**BGC ENGINEERING INC.**
AN APPLIED EARTH SCIENCES COMPANY

# NANISIVIK MINE, A DIVISION OF CANZINCO LTD.

## NANISIVIK MINE CLOSURE STUDIES



# WEST TWIN DISPOSAL AREA CLOSURE PLAN

**(WATER LICENSE PART G, ITEM 15)**

Volume 1 of 2

**FINAL**



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# EXECUTIVE SUMMARY

Under the terms of Water Licence NWB1NAN0208 issued by the Nunavut Water Board (NWB), CanZinco Ltd., the current owner of the Nanisivik Mine is responsible for continuation of on-site environmental protection activities and developing for submission and approval of a final Reclamation and Closure Plan ("RCP").

The Nanisivik Mine FCRP has been developed, as per the terms of the Water Licence as a series of stand-alone documents, each addressing in detail the information and proposed closure measures for one specific component or topic area. This document and the information presented herein are provided in response to the requirements for report Part G, Item 15, the West Twin Disposal Area (WTDA) Reclamation and Closure Plan.

In accordance with Part G, Item 15, of the Water Licence, this report provides the following requirements for the WTDA Plan:

1. A brief description of historical operating practices, water movement and overall function of the system.
2. An updated water balance for the system.
3. Current site assessment including characterization of all tailings both for physical properties (gradation, density, mineralogy) and thermal conditions in the surface cell dike and possibly the reservoir.
4. Cover design and description of all construction activities associated with the closure plan, predictions of site stability and water quality with details of analyses that support the plan.
5. Contingency plans for dealing with uncertainties and adverse performance during the post-closure monitoring period. These plans need to include a discussion of events that trigger their implementation.
6. A monitoring program that includes: permafrost stability, deformations of both the dike and soil cover as well as water quality determinations.
7. An appendix that constitutes a construction plan with material specifications, a quality control plan and as-built drawings stamped by an engineer.

Additionally, requirements 6 and 9 of Part G, Item 4 (the Covers Report), which apply to the water covered tailings in the Reservoir, are addressed within the context of the closure plan provided herein. Those two requirements are as follows:

6. The bathymetry of sub-aqueous tailings in West Twin Lake Reservoir which shows the extent of tailings located within 1.0 m of the water surface, and plans for mitigation of wave action on these tailings.

9. An evaluation of alternatives for increasing minimum water depth in the Reservoir with emphasis on possible effects of waves and winter ice cover on long term water quality.

The report provided herein attempts to be comprehensive in its treatment of the elements and technical information and issues with regards to the closure of the WTDA. The following list provides guidance on the closure elements covered in this report, as opposed to other submitted reports:

- Surface Cell and Test Cell cover design – covered in Cover Designs Report (Part G, Item 4).
- Talik characterization – covered in Talik Report (Part G, Item 5).
- Reclamation materials – covered in the Quarry Report (Part G, Item 6).
- West Twin Dike spillway design – covered in Surface Cell Spillway report (Part G, Item 7).
- Reservoir water cover and submerged tailings – covered in current report.
- Reservoir shoreline protection design – covered in current report.
- Breaching of baffle dike in Reservoir and access road berm at Polishing Pond – covered in current report.
- Breaching of Polishing Pond Outlet Structure and design of Outlet Channel and Overflow Weir – covered in current report.
- Erosion protection for East Twin Diversion Dike and channel – covered in current report.

As noted, the current report attempts to be comprehensive on the topic, without repeating all applicable detail from each of the individual component reports.

The WTDA consists of an upper solids retention pond, known as the Surface Cell and a lower water retention pond, known as the Reservoir. An earthen dike, the West Twin Dike, separates the Surface Cell and Reservoir. The Reservoir is further divided by the Test Cell Dike, which separates the Reservoir and the Test Cell. The Test Cell was used to evaluate the performance of several test cover designs. Both dikes are constructed of frozen shale fill and are founded on frozen, settled tailings. The current crest elevation of the West Twin Dike is about 388 m. The Test Cell Dike was raised in two stages. The first stage was raised to elevation 383.5 and the second stage was to about elevation 385.5. The staged construction resulted in the formation of a bench on the Reservoir side of the dike.

