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Giant Mine Remediation Plan

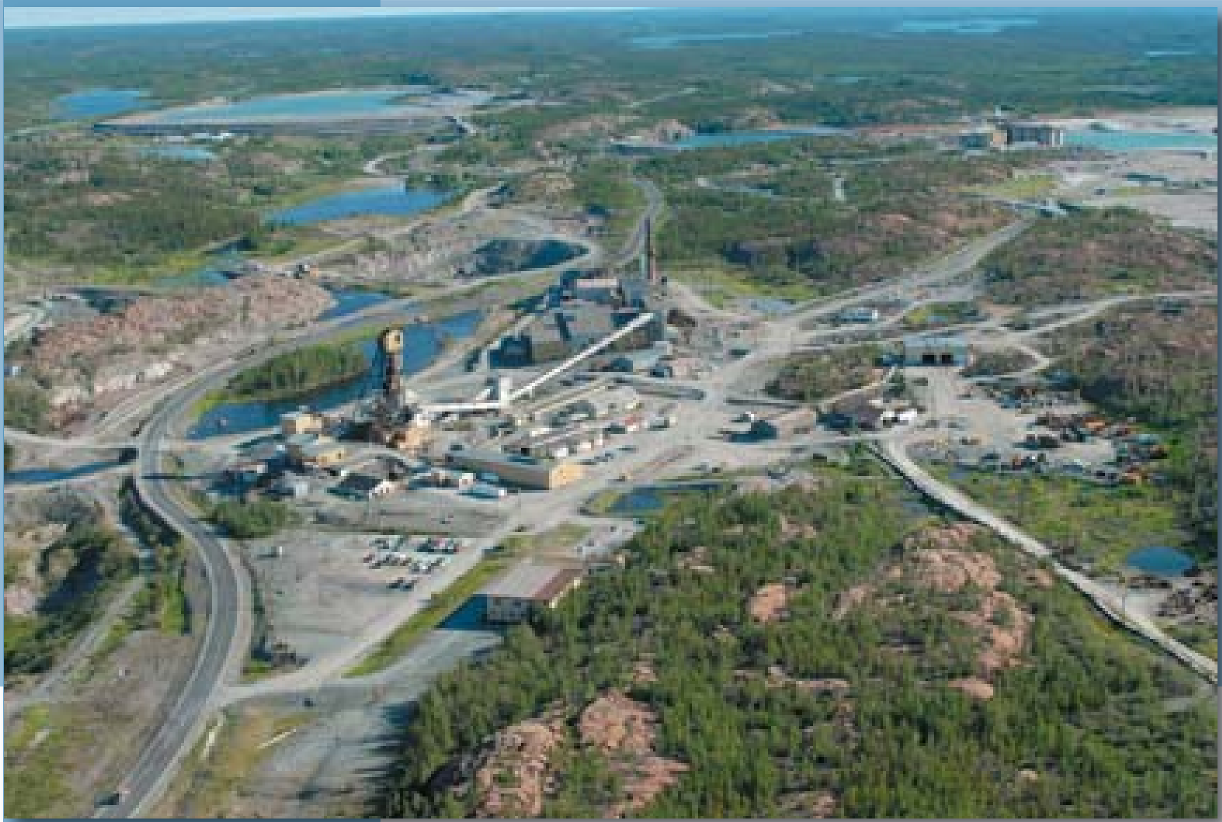

Photo by: Paul Vecsei

Prepared for:

Indian and Northern Affairs Canada
Giant Mine Remediation Project

Prepared by:

SRK Consulting
Engineers and Scientists

SENES Consultants Limited

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Northwest Territories

Canada

Giant Mine Remediation Plan

Giant Mine Remediation Project Team
Department of Indian Affairs and Northern Development

5th Floor, Precambrian Building
P.O. Box 1500
Yellowknife, NT X1A 2R3

SRK Consulting (Canada) Inc.
Suite 800, 1066 West Hastings Street
Vancouver, B.C. V6E 3X2

SENES Consultants Limited
121 Granton Drive, Unit 12
Richmond Hill, Ontario L4B 3N4

SRK Project Number 1CI001.013

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Executive Summary

The Giant Mine is located in Yellowknife, Northwest Territories, and produced gold from 1948 until 1999. After the mine owner went into receivership in 1999, the mine was transferred to the Department of Indian Affairs and Northern Development (DIAND). Immediately thereafter, DIAND entered into an agreement by which Miramar Giant Mine Ltd. took ownership of the property. Under that arrangement, the mine continued to operate, with the gold ore shipped offsite for processing, from 1999 until 2004. Mining ceased in July 2004 and DIAND again took control of the site one year later, after an orderly transition. The surface land lease was returned to the Government of the Northwest Territories. The GNWT subsequently established a reserve in favour of DIAND with the same boundaries as the former lease. DIAND remains in control of the site, and has contracted the Deton'Cho-Nuna joint venture to continue the required maintenance and environmental management activities.

