiation of the active operation.

North Island D

The layout is illustrated on figures 3.50 and 3.51. Three thermistor strings are presented; T223 is situated in the cut-off wall on the island, T2222 is in previously frozen ground of the island on the lake side of centerline and T2201 is in previously unfrozen ground on the pit side of centerline just beyond the last thermosyphon pair.

For the group, till foundation elevation is around 415m, bedrock at around 400 m and the bottom of the thermosyphons at around 389m. At T2222 (figure 3.52), frozen conditions had been well established at the time of dewatering and cooling continued by active or passive means to attain a minimum temperature of -19°C in March 2004 and again in mid-February 2005. From that time, the temperatures have been rising but still indicate frozen conditions within the body of embankment and foundation that the thermosyphon group is intended to affect. Despite the milder winter, the temperatures immediately prior to active cooling in 2006 were only 1°C to 2°C higher than in 2005. Active cooling in 2006 began at the beginning of July and was still in operation in August at the time of the inspection.

At T223 (figure 3.53), despite being in previously frozen ground, the heat of hydration of the cut-off wall had raised the temperature to above zero. Active cooling froze the part in the rock prior to dewatering and the freezing of the part in the overburden continued during the winter passive operation of 2003. From a low of around –13°C over the 2005-2006 winter, the temperatures have warmed to between –8°C and –11°C for most of the beads.

Beyond the thermosyphon group, at T2201 (figure 3.54), the conditions have remained below 0°C throughout the year. The steep rise noted at beads B7 and B8 in 2003 and 2004 have not been seen in the last two years indicating that local water flows have been cut off.
South Island D

The temperature measurements at the thermistor strings associated with this thermosyphon group show that freezing has been maintained throughout the year. The compressors were in operation at the time of the visit.

3.7.2 Other areas

Other than at the thermosyphon groups, thermistors are located on the abutment areas and along the dike. A selection of thermistor results is attached in figures 3.55 to 3.59.

The important abutment areas have not shown any sign of permafrost degradation but temperatures indicate warm permafrost with little room for maneuver.

At station 0+250, the thermistor string T025 has shown rising temperatures over the previous 12 months. The beads #4 and #5, at elevations 410m and 408m respectively, are mentioned in the data as giving false readings and, as indicated on the upper graph of figure 3.55, this is shown as 0°C. The dike sits on the ground at the neck of a small peninsula where the water depth was only a few centimeters. A shallow cut-off down to elevation 412m was installed in this area. The instrument and the area in general merits close observation.

T2275 is a thermistor string that was installed to measure temperature in the bedrock below the level of the other thermistors on island D in order to evaluate the possibility of a talik zone beneath the island. The zero degree isotherm was encountered at elevation 383m, some 20m into rock and the position, previously stable, has risen to elevation 385m during the course of the 2005-2006 period. The milder winter could be a contributing factor.

At T3752 on the SW peninsula (Figure 3.57), a general cooling trend is still evident down to elevation 402m. The changes are only in the tenths of a degree, but the ground temperatures are remaining below zero throughout.

All the thermistor strings located in island E indicate that freezing conditions are being maintained.

The T064 and T270 strings (figures 3.58 and 3.59) are located in the cut-off wall in deep sections of the dike. The instruments indicate that the ingress of freezing has advanced to below lake level. For T064 the zero degree isotherm is at elevation 414m and for T270 it can be interpolated as being around 412m.
3.8 Summary

The review of the instrumentation records indicates that the dike performance is satisfactory. The records show a favorable evolution with time as the structure adapts to the conditions imposed by the hydraulic and temperature environment. Most of the instruments are functioning in a satisfactory manner.

However, the intermittent pump station operation is not a positive development and hampers monitoring of seepage and piezometric levels in the vicinity.

Two zones of minor local warming are indicated by the thermistor strings at T025 and T2275. Attention should be paid to the readings in the next few months.
4 BLAST MONITORING

4.1 Generalities

The operation of the open pit mine obviously involves continuous blasting operations, the effect of which was carefully monitored during the first three years of mine operation. The bottom of the pit has reached elevation 270m which has increased the distance between the source of the blast energy and the water retention dike. Furthermore, as the foundation tills are now in a largely drained state the impact on pore pressures are hardly measurable. Should pit wall slashing at the upper benches be undertaken then monitoring should be reinstated.
5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

With few exceptions the dike is performing as expected.

Foundation pore pressure levels are declining with the progression of mining and a general drainage of the lakebed materials.

