APPENDIX 16

GEOTECHNICAL REVIEW

OF THE

RECLAMATION LANDFILL SUBSIDENCE AREA

teckcominco

POLARIS MINE

RESPONSE TO REGULATORS QUESTIONS REGARDING SUBSIDENCE AT THE RECLAMATION LANDFILL

Prepared by: Trevor Feduniak, P.Eng.

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EXECUTIVE SUMMARY

The Polaris Mine Decommissioning and Reclamation Plan, March 2001 ('DRP') identifies the Reclamation Landfill area as being influenced by significant subsidence referred to as a 'Sinkhole'. The Approved plan is to ensure that there is at least a 1.8 metre cap over the landfill area. However, this does not address the concern that the area is continuing to actively subside which could present a public/wildlife safety issue.

Required in the letter of Approval of the operating protocols for the landfills at the site, and as a result of a site inspection by DIAND in September of 2003, Polaris was requested to review the geotechnical aspects of the 'Sinkhole' area. This report presents the currently available data for this area, an explanation of the subsidence mechanisms at work, and a proposed course of action to respond to the potential issues of concern.

The caving of the overlying strata into the 202 Stage III stope has resulted in substantial localized subsidence ('sinkhole') that is atypical of subsidence being experienced elsewhere at Polaris. Monitoring of subsidence at Polaris indicates that subsidence over the majority of the mine is not a concern in either the short or long term. However, in the area of 202 Stope, substantial subsidence has been occurring since 1999 as evidenced by the precise subsidence monitoring conducted while the mine was operating. The last precise subsidence survey was conducted in 2002 and the sinkhole area was still actively subsiding at that time.

The development of subsidence prediction and modeling is a well developed science in Europe due to the impact of coal mining in populated areas on civil structures. While the behaviour of subsidence not exactly the same in base metal mines, the rock mechanic principles and empirical application of them to base metal mines does give guidance in understanding the subsidence mechanisms at work. Typically in coal mines, the length of time that subsidence occurs is measured in relatively few years. Similar trends have been observed at Polaris over other areas of the mine. In the area of the sinkhole, significant movement at surface has been measured for several years prior to 2002. Conducting a precise level survey in 2004 will indicate whether the subsidence has entered the decelerating phase of the subsidence cycle. Once these measurements have been obtained, a better assessment of the current and future expectations for ground movement around the sinkhole will then be possible. At that time a more informed decision as to whether or not any future action or monitoring is required.

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RESPONSE TO REGULATORS QUESTIONS REGARDING SUBSIDENCE AT THE RECLAMATION LANDFILL

1. Introduction

Part H, Item 6 of Polaris's Water Licence requires an annual geotechnical inspection be conducted. Included in the approval of Polaris's Landfill Operating Protocol's, is the requirement 'That TCL provide assurance which demonstrates that the mine workings under the Reclamation Landfill have been sufficiently supported or backfilled to prevent further subsidence.' as part of the Annual Geotechnical Inspection.

The Department of Indian Affairs and Northern Development (DIAND) conducted a site inspection between September 8th to 10th, During the site visit, discussions were held with John Knapp (Site Manager) regarding ongoing subsidence over the underground mining area. The inspection report requested that the following issues be evaluated:

1. A description of the mechanism of subsidence
2. Thermal regime and ice conditions in the overburden
3. Thermal regime and need for installation of thermistors to monitor permafrost temperatures from the surface, around the underground opening
4. Impact of surface water pond on thermal regime and permafrost stability.
5. Impact of placing fill on the rate and amount of subsidence and the permafrost regime
6. Estimate of maximum extent and depth of subsidence zone
7. Assessment of physical stability and protection required
8. Recommendations for ongoing assessment and monitoring

This document will respond to all of the above comments although not in the order listed above.

2. Description of Mechanisms of Subsidence

2.1. Rock Mechanics and Subsidence Monitoring at the Polaris Mine

Monitoring and prediction of the stability of underground mine workings has been key to the successful mining of the Polaris ore body. The objective of recovering a mineral resource is to extract the maximum ore possible given safety and economic constraints. As such, mine planning attempts to maximize the volume of ore removed in a manner that minimizes the quantities of ore that must remain in place either because they are uneconomic or are required to support the ground around the mine workings (i.e. 'pillars').