Excess water from the Surface Cell is transferred to the Reservoir by pumping or a siphon system that controls water levels. The Reservoir and a final Polishing Pond are separated by a causeway and stop log structure, which controls the water level in the Polishing Pond. Water from the Polishing Pond is discharged to Twin Lakes Creek through the West Twin Outlet Structure, a 3 to 5 m high earth fill dam with a valve controlled, concrete lined spillway. Excess water from the WTDA is then discharged to the environment via the West Twin Outlet Structure between July and September of each year.

The primary risks posed by the WTDA facilities are related to the potential for acid rock drainage, the potential for the physical movement of tailings to the environment and the loss of surface land use values. The specific reclamation objectives for the WTDA reclamation plan are as follows:

1. Isolate potentially acid generating tailings from the atmosphere to minimize the risk of acid rock drainage.
2. Minimize the risk of physical movement of tailings to the environment.
3. Provide a safe and usable surface environment that corresponds to the natural surroundings.

Specific reclamation measures described in the report include:

- Minimization of oxygen exchange in the Surface Cell and Test Cell tailings by placing a cover of shale and sand and gravel over the exposed tailings. The cover will provide thermal insulation, to maintain frozen conditions and allow for permafrost aggradation. The sand and gravel surface layer will provide a durable cap of local material. The cover will be thick enough to maintain continuous frozen conditions within the underlying tailings during mean annual and warmer conditions, even with a worst case estimate of future climate change predictions over the next 100 years.
- Minimization of oxygen exchange in the Reservoir tailings by means of a minimum 1 m water cover. Erosion protection will be placed over the tailings within the shoreline area to minimize the risk of re-suspension of tailings due to wave and ice action. The final water level in the Reservoir and Polishing ponds will be the same as the original, pre-mining elevation of West Twin Lake.
- Transfer of water flow from the Surface Cell to the Reservoir via a new spillway and outlet channel around the south end of West Twin Dike. This structure will be designed to safely pass seasonal run-off and the routed 24-hour probable maximum precipitation (PMP) storm event.
- West Twin Dike will remain in place during closure for permanent retention of the Surface Cell tailings. The outer slope of the dike will be graded smooth to a flatter slope and covered with Twin Lakes sand and gravel to prevent erosion.
- The Test Cell Dike will remain to retain the tailings solids. The crest of the Test Cell Dike will be graded as a portion of the grading plan for the entire cell.
- The water control outlet structure that was used to release water in a controlled manner during mine operations will be removed and replaced with an open outlet channel and overflow weir. The new outlet channel will be located at the natural, original elevation (370.2 m) of the outlet of West Twin Lake. Water passing through the outlet channel will join with water flowing from East Twin Lake and flow into Twin Lakes Creek. This structure will not be removed until after the main work is done to ensure that WTDA water can be managed in the unlikely event that treatment is required.

Design details are presented for each of the areas to be reclaimed. Specific design details for the shale covers on the Surface and Test Cells are provided in the report "Engineering Design of Surface Reclamation Covers" (Water Licence Part G, Item 4).

Discharge water quality from the Polishing Pond is predicted to remain constant over the next 25 years, at about 0.07 mg/L zinc. This is similar to the natural background level of 0.056 mg/L zinc. Over time, the volume of water passing through the Polishing Pond is projected to decrease marginally, due to decreasing rates of porewater expulsion from the tailings.

Construction quality control and quality assurance requirements are included for all aspects of construction associated with the WTDA reclamation. These include:

- Fill placement
- Soil excavation
- Rock excavation
- Drilling and grouting
- Concrete
- Rip rap
- Surveying
- Instrumentation

A comprehensive program for evaluating the long-term performance of the proposed reclamation measures is to be implemented. The monitoring program will also identifies areas where maintenance, repairs or contingencies may be required in the short term. The monitoring information to be collected includes:

- Ground temperatures within the cover, the tailings and the natural ground.
- Subsurface water pressures related to the freezing of the taliks.
- Quality of water entering the environment.
- Climate data.
- Regular inspections of surface conditions by trained technical staff.
- Scheduled inspections of surface conditions by a professional geotechnical engineer.