Deformation is within the values determined from the stress/strain analyses but movement is ongoing and continued monitoring is required.

The frozen ground conditions are being maintained at the abutments, but two locations have been identified for attention namely instruments T025 and T2275.

Blast monitoring is no longer carried out on a regular basis and coordination is required between the mining group and the geotechnical department to ensure that it will be reinstated should work be carried out on the upper benches.

The results obtained from the instruments fully justify the scope of the instrumentation and the automated data acquisition system that was installed in the dike

5.2 Recommendations

The following recommendations were formulated as a result of the site visit and examination of the instrument data. Several have already been implemented.

Continue dike monitoring with the measurement frequencies revised as appropriate to take into account the reliable performance of the automated reading and the evolution of various values. Manual readings of the vibrating wire piezometers have been reduced to once per month as a check of the automated readings for the latter are now showing reliable and consistent results. However, the reading frequency should be increased in the case of a malfunction of the automated system.

Complete the repairs to the discharge line from pump stations DPS-1 and DPS-2 and replace the pump controllers at these stations and at DPS-4 so as to permit automated pumping from the stations and providing the means to evaluate the water inflow.
Backfill the pit at Stn. 1+540 and regrade the area downstream of island E to improve drainage, reduce the extent of ponded water and lower the water table in the spring.

Ensure a periodic review by the engineering staff of the thermistor readings in marginally frozen areas.

Maintain control of blast parameters to ensure a maximum PPV of 50 mm/sec on the dike. Reinstate blast monitoring and increased piezometer reading frequency if required by work on the upper benches. Periodically check the functioning of the return valves in all pump stations.

Add slope protection around the intakes to the pump stations.

Clean out the sediment traps at the intakes.

Install survey monuments with anchors buried in the crest of the dike above and below elevation 419m to assist in better understanding the cracking phenomenon.

Remain vigilant despite the reduction in seepage as manifested at the dike toe. Flow is now taking place at greater depth and though overall slope stability has been enhanced by lower piezometric levels in the foundation, the high gradients may increase the potential for internal erosion. Pay particular attention to areas where dumps prevent visual observations to be made.
APPENDIX 1

PLATES
APPENDIX 2

FIGURES
A154 DIKE
STATION 0+340

DIKE AXIS

UPSTREAM

GUIDE WALLS
(LEFT IN PLACE)

AS-BUILT
GEOMETRY

M.H.W.L.
415.8

VIBRO-
DENSI FICATION
AREA

PREPARED
FOUNDATION

DIAPHRAGM
WALL

JET GROUT
COLUMN

GROUT
CURTAIN

NOMINAL
GEOMETRY

TOE BERM

ZONE 1A
BLANKET

TOE DRAIN

BEDROCK

26-Aug-06

26-Aug-06

SPOIL

V0345

V0344

V0343

SPOIL

V0346

V0345

V0344

V0343

V0342

V0341

V0340

H.H.W.L.
415.8

SCALE 1 = 600

1 0-56 mm CRUSHED STONE
2 0-200 mm CRUSHED STONE
3 0-900 mm QUARRY ROCK

FOR AS-BUILT DIMENSIONS, SEE REFERENCE INSTRUMENTATION DRAWING No 2110-4805-1011

DIAVIK DIAMONDS PROJECT

A154 DIKE - INSTRUMENTATION
CURRENT PIEZOMETRIC LEVELS IN FOUNDATION
STATION 0+340 - AUTOMATED READINGS

FIGURE 3.1

CURR_A_0+340
READINGS NOT CORRECTED FOR BAROMETRIC PRESSURE CHANGES. USE THIS BAROMETRIC SCALE.

PIEZOMETERS AT STATION 0+340
- V0341
- V0342
- V0343
- V0344
- V0345

STATION 0+340

A154 DIKE - INSTRUMENTATION
PIEZOMETRIC CHANGE SINCE BEGINNING
STATION 0+340 - AUTOMATED READINGS

FIGURE 3.2
A154 DIKE
STATION 0+600

SCALE 1 = 600

1 0-50 mm CRUSHED STONE
2 0-200 mm CRUSHED STONE
3 0-900 mm QUARRY ROCK

DIAVIK DIAMONDS PROJECT
A154 DIKE - INSTRUMENTATION
CURRENT PIEZOMETRIC LEVELS IN FOUNDATION
STATION 0+600 - LATEST READINGS

