

# Teck

## Red Dog Mine Closure and Reclamation Plan

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**- Final -**

*Prepared for:*

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*Project Reference Number*  
SRK 1CT006.000

**May 2009**

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- A2 Legal Description of Property

### Supporting Document B: Plans of Operations

- B1 Red Dog Mine Development Plan (TCAK, 2004)
- B2 Plan of Operations for Waste Rock Management
- B3 Plan of Operations for Tailings and Water Management

### Supporting Document C: Geotechnical

- C1 Main Waste Stockpile Stability Assessments
- C2 Drawings from Updated Geotechnical Report (URS, 2008)
- C3 Dam History Report, Red Dog Tailings Main Dam, Future Raises to Closure (URS, 2007)
- C4 Preliminary Conceptual Design Report, Red Dog Tailings Main Dam, Future Raises to Closure (URS, 2007)
- C5 Stability Analysis for Future Raises to Closure, Tailings Main Dam (URS, 2007)
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### Supporting Document D: Geochemistry

- D1 Consolidation of Studies on Geochemical Characterization of Waste Rock and Tailings
- D2 Supporting Geochemical Review and Interpretation
- D3 Aqqaluk Geochemistry – Supplemental Testing Program
- D4 Lime Requirements and Predicted Geochemical Changes

### Supporting Document E: Water Management

- E1 Red Dog Water and Load Balance
- E2 Flood Frequency Update for Middle Fork Red Dog Creek (Peratrovich, Nottingham & Drage Inc., 2002)
- E3 Red Dog Creek Rediversion Design Criteria & Plan (TCAK, 2004)
- E4 Assessment of Water Treatment Methods Applicable for Closure
- E5 Assessment of Methods for Managing Post-Closure Water Treatment Sludge

### Supporting Document F: Reclamation and Revegetation

- F1 Mine Area Closure Options – Summary of the Cover Studies
- F2 Evaluation of Borrow Sources
- F3 Revegetation Plan for the Red Dog Mine (ABR, Inc., 2007)

### Supporting Document G: Demolition

- Demolition Cost Estimates (Denison Environmental Services, 2004)

### Supporting Document H: Ecological Risks

- Evaluation of Ecological Risk within the Ambient Air/Solid Waste Permit Boundary (Exponent, 2008)

Supporting Document I: Monitoring Plans

Red Dog Mine, Waste Management, Reclamation and Closure Monitoring Plan (TAK, 2009)

Supporting Document J: Cost Estimates

- J1 Basis of Estimate – Closure Costs
- J2 Basis of Estimate – Post-Closure Costs
- J3 Basis of Estimate – Suspension Costs



# 1 Introduction

## 1.1 Purpose

Teck Cominco Alaska Incorporated (TCAK) and NANA Regional Corporation (NANA), as associates in the operation of the Red Dog Mine, are committed to protecting the environment and the people around the mine. Part of that commitment includes developing plans for orderly closure of the mine and reclamation of disturbed areas.

This document presents a comprehensive Closure and Reclamation Plan for the Red Dog Mine. Although current projections are that the mine will remain in operation until 2031, completing the plan now achieves several purposes. First, closure and reclamation measures benefit from early plans that allow modification or restrictions of operations to facilitate long-term environmental protection. Second, the mine will soon begin development of a new pit, presenting an opportunity to completely integrate long-term operating and closure plans for a major portion of the site. Third, State of Alaska regulations require the early provision of funds to cover costs related to closure and reclamation, and the amount of such funds can only be determined from a thorough plan. Finally, the development of closure and reclamation plans offers an opportunity to engage the local communities that are most affected by the mine operation, and to ensure that long-term plans reflect their concerns.

## 1.2 Overview of Project to Date

Consideration of closure and reclamation requirements was part of the earliest discussions about operation of the mine. The Operating Agreement between NANA and TCAK has eight clauses that relate to environmental protection. Table 1.1 summarizes those clauses. The Agreement called for a reclamation plan, first written in 1983 and revised in 1986.

Reclamation plans were required by the State mining regulations adopted in 1992 (11 AAC 97.300 – 97.350). A reclamation plan was filed under that system, in 1994, and subsequently extended. Table 1.2 summarizes the requirements of the State mining regulations. Neither the mining regulations nor the 1994 plan covered other closure requirements.

In 1998, the State adopted Solid Waste Permit regulations (18 AAC 60.265) that have more comprehensive requirements for closure and reclamation planning, including provision of funding for long-term water treatment. Table 1.3 provides an excerpt of the most relevant part of that regulation. A 2004 amendment to the State Dam Safety Regulation (11AAC93) has similar financial assurance requirements. Table 1.4 provides the relevant excerpt.

It is the intent of the State that all of the large operating mines will file definitive closure and reclamation plans under the Solid Waste Permit regulation, and a Large Mine Permitting Team (LMPT) comprised of representatives from the relevant state agencies was established in part to

facilitate that process. Discussions between TCAK and the LMPT about a new closure and reclamation plan for the Red Dog Mine started in earnest in 2002.

TCAK selected SRK Consulting Inc. and SENES Consultants Ltd. to lead the technical development of the closure and reclamation plan in 2003. An initial workshop to define requirements for additional technical studies was held in January of 2004. That workshop was attended by TCAK staff, State staff, technical representatives of NANA, as well as many of the specialist consultants who had worked on the site in recent years.

The technical studies proceeded over the remainder of 2004 and continued into 2005. That period included the completion of the “Red Dog Mine Development Plan” (TCAK, 2004), which provided the first definitive description of the future development of the Main, Aqqaluk and Qanaiyaq Pits, and established 2031 as the expected date for closure. The results of most of the other technical studies were incorporated into two reports, one presenting options for closure and reclamation of the mine area and the other presenting options for the tailings area.

While the technical work was progressing, TCAK and NANA undertook an intensive program of consultation directed at informing people about the progress of the planning and the options under consideration. The consultation program focused on the communities of Noatak and Kivalina, but included meetings with other NANA communities, the NANA Subsistence Advisory Committee, the NANA Board and staff, the State LMPT and its consultants, and non-governmental organizations. Table 1.5 lists the major consultation milestones. In April and June 2006, two major workshops were held to provide people the opportunity for direct feedback on the selection of closure and reclamation measures. The workshops included representation from all of the groups listed above, and provided for both group and individual feedback. All participants were given copies of the options reports and a video summary. Sixty people attended the first workshop and 45 attended the second. The results of the workshops indicated clear preferences for the closure and reclamation options that form the basis for the current plan. Supporting Document A1 provides details of the workshop proceedings.

**Table 1.1: Closure and Reclamation Provisions in the NANA – Teck Cominco Operating Agreement**

(a)	The parties recognize that reclamation of disturbed lands is desirable.
(b)	The parties recognize that land disturbances related to surface mining and the deposition of tailings and waste rock are inevitable and complete return of all the disturbed land to its undisturbed condition is not possible.
(c)	Reclamation shall be generally designed to mitigate potential long-term danger to human life or the subsistence needs of the natives of the NANA Region, to mitigate any adverse visual or aesthetic conditions, and to the extent reasonably practicable, to restore the land to a condition compatible with surrounding land.
(d)	Disturbed land shall be restored to natural looking contours compatible with the surrounding terrain (it being recognized that the area of the mine excavation will not be refilled).
(e)	Where available in appropriate quantities, topsoil shall be separately removed and stockpiled for final application after reshaping of disturbed areas has been completed. However, the parties recognize that permafrost conditions could cause long-term stockpiling of topsoil to be impractical.
(f)	Appropriate measures shall be taken to control or reduce erosion, landslides and water runoff to the extent practicable.
(g)	Fisheries and wildlife habitats shall be rehabilitated to the extent practicable.
(h)	To the extent practicable, disturbed areas shall, through seeding, fertilizing, and other appropriate means, be revegetated with a diverse vegetative cover of species native to the area and similar to that on adjoining areas.

**Table 1.2: Reclamation Requirements in the State Mining Regulations**

<p>"reclamation of the area so any surface that will not have a stream flowing over it is left in a stable condition to ensure:</p> <ul style="list-style-type: none"><li>• return of waterborne soil erosion to pre-mining levels within one year after the reclamation is completed, and that can reasonably be expected to achieve revegetation, where feasible, within five years after the reclamation is completed, without the need for fertilization or reseeding;</li><li>• segregation of topsoil removed during the mining operation to protect it from erosion, protect it from contamination by acidic or toxic materials, and preserve it in a condition suitable for later use; and</li><li>• promotion of natural revegetation wherever possible, including redistribution of topsoil where available"</li></ul>
<p>"reclamation of the area so that surface contours after reclamation are conducive to natural revegetation or are consistent with an alternate post-mining land use"</p>
<p>"reclamation of a pit wall is not required if the steepness of the wall makes it impracticable or impossible to accomplish; however, the wall must be left in a stable and safe condition"</p>
<p>"re-establishment of any stream channel, that was diverted and is no longer stable, to a stable location..."</p>
<p>"... reclaim a mined area that has potential to generate acid rock drainage (acid mine drainage) in a manner that prevents the generation of acid rock drainage or prevents the offsite discharge of acid rock drainage"</p>

**Table 1.3: Financial Requirements of the Solid Waste Permit Regulation**

"...(ADEC) will require proof of financial responsibility to cover the cost of closing a landfill and, if monitoring is required, the cost of post-closure monitoring, if the department determines proof of financial responsibility is necessary to protect the public health, safety, welfare, or the environment. Proof of financial responsibility under this section may be demonstrated by self insurance, insurance, surety, or other guarantee approved by the department to assure compliance applicable closure standards and post-closure monitoring requirements."

**Table 1.4: Financial Requirements of the Dam Safety Regulation**

"... the owner must provide a performance bond or other financial assurance adequate to provide sufficient money to pay for the costs of safely breaching the dam at the end of the dam's service life and restoring the stream channel and reservoir land to natural conditions, or for the costs of performing reclamation and post-closure monitoring and maintenance"

**Table 1.5: Project Consultation Milestones**

January 2004	Initial mine closure workshop at Red Dog Mine
May 2004	General discussion in Noatak and Kivalina meetings
July 2004	NANA mine closure workshop
August 2004	Subsistence Committee meeting at Red Dog Mine
September 2004	Detailed discussion in Noatak and Kivalina meetings
October 2004	Technical workshop for all interested parties, Anchorage
January 2005	Presentations in all eleven regional villages and additional sessions in Noatak & Kivalina
April 2005	Tailings Multiple Accounts Analysis in Anchorage
August 2005	Update to Subsistence Committee
December 2005	Presentation to NANA Board
January 2006	Meetings with Subsistence Committee, and in Noatak and Kivalina
March 2006	Distribution of video-cassette and DVD's to all Kivalina and Noatak residents
April 2006	Options Evaluation Workshop on Anchorage
June 2006	Options Evaluation Workshop in Kotzebue
September 2006	Update to all eleven villages
December 2006	Presentations of selected options in Noatak and Kivalina

### 1.3 Overview of Closure & Reclamation Plan

Figure 1.1 shows the location of the Red Dog Mine. Figure 1.2 shows the boundary of the area considered in this plan. The boundary is being proposed as the limits of the Solid Waste Permit, and it coincides with the boundary of the current Air Quality Permit. The proposed boundary encompasses all of the areas that are likely to be directly impacted by operations at the site. Supporting Document A2 provides the legal description of the boundary.

The port and road facilities shown in Figure 1.1 are generally outside the boundary, and therefore outside the scope of this plan. It is recognized that a comprehensive and global view of the area's environment must consider those features, but differences in ownership and use require that the port and road be dealt with through other planning and regulatory processes.

The plan considers three periods: operations, closure and post-closure. Chapter 2 deals with the operations period, which is assumed to extend to the end of mining and ore processing, currently estimated at 2031. Changes to the site that will result from future operations are described. The long period of continuing operations will also allow for early reclamation of portions of the site. These "progressive reclamation" measures are also described in Chapter 2.

The closure period is assumed to begin when operations cease, and to extend until closure construction and reclamation are complete. Chapter 3 describes the activities planned for the closure period.

The post-closure period is assumed to commence once the closure measures are completed, and to extend indefinitely thereafter. Water treatment, maintenance and monitoring are among the post-closure activities that are expected to be required for the long term. Chapter 4 discusses the post-closure period in more detail.

The final section of this plan, Chapter 5, presents a summary schedule and cost estimates covering all of the closure and reclamation activities discussed herein. It also discusses the costs that would be associated with premature closure of the mine, i.e. prior to 2031.

This document is intended to present the proposed closure and reclamation activities in sufficient detail for most readers. However, technical reviewers may require more information in particular areas. A series of supporting documents have been prepared to present those details. The supporting documents are referenced where relevant, and a complete list can be found under the table of contents.

## 2 Site Components and Operations

### 2.1 Mine Area

#### 2.1.1 Current and 2031 Layouts

Figure 2.1.1 shows the current layout of the mine area, and identifies key features:

- Main Pit, and exploration roads in the areas of the future Aqqaluk and Qanaiyaq Pits;
- Main Waste, Oxide, and Low Grade Ore stockpiles;
- Middle Fork Red Dog Creek, Rachel Creek, Connie Creek, Shelly Creek and Sulfur Creek;
- Red Dog Creek diversion channel and culvert, and the associated Shelly Creek diversion pipe and Connie Creek diversion channel; and
- Minewater diversion dam, mine sump, and piping to the tailings impoundment.

The “Red Dog Mine Development Plan” (TCAK, 2004) has identified sufficient resources to support mining until the year 2031. Figure 2.1.2 summarizes the planned ore and waste production from each pit. The complete development plan is included in Supporting Document B1. (The units used in the development plan are metric tons, normally written as “tonnes”, which is the standard unit used in mine planning. One tonne is equivalent to 1.1 tons, meaning that “tonnes” are about 10% heavier than the “tons” used in this report.)

Figure 2.1.3 shows the mine area layout as it would be at the end of operations in 2031. The 2031 layout takes into account both the continued mine and waste pile development and the progressive reclamation measures discussed in the following sections of this report.