In general, the monitoring program provides for performance monitoring during the 2 year Reclamation Period and for a subsequent 5 year Closure Period. During the Reclamation Period, worker presence at the mine site is anticipated for construction monitoring and general reclamation activities. This presence will enable the proposed monitoring programs to be carried out by the on-site personnel under the direction of an Environmental Coordinator and geotechnical engineer. During the Closure Period, performance monitoring will be conducted to evaluate the success of the reclamation measures. Continuous worker presence at the mine site is not planned during the closure period and environmental monitoring programs will be carried out during scheduled site visits and possibly utilizing trained, local field assistants and staff hired from nearby Arctic Bay.

CanZinco and other technical experts, as required, will review the information obtained from the monitoring program. CanZinco will take appropriate action to maintain or repair the reclaimed areas. The data obtained from the monitoring program will be forwarded to the Nunavut Water Board for their review and public posting.

Several contingency plans have been developed in order to address performance issues that may be identified during the reclamation and closure monitoring periods. For each issue, the consequences and suggested mitigation approaches are also identified. Common to all suggested mitigation measures is identification of the root cause and appropriate reaction to limit the environmental consequences. The mitigation measures range from performing localized maintenance of the covers to treatment of Reservoir water.

In 2010, a comprehensive, all encompassing assessment of the monitoring information is to be conducted that will determine whether the reclamation objectives have been achieved and whether the WTDA is considered to be successfully reclaimed.

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# LIMITATIONS OF REPORT

This report was prepared by BGC Engineering Inc. (BGC) and associated companies (as noted in Section 1.3) for the account of CanZinco Ltd. The material in it reflects the judgement of BGC staff in light of the information available to BGC at the time of report preparation. Any use which a Third Party makes of this report, or any reliance on decisions to be based on it are the responsibility of such Third Parties. BGC Engineering Inc. accepts no responsibility for damages, if any, suffered by any Third Party as a result of decisions made or actions based on this report.

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# 1.0 INTRODUCTION

## 1.1 Overview of Development of the Nanisivik Mine Final Closure and Reclamation Plan

The Nanisivik Mine began production of zinc and lead concentrates in 1976. The current owner of the mine, CanZinco Ltd. (CanZinco), has been in possession of the mine since 1996.

Prior to mid-2002, the Nanisivik Mine was scheduled to operate until the depletion of economic ore reserves in 2004 or 2005. However, depressed international base-metal prices necessitated a re-evaluation of the mine production plan in mid-2002. This assessment resulted in a reduction of economic ore reserves such that these reserves were depleted in September 2002. The mine was permanently closed at that time.

An interim mine reclamation plan had been developed and updated on a regular basis by CanZinco in response to terms of the Water License. However, the announcement of permanent closure in October 2001 triggered a requirement in the (then) current water licence for submission of a Final Closure and Reclamation Plan. In response to this trigger, CanZinco submitted a Closure and Reclamation Plan (C&R Plan) in February 2002 that described CanZinco's approach to closure and reclamation of the Nanisivik site.

Subsequent to a Public Hearing on renewal of the water licence held in the community of Arctic Bay in July 2002 and a technical meeting held in August 2002, the Nunavut Water Board ("NWB") issued Water Licence No. NWB1NAN0208, with an expiry date of May 1, 2008 (the "Water Licence"). The Water License provides for the continuation of on-site environmental protection activities during the development and submission, for approval, of a final Reclamation and Closure Plan ("RCP").

The Nanisivik Mine 2004 RCP has been developed, per the terms of the Water License, as a series of stand alone documents, with each document providing, in detail, information and proposed closure measures for one specific component or topic area. The individual reports that have been developed in this manner are listed under Section G of the Water License as summarized in Table 1.

This document and the information presented herein are provided in response to the requirements for component Part G Item 15, the West Twin Disposal Area (WTDA) Closure Plan.