FOR AS-BUILT DIMENSIONS, SEE REFERENCE INSTRUMENTATION DRAWING No. 2110-48D5-1028
INTERFACE BETWEEN ZONE 1 AND ZONE 2 MATERIALS FOR TOE BERM NOT SHOWN ON REFERENCE DRAWING.
VW PIEZOMETER READINGS ARE FROM GEOMATION DATA ACQUISITION SYSTEM

FIGURE 3.3
A154 DIKE
STATION 0+640

DIKE AXIS

UPSTREAM

GUIDE WALLS (LEFT IN PLACE)

VIBR DRIVE ZONE AREA

AS-BUILT GEOMETRY

DIAPHRAGM WALL

PREPARED FOUNDATION

JET GROUT COLUMN

GROUT CURTAIN

DOWNSTREAM

NOMINAL GEOMETRY

ZONE 1A BLANKET

TOE DRAIN

BEDROCK

SPOIL

WATER LEVEL MARKER

SCALE 1 = 600

1 0-56 mm CRUSHED STONE

2 0-200 mm CRUSHED STONE

3 0-900 mm QUARRY ROCK

ALERT LEVEL (Bottom of Symbol)

CURRENT PIEZOMETRIC LEVEL

FOR AS-BUILT DIMENSIONS, SEE REFERENCE INSTRUMENTATION DRAWING NO 2110-48D5-1031

SURVEY DATA FOR BERM ZONE 1 MATERIAL NOT AVAILABLE.

VW PIEZOMETER READINGS ARE FROM GEOMATION DATA ACQUISITION SYSTEM

DIAVIK DIAMONDS PROJECT

A154 DIKE - INSTRUMENTATION
CURRENT PIEZOMETRIC LEVELS IN FOUNDATION
STATION 0+640 - LATEST READINGS

FIGURE 3.4

CURR_L_01640
A154 DIKE
STATION 0+940

UPSTREAM

DIKE AXIS

DOWNSTREAM

GUIDE WALLS
(LEFT IN PLACE)

AS-BUILT
GEOMETRY

M.H.W.L.
415.8

414.5

NOMINAL
GEOMETRY

ZONE 1A
BLANKET

TOE BERM

TOE DRAIN

ZONE 2
(FROZEN)

V0946

V0943

V0942

V0941

PREPARED
FOUNDATION

DIAPHRAGM
WALL

JET GROUT
COLUMN

GROUT
CURTAIN

26-Aug-06

26-Aug-06

26-Aug-06

SCALE 1 = 600

1 0-56 mm CRUSHED STONE
2 0-200 mm CRUSHED STONE
3 0-900 mm QUARRY ROCK

\( \triangledown \) ALERT LEVEL (Bottom of Symbol)
\( 408.1 \) CURRENT PIEZOMETRIC LEVEL

FOR AS-BUILT DIMENSIONS, SEE REFERENCE INSTRUMENTATION DRAWING No 2110-4405-1051

VW PIEZOMETER READINGS ARE FROM GEOMATION DATA ACQUISITION SYSTEM

DIAVIK DIAMONDS PROJECT

A154 DIKE - INSTRUMENTATION
CURRENT PIEZOMETRIC LEVELS IN FOUNDATION
STATION 0+940 - LATEST READINGS

FIGURE 3.7
A154 DIKE
STATION 1+040

SCALE 1 = 600

1 0-56 mm CRUSHED STONE
2 0-200 mm CRUSHED STONE
3 0-900 mm QUARRY ROCK

DIAMOND DIAMONDS PROJECT
A154 DIKE - INSTRUMENTATION
CURRENT PIEZOMETRIC LEVELS IN FOUNDATION
STATION 1+040 - LATEST READINGS

FOR AS-BUILT DIMENSIONS, SEE REFERENCE INSTRUMENTATION DRAWING No 2110-48DS-1055
VW PIEZOMETER READINGS ARE FROM GEOMATION DATA ACQUISITION SYSTEM
A154 DIKE
STATION 1+450

DIKE AXIS

DIKE AXIS

UPSTREAM

SHALLOW CUTOFF WALL

AS-BUILT GEOMETRY

ZONE 1A BLANKET

TOE DRAIN

BERM

TOE

26-Aug-06

V1452

26-Aug-06

V1451

410.9

409.6

403.1

391.6

424

420

416

412

408

404

400

396

392

388

384

380

376

-50

-40

-30

-20

-10

0

10

20

30

40

50

60

70

80

90

SCALE 1 = 600

1  0-56 mm CRUSHED STONE

2  0-200 mm CRUSHED STONE

3  0-900 mm QUARRY ROCK

FOR AS-BUILT DIMENSIONS, SEE REFERENCE INSTRUMENTATION DRAWING No 2110-4605-1066
AS-BUILT PROFILE FOR ZONE 1A MATERIAL NOT AVAILABLE - ASSUMED 1 m NOMINAL THICKNESS
VW PIEZOMETER READINGS ARE FROM GEOATION DATA ACQUISITION SYSTEM