The Red Dog Mine Development Plan is based on 2004 estimates of long-term metal prices and operating costs. Changes in metal prices or operating costs may affect future plans. For example, the Aqqaluk deposit continues north of the currently estimated pit limits, and future increases in metal prices could lead to further expansion in that direction, resulting in additional waste rock and tailings. Conversely, lower metal prices or higher operating costs could result in the planned third and fourth phases of the Aqqaluk pit being curtailed. It is expected that future updates to this Closure and Reclamation Plan will address any implications of such changes.

#### 2.1.2 Pits

##### *Main Pit*

The Main Pit is the site of current mining at Red Dog, and mining is expected to continue there until 2012. The geology of the Main Pit has been extensively discussed elsewhere, for example in “Red Dog Mine Site Current Conditions” (TCAK, 2002). Figure 2.1.4 shows a plan view of the Main Pit at the end of its production in 2012. At that time, the pit will extend over a plan area of

approximately 150 acres, and its deepest point will be at elevation 450 feet above mean sea level. The volume-elevation curve for the completed pit is shown in Figure 2.1.5.

The stability of the Main Pit walls is regularly assessed during mine planning. Current design slope angles range from 41° to 47°. Figure 2.1.6 shows the rock types that will be exposed in the end of production pit walls. However, the mine plan calls for Aqqaluk and Qanaiyaq waste rock to be placed into Main Pit, almost entirely covering the pit walls by 2031 (see Figure 2.1.3). Pit wall stability and geochemical reactivity are therefore expected to be of little concern at closure.

Waste rock from the Main Pit will be deposited on the Main Waste stockpile, as discussed in Section 2.1.3 below. The management of water around and in the Main Pit is discussed in Sections 2.1.4 and 2.1.5 below.

#### *Aqqaluk Pit*

The Aqqaluk Pit is expected to be opened in 2010, with ore production commencing in 2011 and continuing until 2031. The current understanding of the Aqqaluk Pit geology is summarized in Supporting Document B1. Figure 2.1.7 shows the planned phases of development of the Aqqaluk Pit. The ultimate pit will cover a plan area of 115 acres, and the deepest point of the pit will be at elevation 425 feet. The volume-elevation curve for the ultimate pit is shown in Figure 2.1.8.

The current mine plan assumes pit wall design slopes of 41° to 47°. That value will be refined on the basis of additional drilling, and refined again after mining begins to expose pit walls for direct inspection. The rock types expected to be exposed in the ultimate pit walls are shown in Figure 2.1.6.

#### *Qanaiyaq Pit*

The current mine plan calls for ore production from the Qanaiyaq Pit to begin at a very low level in 2016, and to be more significant during the period 2021 to 2025. However, investigation of the Qanaiyaq deposit is far from complete. Additional ore and geotechnical drilling, metallurgical testing and geochemical studies are needed before the pit design and mine scheduling can be finalized.

Figure 2.1.9 shows the current proposal, with the final pit covering a plan area of 42 acres, and the deepest point at elevation 1075 feet. The associated volume-elevation curve is shown in Figure 2.1.10. The configuration conservatively assumes pit wall design slopes of 37°. There is insufficient information to create a map of the pit wall geology.



### 2.1.3 Waste Rock and Ore Stockpiles

#### *Main Waste Stockpile*

The Main Waste stockpile currently covers roughly 190 acres and contains 17,000,000 cubic yards or 33,000,000 tons of waste rock, i.e. rock with metal contents that are too low for economic processing. By 2031, the Main Waste stockpile is predicted to cover 275 acres and contain 31,000,000 cubic yards or 62,000,000 tons of waste rock.

Figure 2.1.11 shows the Main Waste stockpile at the end of production in 2031. The highest bench of the Main Waste stockpile will be at elevation 1300 feet. The upper bench will be lower in the southwest corner to avoid interference with the flight envelope for the airport, which is just over a mile to the south.

Waste rock deposition on the southern half of the Main Waste stockpile is expected to be completed by 2008. Progressive reclamation of that area will be initiated in 2009, and will consist of local regrading, construction of a two-layer soil cover, and revegetation. Waste rock deposition on the northern half of the Main Waste stockpile will cease by 2012, and progressive reclamation could begin thereafter. However, the need for continued access to the Qaniyaq deposit may delay progressive reclamation in at least part of that area. Figure 2.1.11 shows the areas that can certainly be progressively reclaimed by 2031. Details of the reclamation methods are discussed further in Section 3.1 below. Other details are included in Supporting Document B2, "Plan of Operations for Waste Rock Management", and Supporting Document I, "Monitoring Plans".

The stability of the Main Waste stockpile was assessed as part of the initial designs in 1987, and reassessed in 1997 and 2002. Supporting Document C1 presents a summary of those assessments. Golder Associates (2003) presented analyses of a hypothetical "ultimate dump", with angle of repose slopes and maximum elevations of 1315 feet at the north end and 1575 at the south end. They found that configuration to be stable under static loading and under the design operating earthquake of 0.05 g, even with very high pore pressures at the toe. They also assessed stability of a re-sloped "ultimate dump", under the drained conditions that they expected to prevail over the long term, and found it to be stable even under the Maximum Credible Earthquake of 0.1g.

The geochemistry of the Main Waste stockpile is reviewed in "Consolidation of Studies on Geochemical Characterization of Waste Rock and Tailings" (SRK, 2003), and in "Supporting Geochemical Review and Interpretation" (SRK, 2005), which are included as Supporting Documents D1 and D2. The key conclusions are that the majority of waste rock in the Main Waste stockpile weathers rapidly and either already generates acid or has the potential to generate acid. Seepage water quality is discussed in Section 2.1.6 below.

### *Main Pit Stockpile*

Figure 2.1.12 shows the Main Pit stockpile in 2031. The backfilled Main Pit is expected to cover approximately 150 acres and contain 55,000,000 cubic yards, or 104,000,000 tons of waste rock.

The majority of the rock in the Main Pit stockpile will come from Aqqaluk Pit. The Aqqaluk waste will be segregated and about 26,000,000 tons of the most strongly acid generating rock (as defined by a sulfide sulfur content of greater than 6% will be placed in the base of the Main Pit, below elevation 850 feet, where it will eventually be flooded by groundwater. Units of unreactive or less reactive rock will also be identified and segregated for use in tailings dam raises and cover construction.

The remainder of the Main Pit stockpile will consist of approximately 63,000,000 tons of Aqqaluk waste and 13,000,000 tons of Qanaiyaq waste. The Aqqaluk waste can be characterized from the available drillhole data. Roughly half of it is expected to be strongly acid generating and the remainder either less acid generating or neutral. Further details are provided in Supporting Document D3, "Aqqaluk Geochemistry – Supplemental Testing". The Qanaiyaq waste cannot be as accurately characterized, but is expected to be dominated by strongly acid generating material. Currently, the Red Dog Development Plan calls for the Qanaiyaq waste to be placed on the top of the Main Pit stockpile, where it will cover about half of the upper dump surface. However, further characterization of the Qanaiyaq waste may indicate that it would be preferable to encapsulate it in less reactive Aqqaluk material. Those details will be assessed further in later revisions of this plan.

No stability assessments have been completed on the Aqqaluk waste rock. Based on the geology, it is expected to be very similar to rock in the Main Waste stockpile, and slopes have been designed accordingly.

### *Oxide Stockpile*

The Oxide stockpile contains approximately 2,200,000 cubic yards or 4,200,000 tons of material, and covers about 30 acres. The oxide material is sometimes referred to as oxide ore, because it has a high metal content. However, it cannot be processed in the current sulfide flotation system.

The Oxide stockpile was constructed near the crest of the ridge that separates the catchment of the Middle Fork Red Dog Creek from that of the tailings pond. The stockpile was laid out and constructed to remain on the tailings side of the divide. A zone of impacted vegetation on the eastern side of the ridge is evidence that some of the runoff from the stockpile construction flowed in that direction.

The Oxide stockpile is now largely surrounded by other waste rock and is not expected to receive any further material. Progressive reclamation will begin in 2008, subject to coordination with small scale cover tests that were initiated in 2007. The progressive reclamation will include regrading, construction of a soil cover, and revegetation. The work will allow a full scale test of cover

construction, and will be monitored so that a revised cover design can be available for the progressive reclamation of the Main Waste stockpile.

#### *Low Grade Ore Stockpile*

Currently, the Low Grade Ore stockpile contains approximately 950,000 tons of material, and covers about 16 acres. The mine plan predicts that an additional 7,700,000 tons of low grade ore will be mined from the Aqqaluk deposit, and 660,000 tons from Qanaiyaq, for a total of about 9,400,000 tons or 4,300,000 cubic yards. If the low grade ore can be economically processed, it will be. However, at currently forecasted metal prices and processing costs, the low grade ore would not be processed. The safe assumption for the closure plan is that the Low Grade Ore stockpile will need to be closed and reclaimed.

#### *Ore Stockpile*

To provide a consistent supply of ore to the mill, ore stockpiles are created and consumed as needed. All ore stockpiles are expected to be completely processed prior to closure.

### **2.1.4 Red Dog Creek Diversion**

The main drainage through the mine area is the Middle Fork Red Dog Creek. Tributaries that enter the Middle Fork through the mine area are Rachel Creek, Connie Creek, Shelly Creek and Sulfur Creek.

Flow is conveyed through the mine area in the Red Dog Creek diversion, the components of which are shown in Figure 2.1.13. The first section of the diversion starts below Hilltop Creek and was initially contained within a 3,700-foot long lined channel around the east of the Main Pit. This section was converted to a 72-inch and 96-inch diameter, heat-traced culvert in 2007 due to glaciation problems with the existing installation. The second section is a 1,870-foot long, 96-inch diameter, heat-traced culvert that runs between Main Pit and the Aqqaluk deposit. The third section is a 3,200 foot long lined channel that runs from the culvert mouth to the Red Dog Creek diversion dam, where the flow re-enters the original streambed. Intake weirs and/or pipelines direct Middle Fork, Rachel, Connie and Shelly Creeks into the first section of the diversion. Sulfur Creek enters the third section. A discussion of the 2004 modifications to the diversion is provided in Supporting Document E3, "Red Dog Creek Rediversion Design Criteria and Plan" (TCAK, 2004).

The diversion is designed to pass the estimated 100-year flows, increased by a safety factor of 1.3. Details of the flow estimates are provided in "Flood Frequency Update for Middle Fork Red Dog Creek" (PN&D, 2002), which is included in Supporting Document E2.

As a result of the 2004 modifications, the diversion is located in an alignment that will be adequate until 2020. At that time, about 1,700 feet of the culvert will have to be relocated southwards in order to allow deepening of the Aqqaluk Pit.

## 2.1.5 Minewater

Water that enters the Main Pit becomes contaminated with suspended solids, dissolved solids (TDS), and metals. The contaminated water is collected in sumps within the pit and pumped to the minewater collection sump, from where it is pumped to the tailings pond. Figure 2.1.14 shows the components of the minewater collection system. The pipelines carrying water from the minewater collection sump to the tailings pond include secondary containment.

Other sources of water entering in the minewater collection system are:

- Hilltop Creek, which drains the east side of the ridge below the Oxide stockpile and the Qanaiyaq deposit;
- Areas downstream of the diversion intake points for Connie Creek and Shelly Creek;
- The Aqqaluk Pit area;
- Leakage from the Red Dog Creek Diversion; and
- The main haul road and truck run-out, located above and to the south of the mine sump.

Hilltop Creek is connected to the minewater system by a ditch. Almost all of the water from the Connie and Shelly Creek diversions joins the Red Dog Creek diversion. Small areas above the confluences of Connie Creek and Shelly Creek with the Red Dog Creek Diversion are not captured. Drainage from those areas passes via french drains under the diversions and into the Main Pit. Sulfur Creek runs through the potential area of disturbance associated with Aqqaluk Pit, and channel enhancement or a small diversion may be required to ensure that the creek does not enter the pit. Other water from the Aqqaluk area already enters the Main Pit minewater collection system via french drains that pass under the Red Dog Creek diversion. The Red Dog Creek Diversion is at all points higher than the minewater collection system, so that any leakage from the former finds its way to the latter.

A total of eight pumps are available at the minewater collection sump to pump water up to the tailings pond. June to September flows average 2,100,000 gallons per day (gpd). Two of the pumps are configured for winter operation, when flows average 310,000 gpd. The total annual flow from the minewater sump averages about 0.38 billion gallons.

Typical contaminant concentrations in the minewater since 1998 were 8,000 ppm TDS, 5,000 ppm sulfate, 1,700 ppm zinc and 600 ppm iron. Average concentrations in 2004 were 9200 ppm TDS, 7000 ppm sulfate, 1550 ppm zinc and 700 ppm iron. Figure 2.1.15 presents water quality data collected since 1998.

Details of minewater collection from the Aqqaluk Pit and Qanaiyaq Pit have not been planned. Surface runoff from both the Aqqaluk and Qanaiyaq deposits is already being collected, and development of the pits is not expected to significantly increase the volume of contaminated water. There could be slight increases from pit groundwater and from disturbed areas around the pits.

## 2.1.6 Waste Rock Seepage

Seepage from the Main Waste stockpile is either collected in sumps and pumped to Water Treatment Plant #3, or is allowed to flow directly into the tailings pond.

Estimates derived from water balance calculations suggest that the total annual seepage flow from the Main Waste catchment is 0.18 billion gallons. That catchment includes the Main Waste stockpile, the Low Grade Ore stockpile, the Oxide stockpile and portions of the Qanaiyaq deposit.

Seepage flows and water quality have been monitored at the locations shown in Figure 2.1.16. Flow measurements have been made since 2003, but have been difficult due to the extreme freshet peaks. To date, the total annual flow measured in the seeps is less than the 0.18 billion gallons predicted from the water balance.

Figure 2.1.17 shows contaminant concentrations in the monitored seeps. Samples have been collected sporadically since 1998, and regularly since 2003. Typical contaminant concentrations over the period of monitoring were 14,000 ppm TDS, 9,500 ppm sulfate, 2,700 ppm zinc and 450 ppm iron. In 2004, flow-weighted average concentrations were 17,000 ppm TDS, 11,500 ppm sulfate, 3,400 ppm zinc and 400 ppm iron.