Each underground mine is unique. The shape of the ore body, the composition of the ore and host rock, the depth of the ore body, its width, length and dip are all different. The types of rock underlying and overlying the mine differ from mine to mine. Faulting, weathering, ground water conditions, rock temperatures, faulting of the rock, and surrounding pre-mine ground pressures are all factors that affect the stability and behavior of the mine openings and surrounding rock masses. As a result of these and other variables, the prediction of subsidence is complex and reliant on site specific experience to develop an understanding of how the mining activities will influence subsidence at that site.

Pre-mining evaluations of mine designs are based on data collected at the exploration stage, through lab testing of the rocks to determine their physical characteristics, and experience of mining similar ore bodies at other locations. The development and refinement of mine designs evolve as experience and knowledge of individual ore bodies are gained during the mining process. As the mine is developed, rock mechanics instrumentation is utilized to monitor the physical conditions of the mine such as ground pressures, ground temperatures, and ground movements around the underground openings. At some mines, surface subsidence monitoring is an important aspect that is monitored. Visual observations by experienced mining personal are key in monitoring the immediate day to day stability of the ground surrounding the mine openings. Polaris Operations utilized graduate mining engineers (normally with at least one or more staff members registered as a Professional Engineer) to ensure competent planning and management of the mine design and monitoring process occurred.

At Polaris, early mining was done utilizing open stopes (i.e. areas where a volume of ore is removed is referred to as a 'stope') that were not re-filled (i.e. left 'open') after mining of that area was completed. For this method to work, the size of the stope was limited so that the ground surrounding the stope would stay intact. To allow for improved recovery of ore, and to provide for improved ground conditions (i.e. stable ground that was safe for personnel working in the area), the mine had to provide additional support to the mined out stopes by re-filling the void space in the stopes with fill ('backfill'). Initially the backfill consisted of waste rock with water added to increase the structural strength. The permafrost conditions in the mine caused the water in the rock to freeze adding strength to the backfill. The placement of backfill must be done soon after the stope is mined, before the rock surrounding the stope starts to fail (i.e. break up falling into the stope). While the use of frozen backfill was successful, it became apparent that a stronger backfill would provide additional support allowing for even better recovery of ore. It was determined that the use of backfill consisting of cement mixed with waste rock (i.e. Cemented Rock Fill or 'CRF') would provide superior backfill strength and the strength would be obtained in a shorter period of time. Although this was a very expensive process, the improved ground support and improved ore recovery justified the additional cost. The improved support for the stopes had the additional benefit that the amount of subsidence measured at surface was reduced.

2.2. Subsidence Mechanisms

There is substantial technical knowledge related to the process of mining induced subsidence. This technical expertise was initially developed in Europe where coal mining near populated areas created significant damage related to the subsidence of roads, pipelines, houses and other civil structures. Subsidence related to coal mining typically differs from metal mining ('hard rock mining') subsidence in a number of ways. Normally coal mining is occurs in relatively thin coal beds (several metres thick not tens of metres thick as with Polaris), with relatively substantial thickness of cover (relative to the ore body thickness), and the extraction of the coal beds occurs over large areas (often extending for miles) using relatively uniform patterns of extracted areas and adjacent areas where ground has been left intact for support ('pillars'). These configurations allow for relatively accurate mathematical predictions of amounts of subsidence, timing of subsidence, and amount of surface strains (i.e. surface cracking). Initial planning is done using information from similar mines/ground conditions documented in reference materials but as site specific empirical data is collected, the accuracy of the predictions are refined.

The following explanation is simplistic to give the reader an understanding of the subsidence mechanism coal mines. Typically, the subsidence is caused by the strata overlying the mining area bending uniformly as mining progresses. The overlying stratum behaves like a beam that sags as support is removed from beneath it (i.e. by the mining removing coal or other mineral). As there is less rock to support the weight of the overlying strata, the remaining rock ('pillars') must support increasing loads. At some point, the pillars are not capable of holding the amount of weight they are exposed to and they begin to fail. As the pillars crumble, the overlying strata subsides. The debris from the failed pillars (and roof over the mine openings) starts to partially fill the mine openings. As this process of crushing the pillars progresses, at some point, support for the overlying strata is gradually regained and the subsidence slows and eventually ceases. The surface of the ground appears to gradually and uniformly subside. Some coal mines (but not most), place fill into the areas where they have removed the coal to provide additional support and to reduce the amount of subsidence. The backfill must be placed soon after mining or else the area will start to fail before the backfilling is completed. If the coal seam is very thick and/or if the seam is close to surface, or if there are irregular patterns to the mine layout, or if the overlying strata if more brittle, different mechanisms of subsidence may occur and the resulting subsidence may not be uniform.