DIAVIK DIAMONDS PROJECT

A154 DIKE - INSTRUMENTATION
CURRENT PIEZOMETRIC LEVELS IN FOUNDATION
STATION 1+450 - LATEST READINGS

FIGURE 3.11

CURR_L_1+450
A154 DIKE
STATION 2+010

DIKE AXIS

UPSTREAM

DIAPHRAGM WALL

M.H.W.L.

415.8

AS-BUILT GEOMETRY

VIBRO-DENSIFICATION AREA

PREPARED FOUNDATION

JET GROUT COLUMN

GROUT CURTAIN

NOMINAL GEOMETRY

TOE BERM (DPS-3)

ZONE 1A BLANKET

TOE DRAIN

BEDROCK

SPOIL

SCALE 1 = 600

1 0-56 mm CRUSHED STONE

2 0-200 mm CRUSHED STONE

3 0-900 mm QUARRY ROCK

FOR AS-BUILT DIMENSIONS, SEE REFERENCE INSTRUMENTATION DRAWING No 2110-48D5-1080
AS-BUILT PROFILE FOR ZONE 1A MATERIAL NOT AVAILABLE - ASSUMED 1 m NOMINAL THICKNESS
VW PIEZOMETER READINGS (except V2012) ARE FROM GEOMATION DATA ACQUISITION SYSTEM
PIEZOMETER V2012 HAS BEEN DISCONNECTED FROM L4 DATA LOGGER IN LATE 2002

DIAVIK DIAMONDS PROJECT

A154 DIKE - INSTRUMENTATION
CURRENT PIEZOMETRIC LEVELS IN FOUNDATION
STATION 2+010 - LATEST READINGS

FIGURE 3.13
READINGS NOT CORRECTED FOR BAROMETRIC PRESSURE CHANGES. USE THIS BAROMETRIC SCALE.

DIAVIK DIAMONDS PROJECT
A154 DIKE - INSTRUMENTATION
PIEZOMETRIC CHANGE SINCE BEGINNING
STATION 2+010 - AUTOMATED READINGS

FIGURE 3.14
A154 DIKE
STATION 2+100

SCALE 1 = 600

1 0-56 mm CRUSHED STONE
2 0-200 mm CRUSHED STONE
3 0-900 mm QUARRY ROCK

DIAPHRAM WALL
AS-BUILT GEOMETRY
PREPARED FOUNDATION
JET GROUT COLUMN
GROUT CURTAIN

DIKE AXIS
UPSTREAM

NOMINAL GEOMETRY
TOE BERM
ZONE 1A BLANKET
TOE DRAIN
BEDROCK
26-Aug-06

408.1 CURRENT PIEZOMETRIC LEVEL
415.8 ALERT LEVEL (Bottom of Symbol)

FOR AS-BUILT DIMENSIONS, SEE REFERENCE INSTRUMENTATION DRAWING No 2110-48D5-1082
AS-BUILT PROFILE FOR ZONE 1A MATERIAL NOT AVAILABLE - ASSUMED 1 m NOMINAL THICKNESS
VW PIEZOMETER READINGS ARE FROM GEOMATION DATA ACQUISITION SYSTEM

DIAVIK DIAMONDS PROJECT
A154 DIKE - INSTRUMENTATION
CURRENT PIEZOMETRIC LEVELS IN FOUNDATION
STATION 2+100 - LATEST READINGS