## 2.2 Tailings Area

### 2.2.1 General Layout and Basin Bathymetry

The tailings impoundment is located in the valley below the Main Waste stockpile. Figure 2.2.1 shows the layout of the impoundment, along with topography and bathymetry from 2004. A volume-elevation curve for the impoundment has been generated from a combination of topographic and bathymetric surveys. The combined volume-elevation curve is shown in Figure 2.2.2.

### 2.2.2 Tailings

#### *Tailings Physical Properties*

The specific gravity of the tailings solids has been estimated at 2.93, based on composite samples generated from Main Pit ore. The grain size ranges from 6 to 120 microns, with 80% less than about 70 microns. Figure 2.2.3 shows typical particle size distributions.

The Aqqaluk and Qanaiyaq ores are expected to result in tailings with a slightly higher specific gravity. However, the Main Pit values result in more conservative (higher) estimates of volume requirements, and therefore are used for the calculations herein.

As shown in Table 2.1, the *in situ* dry bulk density of the tailings, after deposition, settling, and some consolidation, has been estimated from bathymetric surveys to range from 94.3 to 98.6 pcf. The lowest estimate of 94.3 pcf was derived from the most recent bathymetric data and is therefore adopted herein. Combining that value with the specific gravity leads to an estimated *in situ* void ratio of 0.94.

**Table 2.1: Geochemical Characteristics of Tailings Samples**

Sample	Description	Analytical Results										Calculated S-Forms					Acid-Base Account			
		Paste pH	TIC ppm	CO <sub>3</sub> - NP kg/t	Pb %	Zn %	Ba %	Cu %	Sulfur S,%			BaSO <sub>4</sub> S,%	ZnS S,%	PbS-SO <sub>4</sub> S,%	SO <sub>4</sub> S,%	FeS S,%	AP	NP	NNP	NP/AP
RDP1-48	0 to 40'	6.8	791	7	2.4	5.14	6.9	-	9.65	0.18	9.47	1.61	2.52	0.37	0.18	4.97	155	9.4	-146	0.060
RDP1-49	Beach	5.9	136	1	2.6	5.55	7.7	-	12.76	0.62	12.14	1.79	2.72	0.40	0.62	7.24	226	0.4	-226	0.002
RDP1-50	June 1997 Composite	6.2	436	4	2.1	3.59	5.3	-	11.11	0.27	10.84	1.22	1.76	0.32	0.27	7.53	235	8.0	-227	0.034
Red Dog Tailings	July 1998 Composite	6.5	450	4	1.6	3.20	3.1	0.016	10.30	0.11	10.19	0.71	1.57	0.24	0.11	7.67	240	1	-238	0.005
Stockpile 150	Tailings	-	-	-	2.0	4.60	-	-	16.00	-	-	-	2.25	0.31	-	-	-	-	-	-
Stockpile 152	Tailings	5.5	-	-	1.4	5.40	-	-	14.00	0.20	13.80	-	2.64	0.22	0.20	-	-	2	-	-

Notes:  
 A sample labeled RDP1-47 was indicated as tailings by Schafer (1997) but is not shown in this table as it is believed to have been mislabeled in the field  
 TIC - Total Inorganic carbon (carbonate)  
 WA - Weak acid (HCl) soluble  
 AP - acid potential calculated from S as FeS  
 NP - Neutralization Potential  
 NNP - NP-AP

**Table 2.2: Tailings Bulk Densities Estimated from Bathymetric Surveys**

Deposition period	Dry weight	Volume	Percent solids by weight <sup>a</sup>		Dry bulk density	Void ratio <sup>d</sup>
	(tons)	(yd <sup>3</sup> )	(incr.) <sup>b</sup>	(cum.) <sup>c</sup>	(pcf)	(cum.)
01/01/90 -> 07/31/94	4,990,000	3,850,000	76.4%	76.4%	96.1	0.91
08/01/94 -> 07/15/95	1,700,000	1,250,000	78.2%	76.8%	97.4	0.88
07/16/95 -> 06/15/96	1,450,000	1,080,000	77.7%	77.0%	97.4	0.88
06/16/96 -> 07/15/97	1,580,000	1,360,000	72.4%	76.2%	95.5	0.92
07/16/97 -> 07/14/99	3,370,000	2,270,000	81.5%	77.5%	98.6	0.85
07/15/99 -> 10/02/01	4,950,000	4,400,000	71.0%	75.6%	94.3	0.94

Notes: a. Percent solids = weight solids / (weight solids + weight water)  
 b. Incremental values are for tailings produced during the period  
 c. Cumulative values are for the entire tailings production to the end of the period  
 d. Void ratio = volume of voids / volume of solids

*Tailings Tonnage, Volume and Surface Elevation*

As of May 2006, the tailings impoundment contained an estimated 27,400,000 tons, or 21,500,000 cubic yards, of tailings. As can be seen from Figure 2.2.2, if that volume of tailings was uniformly distributed in the basin, it would rise to a “struck-level” elevation of approximately 912 feet. The total tailings tonnage to be produced from May 2006 to the end of mine life is 59,600,000 tons, leading to a total tonnage of approximately 87,100,000 tons. That tonnage is used for the calculations and discussions presented herein. To accommodate that tonnage at a density of 94.3 pcf, would require a volume of 68,400,000 cubic yards, and the final struck-level tailings surface would need to be at elevation of 975 feet.

Table 2.3 shows the sensitivity of this estimate to changes in the assumed tonnage and density. The estimate is also sensitive to uncertainties in the volume-elevation curve. For example, volume-elevation estimates developed from the original, 2004 and 2006 bathymetry differ by about two feet.

**Table 2.3: Estimated Final Tailings Elevation for Different Tonnages and Densities ( $\rho_b$ )**

Total Tailings Production (tons)	Final “Struck-Level” Elevation (feet)		
	$\rho_b=94.3$ pcf	$\rho_b=96.8$ pcf	$\rho_b=99.0$ pcf
78,300,000 <sup>c</sup>	968	967	965
82,700,000 <sup>c</sup>	972	970	969
87,100,000 <sup>a</sup>	975	973	972
91,500,000 <sup>c</sup>	978	976	975

Notes: a. Current estimates.  
 b. Dry bulk densities estimated from bathymetry vary over this range. Increases in the tailings specific gravity, related to changes in the ore, could also lead to increased densities.  
 c. Changes in the mine plan could lead to changes in the total tailings tonnage.

### *Tailings Geochemistry*

Previous studies of the geochemistry of the Red Dog tailings were summarized in Supporting Documents D1 and D2. The key conclusions of the two reports with respect to the tailings are:

- Zinc contents range from 2.4 to 6.2 weight percent, lead contents from 1.2 to 2.8 weight percent, and iron contents from 4.6 to 11.4 weight percent.
- Total sulfur contents range from 9.65% to 16% (as S). Soluble sulfate, barite ( $\text{BaSO}_4$ ) and galena and anglesite ( $\text{PbS-SO}_4$ ) account for roughly one-quarter of the sulfur. Sphalerite accounts for roughly another quarter, and pyrite accounts for the remainder.
- Comparison of the acid generation and neutralization potentials indicates that the tailings are overwhelmingly acid generating. The acid generation potential is between 155 and 240 kg  $\text{CaCO}_3$ /tonne. The neutralization potential ranges from 0.4 to 9.4 kg  $\text{CaCO}_3$ /tonne.
- Humidity cell tests show evidence of preferential sphalerite oxidation. On a molar basis, zinc release was initially higher than iron release. Zinc release remained steady for about a year, with iron release slowly increasing. Leachate pH was strongly acidic during this period, dropping to less than 3 as iron release increased. After about a year, the sphalerite was depleted and zinc release suddenly decreased. Iron release increased at the same time. These observations are consistent with a galvanic interaction promoting the oxidation of sphalerite and delaying the oxidation of pyrite.
- The delay of pyrite oxidation also creates a delay in the release of sulfate and acidity. The reason is that sphalerite oxidation produces less sulfate and less acidity than pyrite oxidation. In the humidity cell tests, the sulfate release rate increased by a factor of about 2.7 when the sphalerite was depleted, and the acidity release rate increased by about the same factor. However, as explained further in Section 4.2 below, these effects will not affect water treatment requirements.
- Maintaining a water cover over the tailings is an effective means to restrict oxidation and acid generation.

Table 2.3 summarizes the measurements of tailings geochemical properties reported in Supporting Document D1.

### **2.2.3 Tailings Pond**

The tailings pond is a component of the NPDES “treatment works” and currently holds approximately 20,000,000 cubic yards, or about 4 billion gallons, of free water. The volume fluctuates seasonally. Inflows occur throughout the year, but are dominated by the spring freshet, which adds roughly 1 billion gallons to the pond each freshet. Discharge of roughly 1.3 billion gallons per year of treated water is the dominant outflow, but occurs only during the open water season. There is a requirement to maintain a freeboard of five feet below the crest of the Main Dam. There is no emergency spillway.



The pond water is mildly acidic, with a pH of around 5. TDS and sulfate levels vary seasonally, but average TDS concentrations have risen from about 3200 to about 4200 ppm since 1998, and average sulfate concentrations have risen from 2000 to 3000 ppm over the same period. Zinc concentrations fluctuate seasonally between 200 and 400 ppm, with 350 ppm a typical average. Iron concentrations are typically less than 10 ppm.

Figure 2.2.4 shows the expected limits of the tailings and the overlying water at the end of mining in 2031. The sources of water and contaminant inputs to the tailings pond, and the implications for future operations, are discussed further in Section 2.3 below and in Supporting Document B3, “Plan of Operations for Tailings and Water Management”.

Ditches are currently in place in four locations to route clean water away from the tailings pond. The clean water diversions are shown in Figure 2.2.5.

- Diversion Ditch 1 (DD-1) takes water from a draw on the slope above the west shore of the pond and diverts it into the small catchment immediately west of the South Fork.
- Diversion Ditch 2 (DD-2) captures water from south of the DD-2 laydown area and routes it to the west end of the Overburden stockpile.
- Diversion Ditch 3 (DD-3) extends DD-2 past the south end of the Overburden stockpile.
- Diversion Ditch 4 (DD-4) captures additional water from the slope above the west shore of the pond and routes it into DD-1.

## 2.2.4 Main Dam

### *Construction History*

At the northern end of the impoundment is the Main Dam, which is currently a maximum of 182 feet high and has a crest length of approximately 2600 feet. The dam has been constructed in eight stages, a starter dam (Stage I) and seven raises (Stages II to VII-B). Stage VII was designed as two five-foot raises. The second, known as Stage VII-B, was completed in 2007 to raise the dam crest to its current elevation of 960 feet. The construction dates and crest elevation associated with each raise are shown in Table 2.4.

**Table 2.4: Main Dam Construction Stages**

Dam Stage	Year	Crest Elevation <sup>a</sup>	Maximum Height <sup>a</sup>
Stage I (Starter Dam)	1989	865 feet	87 feet
Stage II	1990	890 feet	112 feet
Stage III	1990	910 feet	132 feet
Stage IV	1991	925 feet	147 feet
Stage V	1993	940 feet	162 feet
Stage VI	1993	950 feet	172 feet
Stage VII-A	2003	955 feet	177 feet
Stage VII-B	2005-2007	960 feet	182 feet

Notes:

a. Reported elevations are to the top of the liner. Actual crest elevations are roughly 1 foot higher.

*Foundation Conditions and Dam Components*

A history of the construction of the Main Dam has been completed and is included in Supporting Document C3. Supporting Document C2 also includes selected drawings from recent geotechnical investigations. Additional information on permafrost and groundwater is available in the reports published under the Supplementary Environmental Program (Water Management Consultants, 1999, 2001).

The following points summarize key information from those sources:

- Foundation conditions below the dam include alluvial deposits varying in thickness from 4 to 8 feet, and consisting of moderately graded silt, sand and gravel with occasional cobbles, overlying moderate to highly weathered shale with apparently non-continuous zones of clay gouge. An unfrozen talik was initially present along the creek alignment. The talik has grown wider and deeper and is predicted to reach a maximum width of about 800 feet if thawing continues. The thawed zone connects to subpermafrost groundwater, but the subpermafrost groundwater is isolated by a combination of impermeable geologic structures and the permafrost, and does not flow.
- Similar foundation materials occur in the left (west) abutment, but with competent shale bedrock under the Stage IV raise and moderately weathered shale bedrock under the Stage VII raise.
- In the right (east) abutment, colluvium overlies the highly weathered shale. The colluvium is typically about 5 feet thick, and consists of silty sandy gravel. Foundation conditions are more variable further to the east, below the Stage VII-B extension, with zones of fill up to about 20 feet in thickness, and fill up to greater than 25 feet in thickness. The fill consists of well-graded gravel and sand with cobbles. Recent data collected from thermistor TDAM T15, near the right abutment, indicates that permafrost has thawed to a depth of about 60 feet. Bedrock in the abutment includes zones of poorly durable black shale, with competent siltstone to the east of the current crest.