## 1.2 Specific Requirements for the Reclamation and Closure Plan

The specific requirements for the WTDA Closure Plan come from Part G, Item 15 of the Water Licence. This clause of the Water Licence, as excerpted below, provides the following requirements for the plan:

*The Licensee shall submit to the Board for approval a West Twin Disposal Area Closure Plan, which shall include, but not be limited to:*

1. *A brief description of historical operating practices, water movement and overall function of the system;*
2. *An updated water balance for the system;*
3. *Current site assessment including characterization of all tailings both for physical properties (gradation, density, mineralogy) and thermal conditions in the surface cell, dike and possibly the reservoir;*
4. *Cover design and description of all construction activities associated with the closure plan, predictions of site stability and water quality with details of analyses that support the plan;*
5. *Contingency plans for dealing with uncertainties and adverse performance during the post-closure monitoring period. These plans need to include a discussion of events that trigger their implementation;*
6. *A monitoring program that includes: permafrost stability, deformations of both the dike and soil cover as well as water quality determinations; and*
7. *An appendix that constitutes a construction plan with material specifications, a quality control plan and as-built drawings stamped by an engineer.*

Additionally, requirements 6 and 9 of Part G, Item 4 (the Covers Report) which apply to the water covered tailings in the Reservoir, are addressed within the context of the closure plan provided herein. Those two requirements are as follows:

6. *The bathymetry of sub-aqueous tailings in West Twin Lake Reservoir which shows the extent of tailings located within 1.0 m of the water surface, and plans for mitigation of wave action on these tailings;*
9. *An evaluation of alternatives for increasing minimum water depth in the Reservoir with emphasis on possible effects of waves and winter ice cover on long term water quality.*

The report provided herein attempts to be comprehensive in its treatment of the elements and technical information and issues with regards to the closure of the WTDA. To provide guidance on the closure elements covered herein the current report, as opposed to other submitted reports, the following list summarizes the breakdown:

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- Reclamation materials – covered in the Quarry Report (Part G, Item 6).
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- Erosion protection for East Twin Diversion Dike and Channel – covered in current report.

As noted, the current report attempts to be comprehensive on the topic, without repeating all applicable detail from each of the individual component reports.

### 1.3 Authorship

This closure plan is multi-disciplinary in content and was prepared with input from three companies including BGC Engineering Inc. (BGC), Gartner Lee Ltd. (GLL) and Golder Associates Ltd. (GAL). Each of the companies provided technical input, report text and related figures and tables for their area of responsibility of the plan. BGC provided overall compilation and production of the report while CanZinco provided overall review of the information submitted herein.

Primary authors for the various companies included the following personnel:

1. BGC – Mr. Jim Cassie, P.Eng., Mr. Geoff Claypool, P.Eng. and Mr. Mike McCrank, E.I.T.
2. GLL – Mr. Eric Denholm, P.Eng. and Mr. Alistair Kent, P.Eng.
3. GAL – Mr. Ken Bocking, P.Eng., Mr. David Ritchie, P.Eng. and Mr. Alex Gordine, P.Eng.

## 2.0 SITE CONDITIONS

### 2.1 Location and Topography

Nanisivik Mine is located at the northern end of Baffin Island at approximately 73°N latitude as shown in Figure 1. The mine is approximately 5 km from Strathcona sound, which is connected to the Arctic Ocean through Admiralty Inlet.

The mine area consists of a few intermittent planar areas predominantly surrounded by relatively steep high-relief hills rising out of Strathcona Sound. The surface topography is moderately steep rising from sea level to a high of approximately 650 m immediately west of the mine area (Mt. Fuji).

## 2.2 Climate

Nanisivik Mine is located on Baffin Island in the Canadian Arctic and is therefore subjected to a harsh climatic environment year round. Atmospheric Environment Services (AES) of Environment Canada maintains a network of climate monitoring stations in Nunavut, including one at the Nanisivik Airport, Resolute, Pond Inlet and Arctic Bay. These stations have systematically collected detailed climatic data for the Canadian Arctic. A detailed review of the available climatic conditions at Nanisivik and proximal stations was conducted to aid in reclamation and closure planning activities. The results of this review are discussed in detail in Section 3.2 of the report “Engineering Design of Surface Reclamation Covers” (Water License Part G, Item 4) and the main parameters are summarized in Table 2.