FIGURE 3.15
A154 DIKE
STATION 2+710

UPSTREAM

DIAPHRAGM WALL

AS-BUILT GEOMETRY

M.H.W.L. 415.8

VIBRO-DENSIFICATION AREA

DOWNSTREAM

DIKE AXIS

NOMINAL GEOMETRY

TOE BERM

ZONE 1A BLANKET

SPoil

PREPARED FOUNDATION

JET GROUT COLUMN

GROUT CURTAIN

BEDROCK

SCALE 1 = 600

1 0-56 mm CRUSHED STONE
2 0-200 mm CRUSHED STONE
3 0-900 mm QUARRY ROCK

408.1 ALERT LEVEL (Bottom of Symbol)

CURRENT PIEZOMETRIC LEVEL

FOR AS-BUILT DIMENSIONS, SEE REFERENCE INSTRUMENTATION DRAWING No 2110-4805-1117

VW PIEZOMETER READINGS ARE FROM GEOMATION DATA ACQUISITION SYSTEM

DIAVIK DIAMONDS PROJECT

A154 DIKE - INSTRUMENTATION
CURRENT PIEZOMETRIC LEVELS IN FOUNDATION
STATION 2+710 - LATEST READINGS

FIGURE 3.18
READINGS NOT CORRECTED FOR BAROMETRIC PRESSURE CHANGES, USE THIS BAROMETRIC SCALE.

DIAVIK DIAMONDS PROJECT
A154 DIKE - INSTRUMENTATION
PIEZOMETRIC CHANGE SINCE BEGINNING
STATION 2+710 - AUTOMATED READINGS

FIGURE 3.19
DIAVIK DIAMONDS PROJECT

A154 DIKE - INSTRUMENTATION

PIEZOMETRIC CHANGE SINCE BEGINNING

STATION 2+750 - MANUAL READINGS

FIGURE 3.21
READINGS NOT CORRECTED FOR BAROMETRIC PRESSURE CHANGES. USE THIS BAROMETRIC SCALE.

PIEZOMETRIC HEAD (m)

Sep-02 Nov-02 Jan-03 Mar-03 May-03 Jul-03 Sep-03 Nov-03 Jan-04 Mar-04 May-04 Jul-04 Sep-04 Nov-04 Jan-05 Mar-05 May-05 Jul-05 Sep-05 Nov-05 Jan-06 Mar-06 May-06 Jul-06 Sep-06 Nov-06

PIEZOMETERS AT STATION 3+000

STATION 3+000

DIAVIK DIAMONDS PROJECT

A154 DIKE - INSTRUMENTATION

PIEZOMETRIC CHANGE SINCE BEGINNING

STATION 3+000 - AUTOMATED READINGS

FIGURE 3.23
A154 DIKE
STATION 3+130

UPSTREAM

DIAPHRAGM WALL

DIKE AXIS

AS-BUILT GEOMETRY

M.H.W.L. 415.8

VIBRO-DENSIFICATION AREA

UPSTREAM

3

PREPARED FOUNDATION

JET GROUT COLUMN

GROUT CURTAIN

26-Aug-06

DOWNSTREAM

DIAVIK DIAMONDS PROJECT

SCALE 1 = 600

1 0-56 mm CRUSHED STONE

2 0-200 mm CRUSHED STONE

3 0-900 mm QUARRY ROCK

VW PIEZOMETER READINGS ARE FROM GEOMATION DATA ACQUISITION SYSTEM

FOR AS-BUILT DIMENSIONS, SEE REFERENCE INSTRUMENTATION DRAWING No 2110-4805-1148

DIAPHRAGM WALL

DIKE AXIS

AS-BUILT GEOMETRY

M.H.W.L. 415.8

VIBRO-DENSIFICATION AREA

PREPARED FOUNDATION

JET GROUT COLUMN

GROUT CURTAIN

26-Aug-06

DOWNSTREAM

DIAVIK DIAMONDS PROJECT

SCALE 1 = 600

1 0-56 mm CRUSHED STONE

2 0-200 mm CRUSHED STONE

3 0-900 mm QUARRY ROCK

VW PIEZOMETER READINGS ARE FROM GEOMATION DATA ACQUISITION SYSTEM

FOR AS-BUILT DIMENSIONS, SEE REFERENCE INSTRUMENTATION DRAWING No 2110-4805-1148
SEEPAGE WATER TRAPPED INSIDE THE DOWNSTREAM SHELL DURING THE FIRST WINTER.