- The body of the Main Dam is a zoned rockfill structure constructed primarily with competent and durable material obtained from the mill site, the DD2 borrow pit, and from mining in the Main Pit. The Stage IV raise also included zones of Kivalina shale, and blended Kivalina and Okpikruak shale. All raises have been by downstream construction.
- The upstream face of the dam is covered with 100-mil HDPE geomembrane. The geomembrane is underlain by a thickness of 1 foot of bedding consisting of rock crushed and processed to less than 1 inch. Below the bedding is a 16-oz. non-woven geotextile underlain by 8 feet of filter drain consisting of rock crushed to less than 3 inches. Below the drain rock is a second 10-oz. non-woven geotextile underlain by 12 feet of <12 inch rockfill. The HDPE geomembrane is covered with two protective layers, consisting of 1.6 feet rock crushed and processed to less than 1 inch, and 6.4 feet of random rockfill. (The layer thicknesses are here expressed as vertical depths.)
- Along the upstream toe of the dam, the geomembrane continues into a cut-off system. During the Stage I construction, a wide cut-off trench was excavated. The depth of excavation was much greater than originally planned, so the design was changed in subsequent raises. The design for Stages II through VI called for a cut-off trench to be excavated to a depth of 30 feet below the ground surface, and a much narrower cut-off wall to be excavated to a depth of either 4 feet or to competent bedrock, whichever was greater. The geomembrane was inserted through the trench and into the cut-off wall excavation. Review of the construction records demonstrated that the cut-off wall was built according to the design in Stages II through IV, but that no cut-off wall was built in Stages V and VI because it was intended that tailings would cover the face of the dam. The cut-off system for Stages V and VI was therefore constructed as part of the Stage VII-A and VII-B raises.
- A perforated drain pipe runs along the upstream toe of the dam, below the geomembrane, and collects any water that passes through. The pipe is connected to a gravel drain that runs under the dam along the base of the original valley. The gravel drain acts to keep the phreatic surface in the dam low. A seepage collection pond and pumpback system, located below the downstream toe of the Main Dam, are discussed in the following section.
- Tailings were placed to seal the upstream face of the dam starting in 1997, and a complete tailings beach was formed by 2000. Due to concerns about dust, the beach was allowed to become inundated over the period 2002 to 2004. A series of eight low rock berms were also constructed across the beach to act as windbreaks, and a surface sealant was applied where necessary. Seepage pumpback records indicate that the seepage rate decreased from about 600 to less than 100 gpm over the twelve months prior to August 2002, when the beach was not submerged. The implication is that the tailings beach contributes to seepage control. There are at least three possible mechanisms by which the beach reduces seepage rates: by forcing water to pass through a zone of low permeability tailings; by blocking the direct access of water to the random rockfill that is present above the geomembrane; or by keeping the pond away from permeable zones in one or both of the abutments.

- In the winter of 2005-06, a coffer dam was constructed along the tailings beach to ensure that a minimum 300-foot beach width will be maintained as the pond rises. The water treatment sand filters were also relocated from the east abutment to an area near the WTP1 and WTP2, to facilitate future extensions of the dam and cutoff wall.

### *Seepage Collection System*

A seepage collection and pumpback system is located about 250 feet downstream of the current toe of the Main Dam. The system consists of a pond formed by a lined Seepage Dam, which is less than 20 feet in height. Three pre-cast concrete pump chambers are set into the base of the pond, and each one is fitted with a vertical turbine pump. The pumps are connected via pipes and a manifold system to a 14-inch diameter HDPE pipe through which the seepage is transferred back to the tailings pond. The pipe includes secondary containment. Below the Seepage Dam is a secondary pumpback system consisting of a small sump and well. The secondary system captures escaped seepage and pumps it back to the primary seepage pond. One of the primary conclusions of the Supplementary Environmental Program was that the combination of primary and secondary systems effectively collects all of the seepage that passes through, under or around the Main Dam.

Water pumped back from the seepage collection system below the Main Dam comprises about 0.5 billion gallons per year. Roughly 97% of that is seepage that originates in the pond, and only the remaining 3% is a net input from surface runoff. However, the seepage is a net source of contaminants. It has shown declining pH, from consistently above 6 in 2000 to consistently below 6 since 2003. At the same time, alkalinity decreased from over 100 ppm CaCO<sub>3</sub> to near undetectable. Zinc concentrations currently range from 150 to 280 ppm, and iron concentrations from 10 to 100 ppm. Sulfate concentrations range from 1000 to 4000 ppm, but are typically 3000 ppm.

### *Future Raises*

As the impoundment fills with tailings, the Main Dam will need to be raised further. Water balance predictions indicate that the dam crest will need to reach elevation 970 feet sometime between 2009 and 2012, elevation 980 feet between 2017 and 2021, and the final elevation of 986 feet between 2024 and 2028. The wide ranges in dates result from uncertainty about future inflows to the pond. A series of very wet years would raise the pond level and necessitate the earlier raises. The later dates are based on the long-term average annual precipitation estimate of 20.7 inches/year. Note that all the estimated dam raise dates assume that at least 1.53 billion gallons per year can be discharged from WTP2. If actual discharges were lower, all the dates would be moved forward. Details of these calculations are included in Supporting Document B3.

A conceptual design for the ultimate Main Dam, with a crest elevation of 986 feet, has been prepared by URS Corporation (URS, 2007a) and is included in Supporting Document C4. Figure 2.2.6 shows a plan view of the final dam. A substantial extension will be needed where the dam passes over relatively flat ground to the east of the current structure. Figure 2.2.7 shows a typical section. The dam can continue to be raised by downstream construction, with additional liner placed on the

upstream face. The conceptual design report includes analyses of liner longevity, the potential for plugging of the underdrain, and the potential for earthquakes to cause settlement of the dam crest. Detailed analyses of stability and seepage through the raised dam are provided in separate reports (URS, 2007b, c), provided in Supporting Documents C5 and C6.

### **2.2.5 Back Dam**

The tailings pond is now above the lowest level of the natural divide with the Bons Creek catchment, and the process of constructing a “Back Dam” to keep the pond away from the divide is underway. A coffer dam was constructed in 2003 and 2004 to facilitate investigation and future construction along the northern toe of the Overburden stockpile. A drilling program to further investigate ground and permafrost conditions along the alignment of the proposed Back Dam was completed in 2004. Additional investigation was completed in the winter of 2005-06 and a complete design report was provided for State review in late 2006 (Golder Associates, 2006a, b). Selected drawings from these reports are provided in Supporting Document C7.

The Back Dam design report calls for an initial construction to elevation 960 feet, level with the Stage VIIb raise of the Main Dam. Figure 2.2.8 and Figure 2.2.9 show a plan, profile and section view through the proposed dam. The construction will commence with dewatering of the area between the coffer dam and the Overburden stockpile, followed by excavation of ice rich and organic soils from along the toe. Select fill will be placed and compacted to construct the dam core to elevation 960 feet and rockfill will be placed and compacted along the flanks. A cutting tool will then be used to cut a narrow trench through the center of the dam and the underlying material, penetrating to competent bedrock. The trench will be filled with a low-permeability material to form a cutoff wall. The design report provides further details and includes draft construction drawings as well as stability and seepage analyses (Golder Associates, 2006b).

The Back Dam design report also includes a conceptual design for a future raise of the dam (Golder Associates, 2006b). The conceptual design calls for additional waste rock to be placed to raise the dam crest to elevation 986 feet. A cutoff wall would then be constructed from the new dam crest, to connect with the initial cutoff wall. Figure 2.2.10 shows the conceptual design of the Back Dam raised to elevation 986 feet. Back Dam construction to elevation 970 feet is currently planned for 2009.

### **2.2.6 Overburden Stockpile**

The southern end of the tailings impoundment is currently defined by the Overburden stockpile. The Overburden stockpile has a plan area of 60 acres and a volume of 6,600,000 cubic yards. The tonnage of material deposited there was not recorded, but can be estimated from the volume to be somewhere between 10,000,000 and 11,000,000 tons.

The material in the Overburden stockpile consists of highly weathered but relatively non-mineralized waste rock, stripped organic materials, and materials excavated from the tailings and mill site areas during construction. A survey of the stockpile surface in 2006 found it to be approximately 35%

Kivalina shale, 25% Mélange, 20% Ikalukrok shale, 10% Okipikruak shale, and 10% Siksikpuk shale. Roughly 50% of the surface had zinc concentrations of less than 500 ppm, and another 25% had zinc concentrations less than 1000 ppm. Out of 21 samples, only one had a zinc concentration greater than 2000 ppm.

The Overburden stockpile straddles the divide between the tailings impoundment and Bons Creek, and reaches a maximum elevation of about 1020 feet. Prior to the stockpile construction, the lowest point of the divide was at an elevation of approximately 937.5 feet. There is a system of ditches, sumps and wells on the Bons Creek side of the Overburden stockpile. The system captures runoff from the Overburden stockpile, and pumps it back to the tailings pond.

The combination of direct runoff and seepage return from the Overburden stockpile sum to approximately 50 million gallons per year. Average zinc concentrations are less than 8 ppm, and average iron concentrations are less than 0.4 ppm. Sulfate concentrations are typically 1000 ppm.

## **2.3 Water Treatment and Discharge**

### **2.3.1 Water and Contaminant Load Balance**

Water and contaminant load balances for the entire site have been developed. The water balance consists of a series of calculations that track water flows across the site, from precipitation through treatment and discharge. The contaminant load balance is a similar series of calculations tracking contaminant loadings from their respective sources to the “treatment works”, which consist primarily of the tailings pond and the water treatment plant. The calculations, sources of inputs, calibration procedure and results are described in more detail in Supporting Document E1.

Figure 2.3.1 shows the catchments and sub-catchments considered in the water balance, and Figure 2.3.2 shows a schematic of the flow paths. Numbers on the schematic indicate average annual flows. The schematic shows that all of the impacted water on the site eventually ends up in the tailings pond. As discussed in Section 2.1, seepage from the Main Waste, Low Grade, and Oxide stockpiles contributes roughly 180 million gallons per year of water to the tailings pond, and mine water from the mine sump adds another roughly 400 million gallons per year.

Contaminant concentrations from the mine area sources are also summarized in Section 2.1. Figure 2.3.3 and 2.3.4 show contaminant load balances for an average year. Load balances were developed for all of the major contaminants in the tailings pond water. Sulfate is shown in Figure 2.3.3 because it is a good analogue for both TDS and acidity. Zinc is shown in Figure 2.3.4 because of its importance to the water treatment system.

The water and contaminant load balances were also used to simulate future operations and conditions after closure of the site. Details of the simulations are provided in Supporting Document E1. Key conclusions related to water treatment and discharge requirements are highlighted in the following sections.

## 2.3.2 Water Treatment

Water from the mine and tailings areas is treated in three plants, located as shown on Figure 2.3.5. (Potable water and sewage treatment are discussed under “Mill Area and Infrastructure” below.)

Water Treatment Plant #1 (WTP1) treats water that is reclaimed from the tailings pond for use in the Mill. Approximately 3 billion gallons of water are treated each year in WTP1 when it operates continuously. Most of the treated water comes back to the pond with the tailings, but a small amount, about 1%, leaves the site as moisture in the concentrate. Although it does not result in a significant net removal of water from the pond, the WTP1 system is an important source of alkalinity. It treats all of the acidity in the reclaimed water and counteracts any additional acidity provided by the ore.

Water Treatment Plant #2 (WTP2) treats water from the pond for discharge during the summer months via Outfall 001. About 60% of the water treated by WTP2 is released at Outfall 001. The remainder is returned to the pond along with the treatment sludge and filter backwash.

Water Treatment Plant #3 (WTP3) treats water from the mine sump and waste rock seepage before it enters the tailings pond. It operated for the first time in 2006, and treated 100 million gallons from the mine sump and 11 million gallons of seepage from the Main Waste stockpile. With start-up difficulties now resolved, WTP3 is expected to treat more water in future years.

All three plants use a lime treatment process. Lime is added to the water to raise the pH and precipitate metal hydroxides and gypsum (calcium sulfate). WTP2 also includes sulfide addition to precipitate cadmium, and a sand filter system to remove suspended solids prior to discharge of water to Outfall 001. A review of water treatment methods was completed in 2004, and a complete report is included in Supporting Document E4. It concluded that lime addition is the preferred method of water treatment for the Red Dog site, and that water treatment efficiency could be improved by collecting higher strength water from the mine sump or Main Waste seepage and treating it prior to discharge into the tailings pond. The latter is now being implemented through WTP3.

A further upgrade of the site's water treatment capabilities will be necessary sometime around 2025, in order to reduce contaminant concentrations in the tailings pond prior to closure. A number of options remain under consideration, including direct liming of the pond, and various modifications to the WTP1, WTP2 or WTP3. Supporting Document E1 includes a simulation of the case where WTP3 is upgraded in 2025 to treat all of the flows from the Mine Sump, Main Waste stockpile seepage, and dam seepage.

### 2.3.3 Discharge of Treated Water

Treated water from WTP2 is discharged to the Middle Fork of Red Dog Creek at Outfall 001, which is also shown on Figure 2.3.5. The discharge is regulated by NPDES Permit AK-003865-2. Table 2.5 summarizes key conditions of the 2003 NPDES permit. A revised permit was issued in 2007 but subsequently withdrawn. A new permit is expected to be issued after the ongoing environmental review of the Aqqaluk pit extension plan is completed.

Since 1998, the total annual discharge at Outfall 001 has ranged from approximately 0.9 to 1.5 billion gallons. Historically, annual discharges have not kept pace with inflows, and the excess water has been stored in the tailings pond. During future operations however, it will be desirable to reduce the amount of excess water stored in the pond. The precise discharge requirements will depend on a number of things, most importantly the amount of precipitation.

A water balance simulation for a case where precipitation remains at the annual average level and pond volumes are reduced to post-closure levels by 2025 is presented in Supporting Document E1. The results are summarized in Figure 2.3.6, and indicate that annual discharges will need to average about 1.53 billion gallons per year between now and 2025.



**Table 2.5: NPDES Permit Conditions for Discharge at Outfall 001**

Parameter	Units	Daily Max	Monthly Avg.	Weekly Avg.	Frequency
Cadmium - total	ppb	3.4	2.0	-	1/week
Copper - total	ppb	43.7	15.1	-	1/week
Chromium - total	ppb	-	-	-	1/week
Lead - total	ppb	19.6	8.1	-	1/week
Manganese - total	ppb	-	-	-	1/week
Mercury - total	ppb	0.5*	0.5*	-	1/month
Nickel - total	ppb	-	-	-	1/week
Selenium - total	ppb	6*	6*	-	1/week
Zinc - total	ppb	257.3	119.6	-	1/week
Aluminum - total	ppb	-	-	-	1/ month
Iron - total	ppb	-	-	-	1/ month
Silver - total	ppb	-	-	-	1/ month
Total Suspended Solids (TSS)	ppm	30.0	20.0	-	1/week
Total Dissolved Solids (TDS)	ppm	†	-	-	
TDS Anions and Cations		†	-	-	
Cyanide Total	ppb	9*	9*	-	1/week
Fecal Coliform	#/100	-	200	400	1/ 2 month
Total Residual Chlorine	ppm	-	-	-	1/ month
Biochemical Oxygen Demand	ppm	-	-	-	1/ month
Total Ammonia (as N)	ppm	-	-	-	1/ week
Organic Priority Pollutant Scan		-	-	-	1/month**
Turbidity	NTU	-	-	-	1/ week
Temperature	C	-	-	-	Daily
Hardness (as CaCO <sub>3</sub> )	ppm	-	-	-	1/ week
Cumulative Flow	Gallons	***			Continuous
Whole Effluent Toxicity	TUc	12.2	9.7	-	
		Daily Max	Daily Min		
pH		10.5	6.0		1/week grab

Notes:

\* Interim limits are shown. Actual 2003 permit limits were as follows: Mercury - 0.5 ppb daily max and 0.5 ppb monthly average; Selenium - 5.6 ppb daily max and 4.9 monthly average; Cyanide Total - 9 ppb daily max and 4 ppm monthly average.