The mechanisms of surface subsidence are usually different for metal mines. While the same physical principles apply, the conditions surrounding metal mines are often very different from coal mines. The ore body is often much thicker so that mining open creates high stopes with tall, slender pillars between the stopes. Often, the distance to surface relative to the height of the stope is less that in a coal mine. The rock types are often much harder and more brittle in nature. If the width of the stope is narrow enough and the pillar adjacent to it is strong enough, the stope can remain stable over a very long period of time and there is no disturbance of the surface. If the stope is wider or the adjacent pillar is not strong enough, the roof of the stope or the pillar itself may fail in a brittle manner. As the failure progresses, series of rock pieces or larger blocks of rock from the roof and/or the pillar break up and fall into the stope. Broken rock occupies more space than solid rock due to the void spaces between the broken pieces. As failure of the surrounding rocks progress further and further from the opening, the area affected above the stope typically becomes wider (i.e. similar to the shape of an ice cream cone). As the failure of the overlying strata progresses further and further upward, the volume of broken rock continues to increase so that at some point it occupies enough space that the broken rock starts to provide support again until the remaining strata overtop of it is adequately supported and becomes stable (if the distance is far enough to surface). This mechanism can result in several different subsidence effects on surface. If the volume of the stope is small relative to the volume of rock overlying it, the overlying strata may bend so that at surface subsidence is similar to the example of the coal mine. Alternately, if the volume of the stope is substantial relative to the distance to surface, then failure of the overlying rock can progress through to surface causing a more localized area of subsidence where the surface subsides with steeply dipping angles (i.e. a 'sinkhole'). In extreme cases an open hole extending from surface down into the stope can occur (this would generally only occur when the volume of rock overlying the collapsing stope is relatively small compared to the volume of rock required to fill the stope, typically when the stope is very near surface). As ore bodies are not usually uniform, consequently mine designs are also not normally uniform. As a result, subsidence over the mine may be a mixture of the above subsidence mechanisms. Subsidence at Polaris is primarily smooth and uniform due to the use of backfill. Early in the mine life, there was one area (the 202 Stage III stope) where premature failure of the stope before it could be backfilled has resulted progressive failure of the overlying strata resulting in a 'sinkhole' type of subsidence to occur. The failure of this area emphasized the need to backfill stopes and was the standard procedure adopted for stopes after 202 Stope was mined This procedure has prevented other areas from experiencing excessive subsidence.

Empirical monitoring of subsidence at Polaris has been a useful tool in predicting the behaviour of the ground in response to mining. Monitoring of subsidence at Polaris has been done both utilizing precise survey measurements of the bedrock surface, and through visual observations of indications of subsidence. A network of monitoring pins anchored to bedrock was established over the mining area in the 1980's. While mining was active (until 2002), these monitoring stations were surveyed twice per year with adequate precision to detect small changes in pin elevations. These measurements have identified the expected maximum angle of draw of the subsidence zones (i.e. the angle from the extracted area to surface affected by subsidence) to be approximately 40 degrees. This information is useful predicting the ultimate boundaries of subsidence at surface. The length of time subsidence is active is influenced the area being mined, the depth of mining and the angle of draw. Appendix A shows a graph of subsidence over time at a typical coal mine (Subsidence Engineers' Handbook, National Coal Board). The graph illustrates the relationship between these factors and indicates that typical duration for subsidence to be active in a typical coal mine is up to 5 years. While these charts are not directly applicable to base metal mines, it does indicate that subsidence occurs over a relatively short period of time.