In addition to a review of all available historical climatic conditions at Nanisivik, an estimate of future climate trends was conducted in order to include potential long-term climate changes in the design of the reclamation works. This estimate was conducted utilizing current guidelines for climate warming estimates. This is also discussed in detail in Section 3.2 of the report “Engineering Design of Surface Reclamation Covers” (Water License Part G, Item 4). The estimated climate warming values are also provided in Table 2.

## 2.3 Geology

### 2.3.1 Bedrock

The bedrock geology of the area has been mapped in detail by Patterson and Powis (2002) and Patterson et al. (2003). The regional bedrock stratigraphy is illustrated on Figure 2. The Nanisivik region is underlain by carbonate and terrigenous clastic strata of the Mesoproterozoic Bylot Supergroup. The Bylot Supergroup is comprised of two terrigenous formations (Adam’s Sound and Arctic Bay formations) and two carbonate formations (Society Cliffs and Victor Bay formations) and a mixed carbonate and terrigenous clastic formation (Strathcona Sound Formation). Quartz arenite of the Gallery Formation unconformably overlies the Proterozoic strata.

The Adams Sound Formation is a beige- to light orange-brown, well cemented, medium- to coarse-grained quartz arenite. It is over 100 m thick and is exposed in the Nanisivik Area.

The Arctic Bay Formation is a medium grey to brown, micaceous, fine sandy siltstone interbedded with dark grey micaceous, silty shale. This formation outcrops southeast and southwest of Nanisivik and is approximately 200 m thick.

The Society Cliffs Formation is over 500 m thick and is exposed in the Nanisivik Area. This formation has been subdivided into three units:

- Microbial dolostone (lower);
- Intraclastic dolostone (middle); and,
- Laminated dolomudstone (upper).

All components of the formation exhibit dolomite mineralization. Known sulphide deposits in the Nanisivik area are hosted within the middle and upper subdivisions of this formation.

The Victor Bay Formation is characterized by a gradual upward change from organic rich pyritic shale, to dolomudstone, to more intraclastic and dolomitic facies. It is exposed throughout the Nanisivik area. The formation has been subdivided into three units:

- Shale and dolomitic mudstone unit (lower);
- Dolomitic mudstone and intraclast floatstone (middle); and,
- Silty dolomitic mudstone and intraclast rudstone (upper).

The lower unit is approximately 180 m thick and consists of interbedded, organic rich, fissile shale and light-grey, planar-bedded dolomitic mudstone.

The middle unit is approximately 80 m thick and is marked by the appearance of intraclast rudstone and floatstone. Occasional occurrences of light-grey dolomudstone and black shale similar to those found in the lower unit are observed within the middle unit.

The upper unit is approximately 70 m thick and is characterized by the absence of shale and the prevalence of dolomitic intraclastic carbonate and the presence of terrigenous material within clastic carbonate rocks. This unit forms a transitional unit into the terrigenous Strathcona Sound Formation.

The Strathcona Sound Formation contains two mappable units; a carbonate pebble to boulder conglomerate and an interbedded quartz wacke and shale unit.

The conglomerate unit is a matrix-supported, carbonate pebble to boulder conglomerate that consists of light brown to orange, subrounded to angular 1 to 50 cm diameter dolomudstone clasts in a grey-green, poorly sorted quartz wacke matrix. It thickness ranges from several metres to approximately 50 m.

The interbedded quartz wacke and shale unit is green to dark grey, planar bedded and forms a thick (>130 m), monotonous succession. The quartz wacke and shale are interbedded at scales ranging from 1 to 200 cm. Beds of carbonate pebble to boulder conglomerate are common within 10 m of the contact between the two units.

The Phanerozoic rocks of the Gallery Formation overlie the Mesoproterozoic strata and are exposed predominantly west of Nanisivik. The Gallery Formation forms a thick (>300 m) succession of interbedded red and white, poorly cemented, medium- to fine-grained quartz arenite. The Gallery Formation is easily identified by its deep red hematite-stained colour, and friable texture.