\*\* May, July and September only.

\*\*\* 2,418 billion gallons per year.

† TDS limits from the 2003 Permit are as follows:

3,900 ppm End of Pipe Limit

Outfall 001 Discharges must meet the following in-stream limits:

1,500 ppm in-stream limit @ edge of mixing zone in Main Stem Red Dog Creek

1,000 ppm in-stream limit @ Station 150

500 ppm in-stream limit @ Station 160 from July 25 to end of season

500 ppm in-stream limit @ Station 151 during Grayling Spawn (Condition remanded by the Environmental Appeals Board and awaiting a decision)

## **2.4 Ore Processing Area**

### **2.4.1 Process Overview**

A site plan of the ore processing area is shown in Figure 2.4.1. Ore throughput is approximately 10,800 tons per day of ore; annual concentrate production is about 1.38 million tons. The process flowsheet is shown in Figure 2.4.2.

### **2.4.2 Crushers**

Primary crushing operations involve both a gyratory crusher and a jaw crusher. The gyratory crusher is housed in a building with associated systems, including the apron feeder and drive assembly for the conveyor belt that transports crushed ore to the Coarse Ore Stockpile building. The older jaw crusher is located near the gyratory crusher and is operated when the gyratory crusher is down for maintenance. The jaw crusher is located in an enclosed building which also houses the feeder and related systems, and the drive system for the conveyor belt that transfers crushed ore to the COSB. Both crushers are equipped with baghouses to control dust.

### **2.4.3 Coarse Ore Stockpile Building**

The Coarse Ore Stockpile building (COSB) stores crushed ore prior to milling. It has a capacity of 16,500 tons and feeds conveyors that transport ore from the stockpile to the grinding circuit. The COSB and ore conveyors are completely enclosed. A baghouse to further control dust by creating a negative pressure in the COSB will be installed by the end of 2007.

### **2.4.4 Mill Complex**

The mill complex is enclosed. Inside the mill complex, crushed ore is subjected to primary and secondary wet grinding, lead and zinc rougher flotation and a regrinding operation, as well as lead and zinc cleaner flotation. In the primary grinding circuit, crushed ore is mixed with process water to form a slurry, which is wet-ground in semi-autogenous grinding (SAG) mills and ball mills that reduce the ore particle size to less than 65 microns.

Lead and zinc minerals are separated from the non-economic (gangue) minerals in the froth flotation circuits. Several stages of flotation are necessary to achieve high grade concentrate products with maximum recovery of economic minerals and an efficient separation of the lead and zinc minerals into their respective concentrates. The gangue minerals, referred to as tailings, are discharged in slurry form from the mill to the tailings impoundment for permanent storage.

### **2.4.5 Reagent Building**

The reagent building is located to the west of the mill and is connected to it by an enclosed walkway/utilidor. The building provides temporary storage and facilities to mix process reagents,

which are transferred to the mill via an enclosed utilidor. Reagents are mixed with water in mix tanks and transferred to day tanks from where they flow to holding tanks in the mill.

#### **2.4.6 Concentrate Storage Building**

Slurried lead and zinc concentrates are thickened and filtered to approximately 9% moisture and transported via an enclosed conveyor to a concentrate storage building (CSB) adjacent to the mill. Filtered concentrates of lead and zinc are stockpiled inside the building while awaiting shipment to the port site. The CSB is completely enclosed and has a storage capacity of approximately 35,000 tons of concentrate. Concentrate haul trucks enter the building along one side and are loaded with approximately 130 tons of concentrate by front end loaders operating inside the CSB. Haul trucks enter and exit the building through doors that are closed during loading. Concentrate is trucked about 52 miles from the CSB to the port site, on the Chukchi Sea, where it is stored in two larger CSB's while awaiting the summer shipping season.

### **2.5 Infrastructure**

Due to the remote nature of the site, the mine includes extensive support infrastructure. Figures 2.4.1 and 2.5.1 show the location of the facilities described below.

#### **2.5.1 Airstrip**

An asphalt airstrip capable of handling commercial jet aircraft is located approximately three miles south-southwest of the mill, in the Buddy Creek watershed. The airstrip is used year round to transport personnel, equipment, supplies and perishables to and from the mine site.

#### **2.5.2 Internal Roads**

A series of internal roads provide access to each of the major facilities on site.

#### **2.5.3 DD-2 Material Sites**

The DD-2 material sites are located to the northwest of the Overburden Stockpile, in the drainage area of the tailings impoundment. The two sites are approximately 1200 feet apart, connected by a road that runs along the western side of the tailings impoundment. Initially, both sites were used as borrow sites for non-mineralized construction rock. The northern site is still active, while the southern site, where suitable material was exhausted, is now used for storage of surplus equipment.

#### **2.5.4 Personnel Accommodations Complex**

The personnel accommodations complex, or PAC, is located adjacent to the mill and connected to it by an elevated, enclosed utilidor. The PAC houses up to 365 people and includes kitchen, laundry and recreation facilities.

### **2.5.5 ConPAC**

The construction personnel accommodations complex (ConPAC) is operated seasonally by contractors, as required, depending on construction and exploration activity. The camp is comprised of personnel living quarters, kitchen facilities, sewage and potable water treatment facilities, a backup generator and an equipment staging yard.

### **2.5.6 Services Complex**

The services complex is located on the mill site adjacent to the mill and CSB. The complex includes a warehouse, the analytical lab, the heavy equipment shop and offices for administrative personnel.

### **2.5.7 Powerhouses**

The powerhouses that provide electric power to the site are located on the mill site, adjacent to the mill and CSB. Eight diesel-fired generators, each rated at 5,000 kilowatts electrical output, are shared between the two powerhouses. The generators burn both No. 1 and No. 2 diesel fuel, in addition to small quantities of used oil for energy recovery. Heat is supplied to the mine site buildings by waste heat recovery units that utilize diesel engine cooling water and exhaust gas to heat a glycol/water mixture circulated by pumps. Three 650 kW diesel generators are installed to supply emergency power. In addition, there are three standby water/glycol heaters rated at 8,000,000 BTUs each to provide emergency heat in the event of a power failure.

### **2.5.8 Maintenance Shops**

Mine and mill maintenance shops service equipment used throughout the operation and by contractors. The mill maintenance shop is part of the mill complex. The mine shop, which services mobile equipment, is part of the services complex.

### **2.5.9 Bons Reservoir**

A fresh water reservoir and pumping system are located in the Bons Creek watershed near the airport. The reservoir was created by constructing a small dam across Bons Creek. The reservoir supplies water for drinking and other domestic uses as well as peripheral uses in the mill. The reservoir is filled during the summer by snow melt and precipitation. Fresh water is collected from the reservoir and pumped to the ConPAC and mill site through insulated, heat-traced pipe.

### **2.5.10 Potable Water Treatment Plant**

The potable water treatment plant provides drinking water for people working at the mine site. The plant treats raw water from the Bons Reservoir near the contractors' personnel accommodations complex and supplies potable water at an average rate of approximately 30 gpm. Treatment includes polymer (flocculent) addition, two-stage sand filtering and calcium hypochlorite (chlorine) disinfection. From the treatment plant holding tank, treated water is pumped to the personnel

accommodations complex (PAC), mill complex and services complex as well as to other small buildings within the mill site.

### **2.5.11 Sewage Treatment Plant**

The sewage treatment plant is located between the PAC and the mill. Domestic waste water is collected from the PAC, mill, and services complex and is processed and discharged to the tailings impoundment at an average rate of approximately 16,000,000 gallons per year. Average throughput is typically 30 gpm but this rate varies depending on time of day and camp population. Waste water treatment consists of solid/liquid separation and disinfection.

### **2.5.12 Explosives Handling and Storage**

Ammonium nitrate, emulsions, water gels, cast boosters, electric and non-electric caps and dynamite are stored in several specialized explosives storage units built on gravel pads throughout the mine site.

### **2.5.13 Laydown Yard**

The laydown yard, also known as cold storage, is located along the east side of the tailings impoundment about one mile from the mill, and is the major bulk materials storage facility at the site. The yard is used as storage for reagents, other mill supplies, large heavy equipment parts, drums packaged for off-site shipment, HDPE liners and other miscellaneous supplies that can tolerate freezing conditions. All materials except oversize items are stored inside shipping connexes, which are by design watertight.

### **2.5.14 Fuel Storage**

The Red Dog Mine consumes about 40,000 gallons of diesel fuel daily for power generation, equipment operation, and vehicle use. Fuel is shipped by barge to the port site during the summer and transported to the mine site daily in a 25,000 gallon tanker truck. Diesel is stored in two tanks (#3 and #4) located on a hill above the mill site. Tank #3 has a capacity of 1.1 million gallons and tank #4 has a capacity of 1.0 million gallons. A lined berm provides contingency for secondary containment.

### **2.5.15 Natural Gas Project**

Not shown on Figure 2.5.1 are the facilities associated with the Natural Gas Project, which is evaluating the feasibility of extracting shale-hosted methane gas. The facilities include a road, five drill pads for the well casings, pump shacks, a 7000-foot water line, and a pump station south of North Fork Red Dog Creek. Water from the exploration wells is pumped to Main Dam seepage collection pond. The future of the Natural Gas Project is uncertain at this time and these facilities are considered temporary.

### **2.5.16 Solid and Hazardous Waste Management**

Solid waste is managed in accordance with the requirements of the Resource Conservation and Recovery Act and the Alaska Solid Waste Management Regulations (18AAC60).

An incinerator is located along the east side of the tailings impoundment and north of the laydown yard, and is used for burning all putrescible wastes, drained oil filters and oily absorbent pads, paper and other combustible non-hazardous solid waste. One active solid waste landfill is located at the mine site, in the Main Waste stockpile.

The landfill is used for the disposal of incinerator and burn pit ash, construction waste and domestic garbage. The landfill is operated under permits specifying covering, grading, working face size, etc., and according to documented procedures. At the end of mine life, it would be closed in accordance with 18AAC60.

Hazardous wastes are disposed of offsite at permitted Treatment, Storage and Disposal Facilities (TSDF) regulated for handling hazardous wastes. Most liquids wastes are shipped offsite for disposal or recycling. Glycols are cleaned and/or recycled on site where possible. Used oil is mixed with diesel and burned onsite for energy recovery. By-products of the used oil recovery process are shipped offsite as used oil. Liquid wastes are stored in connexes prior to shipping offsite. Solid waste items shipped offsite, such as batteries, are stored in sealed containers and connexes prior to shipping.

### 2.5.17 Fugitive Dust Management

Fugitive dust emissions within the air permit boundary are controlled using a variety of methods, including enclosures and stationary dust control devices for coarse ore and concentrate handling areas, addition of palliatives and control of water levels for the tailings beaches, and watering and calcium chloride application for roads and laydown areas. TCAK has spent over \$15 million between 2001 and 2006 on facility upgrades to improve fugitive dust control, and more improvements are in the planning stages. While these measures have resulted in substantial reductions in fugitive dust emissions, there have been some impacts to vegetation and soil resulting from historical emissions.

In September 2005, TCAK entered into a *Memorandum of Understanding* (MOU) with the ADEC (<http://www.dec.state.ak.us/air/reddog.htm>) to set out the steps TCAK would take to better identify and understand:

- Potential historic and current sources of fugitive dust emissions at the Mine;
- Reasonable control measures that can be implemented to reduce these emissions over time;
- The likely source of the elevated metals in the tundra around the Mine; and
- The likely impact, if any, of these elevated metals concentrations over time.

The *Memorandum of Understanding* was also intended to provide the means for ADEC to coordinate its review and response to information regarding fugitive dust generated at the Mine, including both present and historical emissions. The MOU was restated and amended in 2007 to include an update of activities that occurred between 2005 and 2007, including completion of an ecological risk

evaluation for the area within the ambient air/solid waste permit boundary (see Section 4.6 and Supporting Document H).

A risk management plan is currently under development. The overall goal of the risk management plan is to minimize the potential for effects to human health and the environment from fugitive dust. This plan will also serve to integrate all of the dust related management and monitoring programs into one cohesive effort. As part of this effort, a workshop was held on March 25-27, 2008, in Kotzebue with a variety of stakeholders to share information about what is being done to address fugitive dust issues at the mine and to gather input from stakeholders for the development of the risk management plan. A draft of the risk management plan is anticipated in July 2008.

Air quality monitoring for lead at the mine site indicates full compliance with federal standards at the ambient air boundary. No mine site related impacts to air quality have been measured in Noatak and Kivalina, the two closest villages. Testing of blood lead levels in employees and local residents confirms the health and safety of the people have been protected (*Summary of Mine Related Fugitive Dust Studies*, TCAK 2005a).

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## 3 Closure and Reclamation Methods

### 3.1 Mine Area

#### 3.1.1 Overview

Figure 3.1.1 summarizes the proposed closure methods for the mine area. The methods are based on the “Complex Soil Covers” option selected through the consultation process described in Section 1.2. The primary objectives are:

- Limiting safety hazards and acid generation associated with the pit walls;
- Covering of the waste stockpiles to allow reclamation of the surface and limit the release of acidic drainage; and
- Keeping the clean water of Red Dog Creek away from contaminated water stored for treatment.

#### 3.1.2 Pits

The Main Pit would be nearly completely backfilled during operations with waste from the mining of Aqqaluk and Qanaiyaq Pits. Only the portion of the Main Pit to the east of the Red Dog Creek Diversion would remain open. The wide and accessible benches in that area would be covered and revegetated in the same manner as the waste stockpiles (see next section). The highwall along the eastern limit of the pit would be blasted back to a 4:1 slope to allow snow machine operators to see the pit wall in sufficient time to stop safely.