PIEZOMETRIC HEAD (ft)

PIEZOMETERS AT STATION 3+220

DIAMOND DIKES PROJECT

A154 DIKE - INSTRUMENTATION

PIEZOMETRIC CHANGE SINCE BEGINNING

STATION 3+220 - AUTOMATED READINGS

FIGURE 3.31
Borehole: IN044
Project: A154 Dike
Location: 0+455.02 O/S 0
Northing: 7153271.38
Easting: 536019.79
Spiral Correction: N/A
Collar Elevation: 421.84
Borehole Total Depth: 30.5 meters
North Groove Azimuth: 350
Base Reading: 2002 Jul 24 09:59
Axis A Azimuth: 10.0 degrees

Cumulative Displacement

Figure 3.32
Borehole: IN064
Project: A154 Dike
Location: 0+702.94 O/S 0
Northing: 7153425.79
Easting: 536211.63
Spiral Correction: N/A
Collar Elevation: 421.82
Borehole Total Depth: 37.0 meters
North Groove Azimuth: 0
Base Reading: 2002 Aug 09 14:16
Axis A Azimuth: 53.0 degrees

Cumulative Displacement

Axis - A

Cumulative Displacement (meters)

Axis - B

Cumulative Displacement (meters)

IN064-060709 09-Jul-06
IN064-050726 26-Jul-05
IN064-040714 14-Jul-04
IN064-030730 30-Jul-03

IN064-060709 09-Jul-06
IN064-050726 26-Jul-05
IN064-040714 14-Jul-04
IN064-030730 30-Jul-03

Figure 3.34
Borehole: IN088
Project: A154 Dike
Location: 0+821.99 OS 2.62
Northing: 7153436.64
Easting: 536329.06

Spiral Correction: N/A
Collar Elevation: 421.5
Borehole Total Depth: 34.0 meters
North Groove Azimuth:
Base Reading: 2002 Sep 04 15:16
Axis A Azimuth: 354.0 degrees

Cumulative Displacement

Axis - A

Axis - B

Figure 3.35
Borehole : IN112
Project : A154 Dike
Location : 1+120 OS 2.5
Northing : 7153440.03
Easting : 536627.04

Collar Elevation : 421.8
Base Reading : 2003 Aug 14 11:00
Axis A Azimuth : 0.0 degrees
Axis B Azimuth : 0.0 degrees

Spiral Correction : N/A
Borehole Total Depth : 23.0 meters

Cumulative Displacement

Figure 3.38
Borehole: IN121
Project: A154 Dike
Location: 1+210 OS 2.5
Northing: 7153440.10
Easting: 536717.02

Spiral Correction: N/A
Collar Elevation: 421.8
Borehole Total Depth: 11.5 meters
North Groove Azimuth:
Base Reading: 2003 Aug 15 09:23
Axis A Azimuth: 0.0 degrees

Cumulative Displacement

Figure 3.39
Bead Temperature Vs. Elevation in Time

Bead Temperature Vs. Time

Figure 3.47
Bead Temperature Vs. Elevation in Time

Bead Temperature Vs. Time

Figure 3.48
Figure 3.49
Bead Temperature Vs. Elevation in Time

Bead Temperature Vs. Time

Figure 3.53
Figure 3.54
Figure 3.55
Bead Temperature Vs. Elevation in Time

Bead Temperature Vs. Time

Figure 3.59
APPENDIX 3

PHOTOGRAPHS
Photo # 1 North sector. General downstream view of drainage basin for DPS-1

Photo # 2 Flow measuring pipe at Stn. 0+228
Photo #3  DPS-1  High water table due to interruption of pumping station

Photo #4  Depression centred at Stn. 0+470. Small pool zero flow. Turbidity from run-off.
Photo #5  General view of toe area from Stn. 0+400 looking East.

Photo #6  Drainage ditch at Stn. 1+040.
Photo # 7 Area from Stn. 1+040 to Stn. 1+250. Vegetation but no standing water.

Photo # 8 North wall of pit. Note, little or no seepage from upper bench, same as previous inspection.
Photo # 9  U/S slope repair begins at Stn. 0+370.

Photo # 10  U/S slope repair at approx. Stn. 0+950
Photo # 11  Leaking joint in HDPE discharge pipeline at DPS-1.

Photo # 12  Continuing situation of water accumulation on pipe berm as a result of pipe leak.
Photo # 13 Sector D/S of island E. Little water despite recent rain.

Photo # 14 Island D. Slow retrogressive erosion of pit side slope.
Photo # 15  Stn. 2 +485  Flow pipe collecting seepage from area D/S from island D.

Photo # 16  Small pond at around Stn. 2+600 into which the flow measured at Stn. 2+485 enters and subsequently disappears into the ground.
Photo # 17  Intake channel for pump station #4. Small flow in channel from DPS-4 to D/S

Photo # 18  Toe of dike in sector from Stn. 2+950 to Stn. 3+000. Area dry.
Photo # 19  SW peninsula from Stn. 3+100 to end of dike. Drain at Stn. 3+130.

Photo # 20  Toe in area of SW abutment as seen from Stn. 3+650.