3. Estimate of Maximum Extent and Depth of Subsidence Zone

Subsidence progresses through a series of phases over time starting from no movement, to accelerating vertical movement, to decelerating rate of movement, and finally to little or no movement. A typical graph of the amount of subsidence compared to time is presented in the Subsidence Engineers Handbook and is also included in Appendix A. At Polaris, while the time frames for subsidence to occur will be different from the example in the Handbook, the process will be similar showing the same series of phases of changing rates of subsidence over time. Appendix B contains the following figures:

- Location Plan of Subsidence Monitoring Stations and Outline of Mine Workings
  This drawing shows the outline of the mine workings in plan view indicating the locations of the subsidence survey monitoring stations. The majority of these stations are no longer required due to little on-going ground movement and have been

destroyed intentionally as part of re-contouring the site as part of the reclamation activities, through substantial ground movement (in the sinkhole area) or by accident. Our contractor has been instructed to save key monitoring stations around the sinkhole area for future monitoring requirements.

- Graph of Surface Subsidence Versus Time Along Section 1500 E.
  This graph indicates the total subsidence over time for a series of monitoring stations that extend in a North – South line at about the 1500 E section line. The chart shows that subsidence is in the deceleration phase at the south end (Station Sub-5), is still undergoing substantial subsidence just north of the sinkhole (Stations Sub 20 and Sub 22), and has substantially decreasing rates of subsidence as you move further north from the sinkhole (as the amount of mine workings under the stations decrease).
- Graph of Surface Subsidence Versus Time for 2150 N Section – East
  This graph shows the subsidence compared to time for stations east of the sinkhole area. As can be seen from the plan drawing, the location of these subsidence monitoring stations start at the edge of mining and extend out over un-mined areas. The amount of subsidence of these stations is relatively small and subsidence is nearing completion.
- Graph of Surface Subsidence Versus Time for 2150 N Section – West
  This graph shows the subsidence compared to time for stations near the sinkhole area and extending to the west. The stations closest to the sinkhole area are still undergoing significant subsidence and the stations further west are still subsiding significantly but at reducing rates the further away from the sinkhole area. All of the stations in this graph are located over top of mining areas with substantial extraction and that have experienced continuing mining activity throughout the monitoring period. With the cessation of mining, subsidence rates in these areas will start to decrease. The data in this graph is current as of the summer of 2002.

The 'sinkhole' area of subsidence is located directly over top of 202 Stage III stope. A cross section of the stopes in this area relative to the surface identifies the location of this ground failure (Appendix B). Golder Associates Ltd., a mining/rock mechanics engineering consulting firm reviewed this problem as part of their report 'Site Visit to Cominco Ltd.s' Polaris Mine' dated February 1994. This report indicates that a block over top of this stope failed and moved downward in excess of 3.5 metres at the 850 Level (report Section 5.3, Appendix C). The report includes several generalized sketches indicating the observations of the block failure as evidenced underground. Referring to Section 3.3 of Golder Associates' 1995 site visit report (Appendix C), makes a number of observations:

a) Most subsidence monitors at the mine are maintaining constant velocity or de-accelerating.
b) Monitoring data suggests an angle of draw of about 40 degrees.
c) 'At Polaris, the ore is both shallow and thick, and various coal subsidence formula become difficult to apply.'
d) 'A recent review by Golder Associates ….found that published information on subsidence over base metal mines was extremely limited and mainly referred to caving. Thus, there is little precedent which can be used to assess future subsidence (North Keel and Ocean Zone) at Polaris. More or less sole reliance will be on the

information currently being gathered and mine derived relationships (assisted, for example, by numerical modeling).'

The Golder report has photographs of the surface tension cracks which are also included in Appendix C.

Monitoring in the active area of the sinkhole is difficult as the ground movements are large enough that the survey stations have been destroyed and subsequently buried as fill has been placed into the sinkhole. Maximum vertical movement in the area is estimated to be in the order of 10 metres. Subsidence west of the sinkhole is active but more moderate. The area west of the sinkhole is also over areas where thick sections of ore have been mined. However, relative to the horizontal distances involved the change in surface contours are more modest and are not of any concern. A drawing titled '2150 Section Through Sinkhole Area' (Appendix B) indicates the approximate surface over this area and shows the changes to surface contours as a result of subsidence up until relative total subsidence to July of 2002. As there is data missing within the most active area of the sinkhole, the drawing does not necessarily accurately represent the area in the middle of the sinkhole.

As previously identified, most of the monitoring stations have either been destroyed through ground movement or were removed in 2003 as part of the reclamation re-contouring activities. However, key subsidence stations related to the sinkhole area are being retained so that they can be re-surveyed in 2004. It is anticipated that the 2004 survey will indicated decreasing rates of subsidence.