Aqqaluk Pit would be used as a contaminated water storage area. The contaminated water would be allowed to flood to elevation 750 feet. Remaining wide and accessible benches will be covered. A berm will be constructed to mark the high wall as a hazard for snow machines.

Qanaiyaq Pit will be left open and allowed to flood naturally. The small catchment of the pit means it is uncertain whether any water will accumulate. A berm will be constructed around the pit crest to denote the hazard.

#### 3.1.3 Waste and Ore Stockpiles

All stockpiles that remain uncovered at the end of mining will be covered at closure. As discussed in Section 2.1.3, the Oxide stockpile and portions of the Main Waste stockpile will be covered during operations. The remainder of the Main Waste stockpile, the Main Pit stockpile, and any unprocessed material in the Low Grade Ore stockpile will need to be covered after 2031. The main haul road, truck run-out and exposed pit benches would also be covered at that time. Figure 3.1.2 shows the cover requirements for the mine area.

Within each stockpile area that becomes available for covering, the first step will be to flatten slopes to an approximate overall angle of 3H:1V. The flatter slopes are needed to allow compaction of the

cover material. In most cases, the stockpiles will have been constructed at an overall 3H:1V slope, so only limited re-grading will be required.

The final slope angles would be varied where possible to provide more natural looking landforms, to incorporate swales that will collect surface runoff and channel it off the stockpile surfaces, and to minimize the need for engineered channels. Figure 3.1.3 shows an example of what the re-shaped stockpiles might look like. However, final landform engineering will only be possible after each stockpile area is completed.

The current cover design and cost estimate assume a cover consisting of two 18-inch layers of weathered shale, as shown in Figure 3.1.4. The design is based on investigations carried out by O’Kane Consultants using samples from the Overburden stockpile. A summary of this work is provided in Supporting Document F1. An additional consideration in the selection of cover materials was the lack of other borrow sources in the area. Supporting Document F2 includes a memorandum summarizing borrow source investigations.

Okpikruak and unmineralized Kivalina shale from the Main and Aqqaluk deposits will have been segregated during mining, and stockpiled for use as cover material. For this purpose, the term “unmineralized” is provisionally defined as non-acid generating with an average zinc content of less than 0.1%. That definition may need to be revised as more experience is gained with the sampling, analysis and stockpiling of “unmineralized” material. Portions of the Overburden stockpile may also be used as cover material, if they are not required as part of the Back Dam and if they can be shown to meet the above criteria for unmineralized shale.

Cover construction will proceed as follows. An 18-inch layer of the shale will be spread over the area being reclaimed. The first 18-inch layer would be graded and compacted. Depending on the level of weathering in the material stockpile, it may be necessary to allow further weathering time, perhaps even one or two years, prior to final grading and compaction of the first layer. A second 18-inch layer of the shale will then be placed and lightly compacted. Dust and runoff control measures will be implemented in all areas where the cover is being constructed.

The upper layer of the cover will then be seeded and fertilized to promote vegetation. The currently proposed seed mixes are shown in Table 3.1. Results from revegetation trials are needed before final recommendations with respect to seed and fertilizer will be possible. Further details can be found in the Revegetation Plan produced by ABR Inc., which is also included in Supporting Document F3.

Field trials of cover construction are being initiated in 2007 and may lead to changes in the above design. Further changes may be made as experience is gained with the full-scale covers that will be constructed during operations on the Oxide stockpile and portions of the Main Waste stockpile.

The covered and reclaimed areas will be monitored and, where necessary, maintained for several years after construction. The post-closure monitoring and maintenance requirements are described further in Section 4 below.

**Table 3.1: Revegetation Species for Stockpile Covers**

Plant Species		Planting Specifications
Native-grass cultivars Primary List Nortran hairgrass Tundra bluegrass Alpine bluegrass Spike trisetum Thickspike wheatgrass Polargrass Bluejoint		Seeding Rate 20 lb/acre (final mixture). Ratio of species will depend on availability, but mix may include predominantly tundra bluegrass and alpine bluegrass for drier areas and Nortran hairgrass, polargrass, and bluejoint for mesic sites.
Secondary List Bering hairgrass Arctared fescue		
Native forbs Tilesy sage Alpine milkvetch Alpine sweetvetch Boreal sweetvetch Field Oxytrope Boreal yarrow		Seeding rate 40 seeds/yd <sup>2</sup> for each species. Ratio of species will depend on availability, but mix may include alpine milkvetch, field oxytrope, Arctic bladderpod, and Siberian aster for dry areas; and tilesy sage, boreal sweetvetch, alpine sweetvetch, tall fireweed for mesic areas.
Other potential species Tall fireweed Siberian aster Arctic bladderpod		

**3.1.4 Red Dog Creek Diversion**

The Red Dog Creek Diversion will be re-built as an open channel designed to pass the 500-year flood. The alignment will be around the toe of the re-graded Main Waste Stockpile, at a distance sufficient to allow a sediment collection ditch between the toe and the diversion ditch. Figure 3.1.5 shows a conceptual alignment and typical sections. By the time a final design is needed, the site will have almost forty years experience with the Red Dog Creek Diversion. Any details needed to prevent ice formation or sediment deposition, and to minimize long-term maintenance requirements, will be incorporated into the design at that time.

If Hilltop Creek is clean at closure it would be redirected to Red Dog Creek. Otherwise it would be directed to an infiltration basin along the toe of backfilled Main Pit.

A spillway would be constructed to direct any flows greater than the 500-year flood into the Aqqaluk Pit. As mentioned in Section 3.1.2, the water level in the Aqqaluk Pit will be maintained below elevation 750 feet. That will provide sufficient room to store the entire volume of a 1000-year flood.

The area around the channel would be revegetated using a combination of willow cuttings and birch seedlings. Further details are provided in the Revegetation Plan (Supporting Document F3).

**3.1.5 Minewater and Waste Stockpile Seepage**

As noted in Section 3.1.2, ditches and swales would be constructed on the covered stockpiles to collect and remove surface overflow. The water would be monitored and pumped to Aqqaluk Pit or

allowed to flow into the Tailings Pond until it is shown to be sufficiently good quality for direct discharge.

The cover studies to date suggest that a complex cover would reduce the infiltration of water to the underlying waste, but the amount by which infiltration would be reduced remains uncertain. The assumption herein is that about 25% of precipitation would infiltrate through the cover and become contaminated.

Water that infiltrates through the covers on the Oxide and Main Waste stockpiles will be collected in a series of wells and sumps along the toe of the Main Waste Stockpile. From there it would flow or be pumped either directly to treatment or to the Aqqaluk Pit for storage and future treatment. Figure 3.1.6 shows a conceptual design for the seepage collection system. The conceptual design may be significantly modified if the wing wall of the Main Dam is extended southwards. Once the Oxide stockpile cover is complete, there is not expected to be any seepage into the Hilltop Creek catchment.

Water that infiltrates the Main Pit stockpile would be allowed to drain downwards into the pit, where it would be collected by a series of groundwater wells. The collected water will either be pumped directly to treatment or to the Aqqaluk Pit. The groundwater level in the backfilled Main Pit will be maintained to keep it well below the level of the Red Dog Creek Diversion and thereby prevent escape of contamination. Any contaminated water collecting in the mine sump would also be routed to treatment or to the Aqqaluk Pit.

Water will be removed from the Aqqaluk Pit each year and treated for discharge. If significant volumes of water accumulate in Qanaiyaq Pit, it will be pumped either to the Aqqaluk Pit or directly to treatment.

## **3.2 Tailings Area**

### **3.2.1 Overview**

Figure 3.2.1 summarizes the proposed closure and reclamation methods for the tailings area. The methods are based on the “Clean Pond” option selected through the consultation process described in Section 1.2. The primary objectives are:

- Covering the tailings with water to restrict oxidation and acid generation;
- Managing contaminated water to keep the pond as clean as possible;
- Ensuring long-term stability of the dams, while minimizing any seepage; and
- Reclaiming surface disturbances.

### **3.2.2 Tailings**

As discussed in Section 2.2.2, the tailings surface is expected to reach elevation 975 feet by the end of production in 2031. Tailings deposition will be managed to make the final surface as level and as

close to the target elevation as possible. If necessary, the surface will be re-graded using methods developed and tested at Teck Cominco's Louvicourt Mine. Figure 3.2.2 shows the outline of the final tailings at elevation 975 feet.

Section 2.3.2 also points out that the site's water treatment capacity will be upgraded sometime around 2025, to allow pre-treatment of all inflows to the tailings pond. The timing of that change means that the last few years of tailings production will be deposited into a much cleaner pond, which will in turn ensure that the porewater in the upper 5 to 10 feet of tailings is cleaner than the current tailings porewater. Diffusion of contaminants and/or exchange of the porewater is therefore expected to have little effect on long-term water quality in the pond.

### 3.2.3 Pond

A permanent pond will be maintained over the tailings. Through many years of experience at other sites, it has been demonstrated that the most effective way to prevent oxidation and acid generation from sulfidic tailings is to keep them underwater.

The experience at Louvicourt Mine shows that a reasonable minimum water cover would be about 2 feet, leading to a minimum pond surface elevation of 977 feet. Variation in the tailings surface elevation means that a lesser depth of pond would be unlikely to provide uniform water cover. The pond would be drawn down each summer, to provide room to store the next year's freshet. An extreme freshet inflow of 3,500,000 cubic yards would fill the pond to elevation 980.2 feet. The pond limits at 977 and 980.2 feet are shown on Figure 3.2.2.

Water quality in the tailings pond at closure is discussed in Section 3.3.2, and post-closure water quality is discussed in Section 4.2 below. In brief, the interception of seepage from the Main Waste stockpile will keep contaminant concentrations much lower than current levels, but not low enough for the water to be discharged without treatment. Water will therefore need to be withdrawn from the pond each summer, treated and discharged. To minimize the volume of water needing to be treated, the diversion ditches above the west side of the tailings impoundment would be maintained.

### 3.2.4 Main Dam

#### *Final Configuration*

The Main Dam is expected to be raised to its final elevation of 986 feet sometime prior to 2031. Figure 3.2.3 shows the dam with the final raise in place. Further details can be found in Section 2.2 above and in the URS conceptual design report (URS, 2007a), in Supporting Document C4.

The conceptual design shown in Figure 3.2.3 has been checked for stability. Calculations reported in Supporting Document C5 show that the dam would be stable, with a static factor of safety of 1.7, and a seismic factor of safety of 1.2 under the design earthquake. Even in the maximum credible earthquake, the dam is expected to suffer only slight movement of the crest.

### *Spillway*

To completely protect against overtopping of the Main Dam, a spillway would be constructed in the west abutment. A conceptual design for the spillway is shown in Figure 3.2.4. The conceptual design has the spillway located in bedrock. The invert elevation is 983.5 feet, and the width of the channel is sufficient to pass an inflow design flood with a flow depth of 1.4 feet. The flow would therefore remain below the dam crest. Further details of the spillway conceptual design can be found in Supporting Document C8.

### *Surcharge Capacity*

The distance between the assumed tailings surface elevation of 975 feet and the spillway invert at elevation 983.5 feet determines how much water can be stored in emergencies. Calculations provided in Supporting Document B8 show that even the combination of the minimum end of year water cover of 2 feet, a spring freshet, a probable maximum flood (PMF) series, and a 100-year flood could be contained without exceeding the level of the spillway invert.

That surcharge capacity available between elevations 977 feet and 983.5 feet also provides a significant level of safety for other combinations of inflows and upset conditions. For example, in the unlikely event that treatment and discharge of the pond water ceased completely, it would be possible to store more than two years of normal annual inflows, a single year of inflows under 1:100 wet conditions, or a single year of average inflows plus a full PMF.

### *Beach*

Seepage rates at the Main Dam have recently been assessed and a model to predict future seepage rates developed. One of the key findings of that work is that seepage rates are substantially reduced when a beach is maintained in front of the dam. The beach serves to keep water away from the highly permeable material on the face of the dam, and forces it to pass through the much less permeable tailings. The URS report "Main Dam Seepage Assessment" (URS, 2007c) included as Supporting Document C6 provides details of the seepage analyses.

To keep seepage rates low after closure, a permanent beach will be constructed in front of the Main Dam. The beach will be 600 feet wide, which is predicted to restrict seepage rates to about 550 gpm. The beach will be constructed of un-mineralized rock, and a geosynthetic liner will be included to prevent oxygen from reaching the underlying tailings. Figure 3.2.5 shows a typical section through the beach.

### *Seepage Collection*

Seepage collection at the toe of the Main Dam will continue after closure, but the pumpback system will be re-configured to send the seepage to the Aqqaluk Pit, as shown in Figure 3.2.6. That change will prevent the seepage from contaminating the tailings pond.

The seepage management system would need to be backed up by an emergency seepage storage pond sufficient to contain several days of seepage. At the Main Dam, there is limited room for an emergency storage pond below the current seepage dam. Figure 3.2.6 shows a pond that would have a storage capacity of about 30,000 cubic yards. That capacity would be sufficient to store seven days of seepage at the 550 gpm rate specified above.

The seepage collection and pumping system could eventually be converted to a system that could be remotely operated and monitored during the winter months. The general progress in the state of the art of remote systems suggests that such a system should be possible at Red Dog. However, the conversion to a remotely operated system is not part of the current plan. The current post-closure cost estimate allows for the site to be staffed year-round.

### **3.2.5 Back Dam**

As discussed in Section 2.2.6 above, the Back Dam will be raised to elevation 986 feet during operations. The conceptual design alignment for the final Back Dam is shown in Figure 3.2.7.

Any seepage from the Back Dam will be collected and piped to the Main Waste stockpile seepage collection system, through which it will be transferred to Aqqaluk Pit. The conceptual design report for the Back Dam (Golder Associates 2006b) includes results of seepage analyses. Seepage rates through the final dam are predicted to range from about 20 to 40 gpm, for the case without a beach.