#### 2.3.2 Overburden

Overlying the bedrock, specifically in the area of West Twin Lake, is a combined unit of lakebed sediments (silt and sand, trace to some clay) and glacial till (silty sand with gravel fragments). The lakebed sediments are identified by their red colour, a product of hematite oxidation staining. The till is generally very granular in nature, frozen below the depth of active layer thaw and may contain excess ice content. The thickness of the lakebed sediments/ till unit varies from 1 to 4 m. The lake bed sediments/ till upper surface generally follows the underlying bedrock topography.

### 2.4 Regional and Local Seismicity

Information provided by the Geological Survey of Canada and referenced in BGC (2000) notes that the 1 in 476 year event is 0.076g and the 1 in 1,000 year event is 0.099g. According to the Canadian Foundation Engineering Manual (1993), the site is situated in the second lowest seismic hazard zone in Canada, $Z_a$=1 (peak horizontal ground acceleration = 0.04 to 0.08g, 10% exceedance in 50 years). This value is relatively low compared to areas in the highest seismic hazard zone ($Z_a$=6, >0.32g) in areas such as the southern coast of British Columbia.

### 2.5 Permafrost

Nanisivik Mine is located in the region of continuous permafrost, as shown in Figure 3. Permafrost has been observed to extend to a depth of at least 430 m below the mine, as observed in a borehole drilled from the underground workings. Ground conditions in the area have been characterized by NRC (1995) as having the potential for medium amounts of ground ice (as high as 20%) and mean annual ground temperatures colder than -10°C. This has been verified by ground temperature measurements at various locations around the mine site as cold as -13°C at depth. The depth of the active layer in natural ground has been observed to average between 1 to 2 m below ground surface.

## 2.6 Hydrology

A hydrological study of Nanisivik Mine was conducted by Golder (2004b). This study is included in its entirety in Appendix I. The following list contains the principle conclusions of that study:

- The amount of precipitation at the Nanisivik Mine is relatively small. The average annual total precipitation is estimated to be 243 mm. The daily rainfall PMP event is estimated to be approximately 140 mm.
- The average annual lake evaporation at Nanisivik is estimated to be 203 mm; the highest reported monthly lake evaporation of 101 mm occurs in July. The estimated average annual sublimation (evaporation from the snow surface) is approximately 50 mm.
- The watershed area of West Twin Lake (Figure 4) is approximately 300 ha, which includes estimated 127 ha of the Surface Cell drainage basin and 173 ha of the Reservoir drainage area.
- The watershed area of East Twin Lake (Figure 4) is approximately 3460 ha. The lake surface area is approximately 18 ha.
- The frozen ground conditions result in high surface runoff. The estimated average annual runoff coefficient is approximately 0.7. The estimated PMP event runoff coefficient is approximately 0.94.

# 3.0 WEST TWIN DISPOSAL AREA COMPONENT AND OPERATION REVIEW

## 3.1 Current Configuration and Operational Practices

The WTDA, illustrated in Figure 5, is comprised of an upper, solids retention pond, the Surface Cell, and a lower, water retention pond, the Reservoir. An earthen dike, the West Twin Dike, separates the Surface Cell and the Reservoir. The Reservoir is further divided by the Test Cell Dike, which separates the Reservoir and the Test Cell. The Test Cell was used to evaluate the performance of several test cover designs. Both dikes are constructed of frozen shale fill and are founded on frozen, settled tailings.

The first shale lift of the West Twin Dike was built in 1991. The initial lift had a top width of approximately 4 m, which brought the elevation of the top of the dike to approximately 374 m. The dike has been raised in an upstream manner where each new lift begins on top of beached tailings material deposited previously and sealing lift of frozen shale rockfill. The dike was raised every year between 1991 and 1999, except 1994. The current crest elevation of the dike is nominally 388 m.

The Test Cell Dike is also constructed of frozen shale fill overlying frozen (and thawed at depth) tailings. The dike was constructed in two stages. The first stage increased the height of the Test Cell Dike to an approximate elevation of 383.5 m. The second stage increased the height of the Test Cell Dike to an approximate elevation of 385.5 m. The second stage of the dike is partially