A simple method of observing subsidence is from visual observations. At the boundaries of subsidence where the slope of the surface ground changes, the ground surface is placed into tension causing cracks to form in the surface soils. During the snow free months, recording the locations of new tension cracks is a practical method of monitoring if the area of subsidence is expanding. These observations have been mapped on a regular basis with the results plotted on a surface plan (refer to Appendix B). This data was last updated in 2002. As the ground surface was being re-graded during 2003 during reclamation activities, no observations of surface cracks were made. It is planned to identify and map any new cracks during the summer of 2004.

4. Impact of Placing Fill on the Rate and Amount of Subsidence and the Permafrost Regime

4.1. Impact of Placing Fill on the Rate of Subsidence

As referred to in Section 2.2 above, the Subsidence Engineers' Handbook states that the length of time that subsidence is active is a function of mining depth, draw angle and the rate of extraction, and that the time to complete subsidence is measured in years. While the time frames are extended at Polaris, it still indicates that the time frame for active subsidence to be occurring is limited.

The Handbook also indicates that increasing the depth of cover increases the length of time for subsidence to finish (Appendix A). In the area of the Sinkhole, there is approximately 150 metres of cover, so even if 10 or 15 metres of fill were added, the relative change in cover thickness is small and would have little effect on subsidence rates.

4.2. Impact of Fill on the Permafrost Regime

Placing fill in the sinkhole area is no different from placing fill anywhere else on the island. Permafrost will be established in the fill over a relatively short period of time. The thicker the fill, the more time it would take for the permafrost to be fully re-established. The primary purpose of placing fill in the sinkhole area to restore previous elevations of the ground surface in this area. Whether or not permafrost is reinstated in the new fill in several months or in a few years has no impact on the ground surface elevation which is the primary issue of concern.

5. Thermal Regime at the Polaris Mine Site

5.1. The Need for Installation of Thermistors to Monitor Permafrost Temperatures from the Surface and/or Around Mine Workings

There is an extensive history of ground temperature monitoring related to the mine workings at the Polaris Mine. The mine has measured rock temperatures in and adjacent to mining areas for mining planning purposes. Some examples are:

a) Ground Stability of Mine Workings Due to Thermal Regime
   Prior to developing mine workings in an area, mine engineers needed to be confident that the planned workings would be in an area where the ground is frozen. Thermistors were installed in drill holes that were drilled from surface into the ground ahead of mining. Additional thermistors were placed into drill holes that were drilled from underground workings to confirm the temperature forecasts provided by the surface drill holes. Figure 7 in Volume 1 of the Decommissioning and Reclamation Plan (March 2001) was developed though the collection of this data.
b) Ground Stability of Mine Workings Due to Summer Air Temperatures – the stability of the ground immediately surrounding the underground mine workings was key to providing safe working conditions for personnel working underground. Mines utilize high horsepower fans to force large volumes of fresh air underground to provide fresh air for diesel equipment and to provide clean air for personnel. Experience has shown that if the surfaces of the rock around the tunnels underground are allowed to thaw (in summer when air temperatures are above freezing), that localized sections of rock become unstable (referred to as 'Loose') and are a hazard to personnel working in the area. Thermistors were commonly placed into drill holes in the walls and roofs of the tunnels to monitor rock temperature changes related to local mining activities and seasonal temperature changes. This data indicates that warming of the rock face underground is affected within only a few metres of the mine openings during the warm summer months. It is important to note that after the completion of placing contaminated soils underground in 2004, all of the entrances to the mine will be sealed preventing any air flow in the mine so that the warming effect by air during the summer months will no longer be a factor.

c) Performance of Backfill – as indicated earlier in this report, the mine utilized a water/waste rock backfill to increase the stability of most stopes once mining had been completed. It was important from an operational stand point to determine how quickly the water/rock backfill froze as it would not provide adequate strength until this occurred. Thermistors were placed into this fill and into the adjacent pillars to confirm that the fill had frozen and that the surrounding ground did not thaw as a result. Monitoring of the fill indicated that up to two years was required for fill in large stopes to completely freeze. An individual stope could have upwards of 110,000 tonnes of fill placed that would be frozen as a result of the surrounding ground temperatures. The thermal mass of the surrounding ground is immense. Disturbing the thermal regime by placing materials in the mine is very localized and temporary.