The construction of a permanent beach in front of the Back Dam would have a similar effect on seepage rates as observed at the Main Dam. A 600-foot wide beach is predicted to reduce seepage rates at the Back Dam to less than 20 gpm. However, south of the Overburden stockpile, there is room to build an emergency storage pond of almost any size. Figure 3.2.7 shows a pond sized to store up to 35,000 cubic yards, which would be more than 100 days of seepage even at the 40 gpm rate expected without a beach. Therefore it is not clear that a beach will be required at the Back Dam.

Observations of actual seepage rates through the Back Dam will be possible once the first raise is completed in the next two years. More certain predictions of post-closure seepage rates will then be possible, and the need for a beach can be re-assessed. Upgrades to the current Overburden run-off collection system, including deeper components to collect seepage, will also be re-assessed at that time.

### **3.2.6 Overburden Stockpile**

Portions of the Overburden stockpile may be used during operations in construction of the Back Dam or as part of the cover for the Main Waste stockpile. At closure, additional material may be used for covering of the remaining Main Waste and Main Pit stockpiles.

The remainder of the Overburden stockpile and any of its exposed footprint will be re-graded and revegetated. Revegetation trials on the Overburden stockpile have been completed. The species mix for further revegetation would be as shown in Table 3.1 above. Further details on both the trials and the species mix can be found in the Revegetation Plan (ABR, 2007), Supporting Document F3.

## **3.3 Water Treatment and Discharge**

### **3.3.1 Water and Contaminant Load Balance**

The collection and treatment of site water will continue during the closure period. The flows and contaminant loads from each source area will transition from the operational levels discussed in Section 2.3.1 to post-closure levels. Section 4.2.1 below provides a more detailed discussion of the post-closure water and contaminant load balance. The precise timing of the transitions from the operational to post-closure conditions will depend on the schedule of reclamation activities, and therefore has not been worked out in detail.

### **3.3.2 Water Treatment**

Treatment of excess water will continue during the closure period, as requirements transition from the operational to post-closure levels. It is possible that some of the excess water will be directed to Aqqaluk Pit, in order to flood reactive surfaces as quickly as possible.

Modifications to the treatment system will be completed during the closure period. There are several options that remain under consideration, and the final plans will depend largely on the extent of the water treatment upgrades in 2025 (see Section 2.3.2). It is possible that a new treatment plant, designed specifically for post-closure conditions, will be required. Other options, such as modifications to WTP2 and WTP3, may prove to be more cost effective. Also, once ore processing ceases, reclaim of water from the tailings pond will no longer be necessary and WTP1 will be available for either decommissioning or incorporation into the post-closure water treatment system.

### **3.3.3 Discharge of Treated Water**

Discharge of treated water at Outfall 001 will also continue during the closure period. The quantities discharged will transition from operational levels discussed in Section 2.3.3 to the post-closure levels discussed in Section 4.2.3. Contaminant concentrations in the discharge are expected to comply with the current NPDES requirements.



### 3.4 Ore Processing Area

Assuming that no further ore production is envisaged, the ore processing facilities will be decommissioned after operations end in 2031. Hazardous material will be removed and handled according to regulations specific to each material. High value components will be removed for salvage and scrap, and the remainder of the structures demolished. Bulk demolition wastes will be disposed of in a landfill to be developed along the toe of the Main Waste or Low Grade Ore stockpiles.

Denison Environmental Services completed a thorough review of demolition requirements and estimated costs in 2005. That work is included in Supporting Document G.

It is expected that metal-contaminated soils will be found below portions of the ore processing area, once the structures are removed. The contaminated soils will be removed and hauled to the Main Waste or Low Grade Ore stockpiles. Further reclamation of the ore processing area is discussed in the following section.

### 3.5 Infrastructure

After operations cease in 2031, NANA will need to decide how much of the site infrastructure will be left in place. That decision will depend on what other activities are taking place or are reasonably foreseeable at that time.

All infrastructure that is not needed for the post-closure requirements or for other NANA plans will be decommissioned. Hazardous materials and high value components will be removed. The remainder of the facilities will be demolished and placed in the demolition landfill.

Figure 3.5.1 shows the infrastructure locations that are expected to require reclamation. The total surface area is about 225 acres. Any contaminated soil present in these areas will be removed, and the areas regraded. Un-mineralized material will be brought in as fill where necessary, and the areas will be re-vegetated following the recommendations in Table 3.2.

Vegetated areas impacted by fugitive dust will require further monitoring and assessment before appropriate remediation plans can be developed. This will be covered under the Risk Management Plan described in Section 2.5.17.

**Table 3.2: Revegetation Requirements for Infrastructure Areas**

Area	Plant Species	Planting Specifications
Reclaim roads, laydown areas, pads and quarries	Native grass cultivars	(see Table 3.1)
	Native forbs	(see Table 3.1)
Banks of Red Dog Creek Diversion and other wet areas	Shrub cuttings and seedlings	
	Diamond leaf willow	Cuttings on one-foot centers
	Felt leaf willow	Cuttings on one-foot centers
	Richardson willows	Cuttings on one-foot centers
	Shrub/dwarf birch	80 seeds/yd <sup>2</sup>

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## 4 Post Closure Requirements

### 4.1 Overview

After the closure activities are completed, the site will transition to long-term post-closure status. NANA, as the land owner, will determine the post-closure uses of the site. However, a number of activities related to the closed mine will be required. Figure 4.1.1 provides an overview of the reclaimed site and Figure 4.1.2 shows typical sections.

The principal post-closure requirement will be the collection and treatment of contaminated water. The soil covers constructed on the stockpiles will reduce the rate at which contaminants are released from the mine area, but any water that seeps through the covers and/or contacts the exposed pit walls, will still need to be treated. In the tailings area, containment levels in the pond will be much lower than currently and will further diminish over time, so that it might someday be possible to discharge the pond water without treatment. But it is expected that the pond water will need treatment for a very long time.

A second post-closure requirement will be the maintenance and repair of ditches, soil covers and other earthworks constructed during the closure period. Maintenance activities are expected to be substantial in the first few years post-closure, but will gradually diminish as stable conditions develop.

Additional long-term requirements will include the infrastructure needed to support water treatment and maintenance, inspection and monitoring, and restriction on site access or uses.

### 4.2 Water Treatment and Discharge

#### 4.2.1 Water and Contaminant Load Balance

Contaminated water at the site is expected to continue to require active management over the long term. The operations-period water and contaminant load balances introduced in Section 2.3.1 were extended to develop estimates of post-closure flows and water quality. Complete details are presented in Supporting Document E1.

Figure 4.2.1 shows the estimated site water balance for an average year. Aqqaluk pit will be the primary storage area for contaminated water, and will receive seepage from the Main Waste stockpile, Main Dam and Back Dam, minewater from the Main Pit area, and its own direct precipitation and runoff. Each summer, an average of about 1.06 billion gallons of water will need to be extracted from the Aqqaluk Pit and treated.

Flows into and out of the tailings pond are also shown in Figure 4.2.1. Runoff from the covered Main Waste and Oxide stockpiles, and from the northern portion of the Overburden stockpile, will initially continue to flow into the pond. Precipitation, undiverted runoff from the west side of the

impoundment, grey water, uncaptured seepage from the Main Waste stockpile, and backwash water from the treatment plant(s) will also enter the tailings pond. The outflows will be evaporation and seepage, leaving an excess of about 0.47 billion gallons of water to be discharged each year.

Figures 4.2.2 and 4.2.3 shows post-closure load balances for sulfate and zinc, respectively, and indicate that most of the heavily contaminated flows will be routed to the Aqqaluk Pit. Contaminant concentrations in the Aqqaluk pit are estimated at 5300 ppm TDS, 3600 ppm sulfate and 880 ppm zinc.

Contaminant concentrations in the tailings pond are expected to be significantly lower than current concentrations. Two measures that will be implemented during the last few years of operation, construction of the Main Waste seepage collection system and the expansion of the WTP3 treatment system, will divert or pre-treat most of the contaminants. However, water remaining from the earlier period, porewater from the underlying tailings, and uncaptured seepage from the Main Waste stockpile will continue to contribute contaminants to the pond. The first two sources are not expected to significantly impair pond water quality. The third source will be controlled by monitoring of and periodic improvements to the Main Waste seepage collection system, but the possibility that some seepage will remain uncaptured cannot be ruled out. The load balances in Figures 4.2.2 and 4.2.3 assume that 5% of the Main Waste seepage will continue to enter the tailings pond. The resulting contaminant concentrations in the pond water are then estimated to be about 1000 ppm TDS, 640 ppm sulfate, and 16 ppm zinc.

## 4.2.2 Water Treatment

Seasonal water treatment operations will continue after closure. Contaminated water stored in the Aqqaluk Pit will be withdrawn each summer for treatment and discharge. As noted in the preceding section, water from the tailings pond is also expected to require treatment prior to discharge.

The water and load balance estimates required average annual discharges of about 0.95 billion gallons from the Aqqaluk Pit and 0.47 billion gallons from the tailings pond. Slightly larger volumes will need to be treated, because some of the treated water is used for backwashing the sand filters and removing the treatment sludge. The total volumes entering the treatment system each year are estimated at 1.05 billion gallons from the Aqqaluk Pit and 0.52 billion gallons from the tailings pond. The backwash and sludge removal water could be routed either to the Aqqaluk Pit or the tailings pond. (The water balance calculations assume the latter.)

The review of water treatment methods included in Supporting Document E4 concluded that lime addition will remain the preferred method of water treatment after closure. Given the differences in contaminant concentrations, it is likely that the Aqqaluk Pit water will be treated in one set of treatment tanks, and the much cleaner tailings pond water in another. All three of the current treatment plants will be available for use, and various configurations are possible. It may prove more cost-effective to either modify one of the three plants or construct entirely new components.

The water treatment reagent requirements in Supporting Document E4 have been updated to reflect the final water and load balance. Table 4.1 shows the current estimates of lime consumption. The estimates were derived by converting the estimated contaminant concentrations in each source stream to a theoretical lime demand, and then increasing the theoretical values by 12.5% to account for inert and incompletely reacting lime.

Supporting Document D2 discusses the possibility of long-term shifts in water quality as the sphalerite oxidation in the waste rock shifts to pyrite oxidation. Those changes are expected to occur gradually over periods of decades. Although the composition of the treated water will change, the amount of lime needed to treat it will not. Further explanation of the effects of these changes is provided in Supporting Document D4. The “lime demand” approach used in the estimation of reagent requirements is therefore conservative even for the period after the geochemical changes are complete.

**Table 4.1: Estimated Lime Requirements for Water Treatment**

<b>Source</b>	<b>Annual Volume (Million Gallons)</b>	<b>Lime Demand (ppm as CaO)</b>	<b>Theoretical Lime Requirement (tons CaO per year)</b>	<b>Estimated Lime Requirement (tons CaO per year)</b>
Tailings Pond	518	75	160	180
Aqqaluk Pit	1050	1451	6,340	7,130
Total	1568		6,510	7,310

The lime treatment process creates a sludge consisting of gypsum and neutralized metal hydroxides. Estimates of sludge production after closure have also been updated on the basis of the current water and load balance, and are shown in Table 4.2. The sludge generated from the Aqqaluk Pit water is expected to be much denser than that generated from the tailings pond water.

Both sludge streams will initially be directed to a series of cells constructed on a flat bench in the Aqqaluk Pit. They will be stored there for one winter to allow freezing to further increase the densities. The densified sludge will be removed once cells are full and deposited in the Aqqaluk Pit. Other options for sludge management are discussed in Supporting Document E5. The estimates of densified volumes shown in Table 4.2 assume that the freezing will increase densities to about 40% solids.

**Table 4.2: Estimated Sludge Production**

Source	Estimated Production (dry tons per year)	Initial Solids Content	Initial Volume (cubic yards per year)	Densified Volume (cubic yards per year)
Tailings Pond	300	5%	7,000	
Aqqaluk Pit	20,000	20%	130,000	
Total	20,300		137,000	69,000

**4.2.3 Discharge of Treated Water**

Treated water will continue to be discharged at Outfall 001. The average annual discharge will be about 1.42 billion gallons. Contaminant concentrations in the discharge are expected to comply with the requirements of the current NPDES permit, as summarized in Table 2.5 above.

**4.2.4 Possible Modifications Over Long-Term**

The above analyses assume that water in the tailings pond will continue to need treatment prior to discharge. That will surely be the case in the years immediately after closure, but it is possible that the pond water quality will improve over time. Other sites with closed and flooded tailings impoundments have experienced great improvements in pond water quality over time.

If long-term monitoring of water quality in the closed tailings pond shows that it consistently meets discharge requirements (without treatment), several modifications will be considered. The principle change will be conversion of the emergency spillway into a service spillway so that water flows out naturally. The new spillway would need to be deeper than the emergency spillway. Supporting Document C8 presents two concepts for future deepening of the spillway. Other modifications that would be considered if the pond water quality improves over time include breaching of the clean water diversions on the west side of the impoundment, and diversion of any residual sources of loading such as runoff from the waste rock covers or overburden stockpile to the Aqqaluk Pit.

The primary uncertainty with respect to long-term water quality in the tailings pond will be the amount of seepage that escapes the collection system along the toe of the covered Main Waste stockpile. Until the effectiveness of the collection system can be proven, it will be prudent to assume that the water in the pond will require treatment prior to discharge. That assumption is made in the post-closure cost estimate.

**4.3 Maintenance Requirements**

The earthworks and facilities constructed during closure will all need some level of maintenance in the post-closure period. Table 4.3 summarizes the expected requirements.

The requirements for maintenance of covers and ditches are expected to diminish over time. The reason is that the most significant instabilities will be noted and repaired in the first few years after

closure. The development of vegetation also helps to reduce erosion problems and the associated maintenance requirements. However, there will still be a need for maintenance and repairs after significant storm or runoff events.

The maintenance of active facilities, such as the water treatment systems, camp, and access roads will continue as long as they remain in use.