Given over 20 years experience monitoring temperatures in and around the mine during on-going mining and backfilling of openings has clearly demonstrated that there are no concerns with the thawing of the ground at that depth. There is no need to verify this by additional monitoring using thermistors.

5.2. Thermal Regime and Ice Conditions in the Overburden

Temperature monitoring of surface and near surface ground temperatures has been conducted at Polaris for a number of years. Near surface permafrost conditions are a consideration for civil structures at the site such as Garrow Lake Dam and the Operational Landfill. Starting in 2004, monitoring of the Little Red Dog Quarry Landfill will be initiated and continue until 2011. Monitoring of the Garrow Lake dam and the Operational Landfill clearly demonstrates that large quantities of fill placed on surface quickly freeze and within a short period of time, only a relatively shallow active layer (less than 1.5 metres deep) temporarily thaws during the summer season. The effects of global warming were reviewed to determine the effect in the thickening of the active layer related to the landfill cover designs proposed in the DRP. Conservative forecasts indicate on slight increases in the thickness of the active layer (refer to the Polaris Mine Decommissioning and Reclamation Plan, Volume 2, Landfill Closure Report).

The rate of subsidence in the sinkhole area is expected to continue at a decreasing rate over the next few years. Past experience has shown that water pooling over this area during the summer months can infiltrate into new surface cracks caused by ongoing settlement. The depth that this water penetrates the strata overlying the mine has not been investigated. The immense thermal mass of the frozen overburden and bedrock freezes the water before it penetrates into the mine workings (refer to the Conclusion section of the memorandum prepared by Trevor Feduniak titled 'Subsidence Analysis' attached in Appendix D). Once the subsidence in the sinkhole area slows, there will be no new surface cracking and no new conduits for water to flow into the overburden will be created. Existing cracks will be ice filled in a self healing process. Any water penetrating cracks in the near surface strata adds to the strength of the strata as it freezes (a 'healing' process).

5.3. Impact of Surface Water Ponding on Thermal Regime and Permafrost Stability.

During the DIAND site inspection in September 2003, the option of allowing water to pond rather than placing fill into the Sinkhole was discussed as a method of filling any holes caused by subsidence of the sinkhole. It is felt that making this decision is premature at this time until further subsidence data can be collected in 2004.

6. Assessment of Physical Stability and Protection Required

The following is a listing of the types of conditions that if formed by the subsidence referred to as the 'sinkhole' area, could represent a hazard to the public and/or wildlife:

1. If the surface of the ground is unstable it could present a danger to the public/wildlife walking or the public operating motorized equipment over the sinkhole area. The potential danger is that subsidence of the bedrock continues to occur while the overlying soils form a bridge overtop of it. If the activities of people or wildlife were to break the bridging, then the soils could potentially suddenly slump into the underlying void causing harm to those overtop of this area.
   - This area has in the order of 10 to 20 metres of overburden soils overlying the bedrock. During the initial period of active subsidence in this area, heavy mobile equipment has operated adjacent to it and over top of it, placing fill and re-contouring the area without incident. There has never been any evidence of this occurring.
   - As the rate of subsidence decreases, the risk is further reduced as the ground surface has more time to react (i.e. settle).
   - The potential for unexpected, sudden subsidence caused by people or wildlife walking over this area or from operating light motorized equipment is considered remote based on previous experience (at Polaris as well as at other Teck Cominco mine sites) although one can not say categorically that it would never occur.

2. If the slope of the ground is excessively steep, this could represent an unexpected hazard to persons operating motorized equipment in the area. Also at some point, if the slopes are too steep, wildlife could also become trapped in the sinkhole area:
   - The slope of the ground in the area is relatively smooth with low slopes so that there is no concern of thus type of problems at the current time.
   - While there was no survey conducted during 2003, visual observations did not identify localized movement in the Sinkhole area.

- The area will be inspected (and surveyed) in 2004 and if significant subsidence has occurred by that time, adjacent slopes could be re-contoured as there will still equipment available on site.
- Beyond 2004, the rate of subsidence is expected to be decreasing so that the potential for steep slopes forming is a decreasing risk. A survey review in 2004 will be required to confirm this and to forecast future subsidence rates.

3. If the surface contours are altered so that water collects in the low areas creating a pond, there is a potential that the public and/or wildlife could drown in the water.
   - This is not considered a hazard any more or less than any other pond or lake on the island.
   - If ponding of water were to occur, it is not anticipated that any action would be required from a public/wildlife safety perspective.

7. Recommendations for On-going Assessment and Monitoring

As previously discussed the precise surveying of subsidence monitoring stations installed in the surface bedrock were established to provide information for mine planning and design activities. Vertical subsidence movements as little as 0.01 metres were monitored. Now that mining has been completed, the need for this level of accuracy of monitoring is not required. The purpose of monitoring subsidence is now one of public safety which requires a much coarser level of survey accuracy. Once the 2004 precise survey has been completed, subsidence rate curves will be updated and a forecast of future subsidence trends will be more definitive.

Inspection of the mine area will be conducted to determine if there are any new tension cracks in the soils. If there are, these will be surveyed and plotted onto the surface plans to identify any trends indicating changes in the subsidence boundaries. This monitoring can be conducted post 2004 as part of the annual site inspections.

In preparation for longer term monitoring of the site, a topographical survey was completed in 2003. Apart from a final precise survey of the remaining subsidence monitoring stations in 2004, future subsidence monitoring should consist of topographical monitoring of the soil surface to identify potential changes of drainage patterns and for public safety (i.e. settlement causing hazards to the public riding on quads or snow mobiles) purposes. A copy of this survey is included in Appendix E. As with monitoring of the tension cracks, it is recommended that some key locations are surveyed as part of the annual site inspections.

Prepared by:

Trevor Feduniak, P.Eng.
Civil/Mining/Demolition Supervisor
Teck Cominco Metals Ltd.

APPENDIX A

1. **Time / Subsidence Relationships – Subsidence Engineers' Handbook, National Coal Board, 1975**

2. **Time – Subsidence Curve – Subsidence Engineers' Handbook, National Coal Board, 1975**

Subsidence Engineers' Handbook

NCB

National Coal Board
Mining Department 1975

Time/Subsidence Relationship

Permanent repairs should not normally be carried out if a damaged property is due to be undermined again in another seam or by another face in the same seam lying within the critical area. First-aid repairs are often satisfactory for short periods, but discretion is necessary when long intervals are likely to occur between successive excavations or when the property is going to be in an unstable state over a long period.

If the stability of a building is affected and the site is required for development, an estimate should be made of the earliest date when building could safely commence. This should be done by plotting a development curve or a time/subsidence curve and usually ignoring any possible residual subsidence period, which in any case would probably be covered by the site preparation period.

The nomogram in Fig. 33 may be used for this estimation of total time for a single face working. Starting at the depth line, the limit angle is next chosen and this gives the diameter of the critical area (2R). The value for the rate of advance of the face is next intersected to give the total time on the right-hand half of the base line. In the example the broken line shows that for a seam 450 m deep and an angle of draw of 35°, the width of the critical area is 630 m. With a face advance of 1400 m per year the time taken to work the panel is about 6 months.

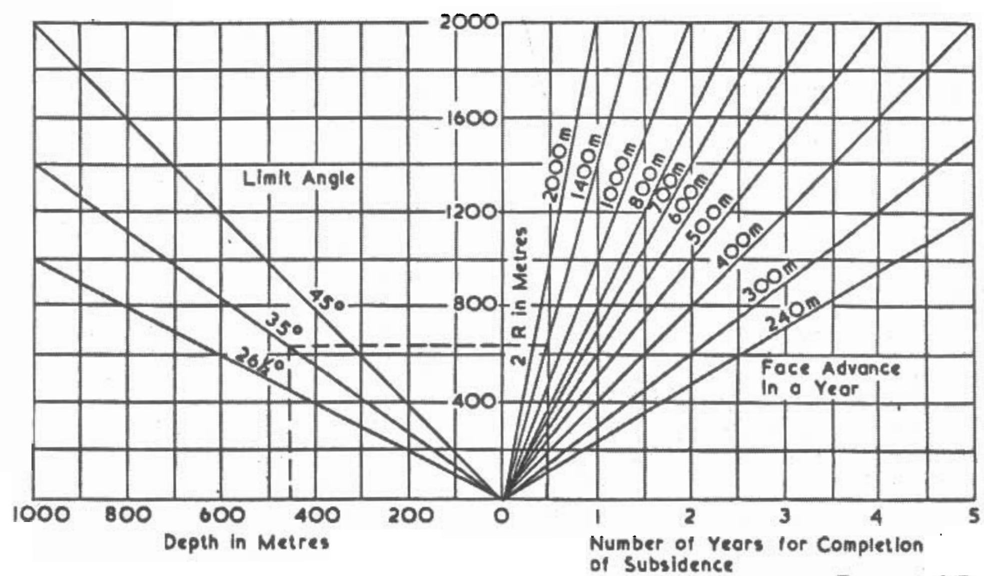

Fig. 33 Nomogram for estimating duration of subsidence.