**Table 4.3: Post-Closure Maintenance Requirements**

Area	Feature	Requirement
Mine Area	Pits	Repair of berms and cutback slopes, where necessary
	Stockpiles	Repair of erosion or settlement damage to covers; Maintenance and repair of surface water ditches and swales; Supplemental planting, seeding or fertilization
	Red Dog Creek Diversion	Maintenance and repair as needed
Tailings Area	Main Dam	Maintenance and repair as needed
	Back Dam	Maintenance and repair as needed; Removal of vegetation
	Covered Beaches	Repair of wave erosion; Supplemental planting, seeding or fertilization
	Spillway	Removal of vegetation
	Overburden dump	Supplemental planting, seeding or fertilization
	Seepage Collection System	Maintenance and repair as needed
Infrastructure	Decommissioned areas	Supplemental planting, seeding or fertilization
	Access roads	Snow removal; Grading and re-surfacing
	Water treatment system	Mechanical & electrical maintenance
	Camp & support facilities	Snow removal; Structural maintenance; Mechanical & electrical maintenance
	Bons Creek reservoir and dam	Monitoring, maintenance and repair as needed

## 4.4 Infrastructure Requirements

The continuing water treatment and maintenance activities will create a requirement for support infrastructure, including access roads, accommodations, the water treatment plant and associated equipment, power supply, fuel storage, materials storage and equipment maintenance. Table 4.4 lists the specific site infrastructure requirements under each category, assuming that only the required activities continue. It is assumed that barge access to the port and access over the port road will also remain. As noted above, NANA may develop other plans for the site and those could include retention of other infrastructure.

**Table 4.4: Infrastructure Requirements after 2031**

Requirement	Infrastructure to be Retained
Site access	Airstrip and airport building Internal road system to any areas needing maintenance
Accommodations	Personnel Accommodations Complex (may be modified) Bons Creek freshwater pumphouse and supply line Potable water Sewage treatment
Water treatment	Water Treatment Plant #2 (may be modified or re-built) Reclaim barge and reclaim line Lime slaking system Sulfide mixing system (currently in Building 2016) Flocculant preparation system (currently in Building 2025) Compressed air system
Power supply	Powerhouse Emergency power supply
Fuel storage	One 1,000,000-gallon bulk fuel tank Fueling island and day tanks
Materials storage and equipment maintenance	Select storage area / Connex ATCO trailer facilities Shop for mobile equipment and some mobile equipment

## 4.5 Monitoring and Inspection Requirements

The site will continue to require monitoring and inspections in the post-closure period. Water quality monitoring will continue for the long term, i.e. as long as water collection and treatment is required. Other programs that are expected to be required in the long term include regular inspection of dams, ditches and any other earthworks that remain in use, and monitoring of caribou and other subsistence foods from the area around the site.

Several other programs will be intensive in the immediate post-closure years, but are expected to be reduced once it can be demonstrated that stable conditions have been established. These include monitoring of cover performance and re-vegetation success, fugitive dust monitoring, groundwater and ground temperature monitoring and ecological risk monitoring specific to the site.

Details of the monitoring and inspection plans for the post-closure period are presented in Supporting Document I.

## 4.6 Site Use Restrictions

The mine area is currently off-limits to subsistence harvesting, and that restriction will remain in effect throughout operations. A study of the potential for contaminant intake by animals around the



closed mine is presented in Supporting Document H (Exponent, 2007). The study used methods developed in the more extensive DMTS ecological risk assessment (Exponent, 2005), and evaluated the risks to animals living in or passing through the mine area and to the vegetation community in the mine area.

The study concluded that the closed mine is unlikely to present any significant risk of adverse effects on caribou, fox, teal or muskrat, but that individual ptarmigan, tundra vole and tundra shrew could take in enough lead or cadmium to be adversely affected. The difference is partly attributable to the small home range of the ptarmigan, shrew and vole, which were assumed to spend their entire lives in areas with the highest metals concentrations. The study conclusions also note that a number of cautious assumptions were made in the evaluation and that more realistic assumptions would in many cases reduce or eliminate the estimated risk.

As noted above, NANA will determine the post-closure uses of the site. The results of the DMTS human health risk assessment indicated that risks to human health would not be elevated even if harvesting were to occur in currently restricted areas of the DMTS (Exponent 2005). Because concentrations within the mine area are similar to port area soil metals concentrations, human health risks would also likely not be elevated if subsistence harvesting were to occur within the mine area. However, the existing restrictions on subsistence harvesting will remain in effect until that conclusion can be verified by post-closure monitoring.

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## **5 Schedule and Financial Assurance**

### **5.1 Schedule**

#### **5.1.1 Progressive Reclamation**

This plan includes a number of commitments to progressive reclamation, i.e. reclamation that will begin during operations, as well as commitments to closure-related changes in the tailings and water management systems. These commitments are more fully described in Chapter 2 above and in the respective operations plans included in Supporting Document B.

Figure 5.1.1 shows a summary schedule that includes the progressive reclamation, tailings and water management activities. Other production milestones are also included to provide context. In many cases, the precise scheduling of activities will depend on factors that are not fully predictable. The schedule therefore shows early and late dates for many activities.

#### **5.1.2 Closure**

The closure activities described in Chapter 3 above will begin in 2031, when production ceases. It is expected that the closure measures will require at least two field seasons to complete. However, the transition from operations to closure may span a calendar year. Figure 5.1.1 therefore shows most of the closure activities taking place in 2031, 2032, or 2033.

#### **5.1.3 Post-Closure**

The post-closure activities described in Chapter 4 could begin in each area immediately after the closure activities are complete. Typically, however, it takes many months or even a few years for employment levels, equipment fleets and other practical matters to fully transition to long-term post-closure levels.

The post-closure activities are expected to be required indefinitely. However, as noted in Chapter 4, requirements for maintenance and monitoring are expected to be more intensive during the first few post-closure years and to diminish thereafter.

#### **5.1.4 Project Suspension and Premature Closure**

The “Red Dog Mine Development Plan” has identified sufficient resources to support mining until 2031, based on suitably cautious assumptions about world metal prices and production costs. However, there is always a risk that prices or costs could change, leading to a requirement to either suspend operations for a period of several years or, in the worst case, to prematurely close the operation. Plans and cost estimates for both of those possibilities are included in Supporting Document J.

The plan and cost estimate for a temporary suspension of mining assumes that the suspension would last approximately five years, and therefore proposes measures to keep the existing facilities in a stable condition, ready for re-commissioning.

All of the systems required to manage surface waters would be kept active and the primary focus during the summer months will be operation and maintenance of the water treatment plant. The water management, site facilities maintenance and environmental monitoring work would continue. Other equipment would be shutdown and protected, and facilities would be cleaned to the extent possible, with water systems drained and blown out to minimize freeze damage.

The plan and cost estimate for premature closure assumes that the mine would close around the year 2012. At that time, the Aqqaluk Pit would be fully stripped of overburden but the Main Pit would not be fully backfilled. The year 2012 therefore represents the worst case in terms of the amount of disturbed area requiring reclamation.

The premature closure scenario for the mine area differs from the planned closure in the following ways:

- Qanaiyaq Pit would not be opened (scheduled for 2016-2025);
- Covers on the Main Waste stockpile would still need to be completed;
- The Main Pit would be allowed to flood and used to store contaminated water (rather than Aqqaluk Pit) and the Main Pit groundwater collection system would not be required;
- The Red Dog Creek Diversion spillway would be constructed between the diversion and the Main Pit (rather than Aqqaluk Pit); and,
- The seepage collection system between the Main Waste stockpile and the tailings pond would still need to be constructed.

### **5.1.5 Further Investigations and Plan Updates**

This closure and reclamation plan is to be updated every five years. The updates will include presentation of all additional closure-related studies, as well as reports on the progress of progressive reclamation activities.

## **5.2 Financial Assurance**

### **5.2.1 Cost Estimate**

Complete estimates of closure and post-closure costs have been prepared. Table 5.1 summarizes estimated costs for the closure activities both as described in this report, *i.e.* with the mine operating until 2031, and for the premature closure scenario. Details of the closure cost estimates are presented in Supporting Document J1.

Table 5.2 summarizes estimated annual costs for the post-closure activities, again for both the planned closure and premature closure scenarios. Details are presented in Supporting Document J2.

Table 5.3 summarizes the estimated annual costs for the five-year suspension scenario, as well as the analogous annual costs for operating the camp and water management system during the two-year closure period.

## 5.2.2 Financial Security

TCAK and NANA will ensure that the funding needed to implement the suspension, closure and post-closure commitments will be available when it is needed, including over the very long term. In accordance with State requirements, the amount of financial security required must reflect the reasonable and probable costs of reclamation. While the most probable closure scenario is the planned closure in 2031, TCAK and NANA have reviewed the various suspension, premature closure, and planned closure scenarios and propose that the more conservative scenario be selected as the basis for determining the level of financial security, as follows:

- A suspension period lasting five years;
- A premature closure, with ongoing water management and maintenance; and,
- Post-closure requirements based on the premature closure scenario.

The resulting sequence of estimated annual costs is presented in Table 5.4.

**Table 5.1: Summary of Estimated Closure Costs**

<b>Cost Category</b>	<b>Planned Closure (2031)</b>	<b>Premature Closure (2012)</b>	<b>Text Reference</b>
<b>Mine Area Direct Costs</b>			
Pits	\$1,190,000	\$930,000	3.1.2
Waste and Ore Stockpiles	\$1,700,000	\$1,600,000	3.1.3
Red Dog Creek Diversion	\$1,180,000	\$1,780,000	3.1.4
Minewater and Waste Stockpile Seepage	\$1,180,000	\$2,640,000	3.1.5
Revegetation	\$120,000	\$660,000	3.1.3
<b>Tailings Area Direct Costs</b>			
Main Dam Spillway	\$150,000	\$150,000	3.2.4
Main Dam Beach	\$4,860,000	\$4,860,000	3.2.4
Main Dam Seepage Collection	\$620,000	\$620,000	3.2.4
Back Dam Seepage Collection	\$680,000	\$680,000	3.2.5
Overburden Stockpile & Borrow Areas	\$380,000	\$380,000	3.2.6
<b>Water Treatment Direct Costs</b>			
Major Equipment	\$2,540,000	\$2,540,000	3.3.2
Installation	\$1,930,000	\$1,930,000	3.3.2
<b>Ore Processing &amp; Infrastructure Direct Costs</b>			
Demolition	\$3,730,000	\$3,730,000	3.4
Contaminated Soils in Ore Processing Area	\$1,000,000	\$1,000,000	3.4
Contaminated Soils in Laydown Area	\$610,000	\$610,000	3.5
Road Decommissioning	\$100,000	\$100,000	3.5
Reclamation of Disturbed Areas	\$290,000	\$290,000	3.5
<b>Subtotal Direct Costs</b>	<b>\$22,260,000</b>	<b>\$24,500,000</b>	
<b>Indirect Costs</b>			
Mobilization and demobilization	\$4,920,000	\$4,920,000	J1
Administration costs	\$1,890,000	\$2,030,000	J1
Field supervision and support	\$3,620,000	\$3,930,000	J1
Contract administration and QA/QC	\$1,770,000	\$1,920,000	J1
Insurance	\$110,000	\$120,000	J1
Contractor overhead	\$700,000	\$790,000	J1
Freight	\$970,000	\$1,130,000	J1
Allowance for haul road maintenance	\$700,000	\$700,000	J1
Contractor profit	\$3,350,000	\$3,650,000	J1
Engineering re-design	\$1,260,000	\$1,360,000	J1
Bonding	\$990,000	\$1,090,000	J1
State management and oversight	\$360,000	\$390,000	J1
<b>Subtotal Indirect Costs</b>	<b>\$20,640,000</b>	<b>\$22,040,000</b>	
<b>Contingency</b>	<b>\$4,000,000</b>	<b>\$4,450,000</b>	
<b>Total Costs</b>	<b>\$46,900,000</b>	<b>\$50,990,000</b>	

**Table 5.2: Summary of Estimated Annual Post-Closure Costs**

<b>Cost Item</b>	<b>Planned Closure (2031)</b>	<b>Premature Closure (2012)</b>
Manpower	\$1,940,000	\$1,940,000
Water Treatment Consumables (lime & additives)	\$3,670,000	\$3,310,000
Mobile Equipment	\$290,000	\$290,000
Maintenance Materials	\$370,000	\$370,000
Capital Replacement	\$580,000	\$580,000
Power (including fuel)	\$1,890,000	\$1,890,000
Environmental	\$570,000	\$570,000
Camp & Administration	\$990,000	\$990,000
Insurance	\$40,000	\$40,000
Contractor Overhead	\$190,000	\$190,000
Contractor Profit	\$220,000	\$220,000
State Contract Management	\$140,000	\$140,000
<b>Total Annual Cost</b>	<b>\$10,910,000</b>	<b>\$10,540,000</b>

**Table 5.3: Summary of Estimated Annual Suspension and Closure Operating Costs**

<b>Cost Item</b>	<b>Suspension Period</b>	<b>Closure Operating</b>
Manpower	\$1,940,000	\$1,940,000
Water Treatment Consumables (lime & additives)	\$5,700,000	\$360,000
Mobile Equipment	\$290,000	\$290,000
Maintenance Materials	\$370,000	\$370,000
Capital Replacement	\$580,000	\$580,000
Power (including fuel)	\$2,250,000	\$2,250,000
Environmental	\$570,000	\$470,000
Camp & Administration	\$990,000	\$990,000
Insurance	\$40,000	\$40,000
Contractor Overhead	\$190,000	\$190,000
Contractor Profit	\$220,000	\$220,000
State Contract Management	140,000	\$140,000
<b>Total Annual Cost</b>	<b>\$13,290,000</b>	<b>\$7,850,000</b>

**Table 5.4: Sequence of Estimates for Financial Security**

	<b>Suspension Costs</b>	<b>Closure Costs</b>	<b>Closure Operating Costs</b>	<b>Post- Closure Costs</b>
Year 1	\$13,290,000			
Year 2	\$13,290,000			
Year 3	\$13,290,000			
Year 4	\$13,290,000			
Year 5	\$13,290,000			
Year 6		\$25,500,000	\$7,850,000	
Year 7		\$25,500,000	\$7,850,000	
Year 8				\$10,540,000
Year 9				\$10,540,000
Year 10				\$10,540,000
Year 11				\$10,540,000
Year 12				\$10,540,000
Year 13				\$10,540,000
Year 14				\$10,540,000
Year 15				\$10,540,000
Year 16				\$10,540,000



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