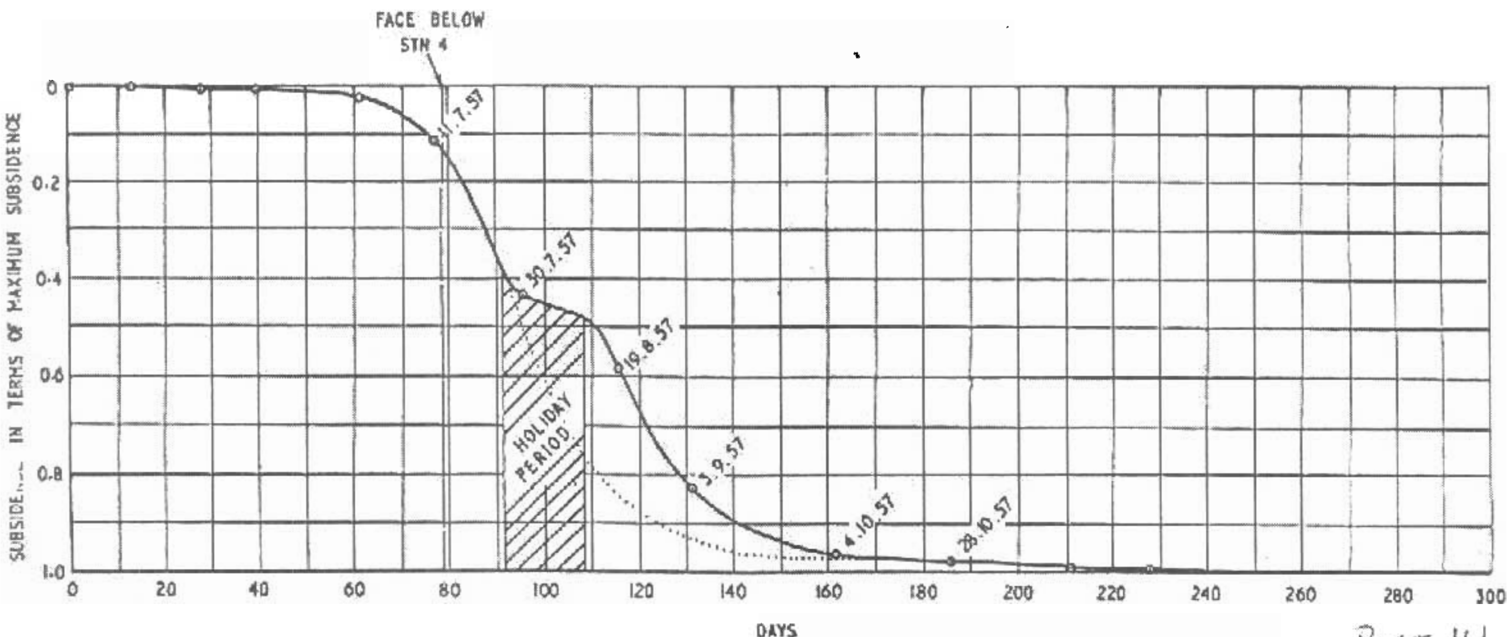

Fig. 30 National Case No. 9—time-subsidence curve.

APPENDIX B

1. **Plan of Subsidence Monitoring Stations and Outline of Mine Workings**

2. **Graph of Surface Subsidence Versus Time Along Section 1500 E**

3. **Graph of Surface Subsidence Versus Time for 2150 N Section – West**

4. **Graph of Surface Subsidence Versus Time for 2150 Section – East**

5. **Cross Section Titled '2150 Section Through Sinkhole Area'**

6. **Plan View of Mine Area Identifying Locations of Surface Tension Cracks**