This document presents a Remediation Plan for the Giant Mine site. The plan was prepared for DIAND by its Technical Advisor, and reviewed by an Independent Peer Review Panel. Under a Cooperation Agreement between the federal and territorial governments, the Government of the Northwest Territories (GNWT) also contributed to the development and finalization of this plan.

Included in the document are a history of the mine, a description of current site conditions, a review of the state of the surrounding environment, details of the proposed remediation activities, an assessment of the post-remediation conditions, a monitoring plan, and a project schedule. Over forty supporting documents provide detailed accounts of scientific and engineering studies. The remainder of this executive summary will focus on the proposed closure and remediation activities and their expected effects on the local environment.

Arsenic Trioxide Dust

Processing of the Giant Mine ore created arsenic trioxide dust as a by-product. Approximately 237,000 tonnes of the dust were produced and stored underground in fifteen purpose-built chambers and mined-out stopes. The dust is about 60% arsenic. To prevent the release of arsenic into the groundwater around the mine, the Remediation Plan calls for the arsenic trioxide dust and the rock around each chamber and stope to be maintained completely frozen.

The freezing will be accomplished by first installing pipes below and around the chambers and stopes, and then pumping a coolant through the pipes. The technology is similar to that used to create hockey rinks. It has also been used to prevent groundwater inflows to other underground mines and, at a smaller scale, to isolate areas of contaminated soil.

Once the dust and the surrounding rock are completely frozen, the freezing system will be converted to thermosyphons. Thermosyphons are tubes filled with compressed carbon dioxide gas that act as completely passive heat pumps, *i.e.* they cool the ground without any input of energy. They are a proven technology and have been used to protect frozen ground throughout the north since the

1970's. Thermal analyses and tests carried out at the site show that, even under an assumption of extreme global warming, the thermosyphons will maintain frozen conditions in and around the chambers and stopes. The thermosyphons will operate indefinitely, with only periodic maintenance and occasional replacement.

Other Underground Mine Components

Portions of the underground mine have been backfilled with tailings and waste rock. Although the concentrations of arsenic in these sources are hundreds of times lower than in the arsenic trioxide dust, their large volumes mean that they also have the potential to contaminate the surrounding groundwater. The only practical method to control that potential is to collect and treat groundwater from the mine area. All underground equipment and infrastructure will be removed or decontaminated prior allowing the mine to flood, and all surface openings will be sealed. The contaminated minewater will then be extracted through a series of wells, piped to a new water treatment plant, treated to remove contaminants, and then discharged to Yellowknife Bay.

Open Pits and Waste Rock

There are eight pits on the site, five of which are substantial in size. The B1 Pit will be backfilled to facilitate installation of the ground freezing system. Contaminated soils from other areas on the site will be placed in the portion of the pit that will ultimately be within the frozen zone. Waste rock, quarry rock or clean demolition waste will be used to fill the remainder of the pit. The entire backfilled area will then be covered with soil and revegetated. The other pits will be surrounded by berms or fences to prevent inadvertent public access.

Tailings and Sludge

There are approximately 16 million tonnes of tailings stored in ponds constructed on the site. The South, Central, North and Northwest Tailings areas cover a total of about 95 hectares. In addition, water treatment sludges are stored in settling and polishing ponds covering an additional nine hectares. Both the tailings and the sludge contain moderate amounts of arsenic. They are subject to wind erosion when dry, and could also be directly taken up by animals looking for salt.

The Remediation Plan calls for the tailings and sludge areas to be covered with one layer of quarried rock and a second layer of fine-grained soil. The lower layer of quarried rock will prevent the upwards migration of contaminants from the tailings, and inhibit the downwards penetration of plant roots. It will also serve as a final protective layer in the event that the soil is removed by erosion. The upper layer of fine-grained soil will allow for revegetation and future recreational or traditional use of the site. The surface of each tailings area will be graded and ditches and spillways constructed to limit erosion and to allow water to run off the cover without becoming contaminated.

Site Water Management

During and after the remediation, it will be necessary to continue collecting and treating any contaminated water. The plan calls for a new water treatment plant to be constructed. The plant will be used to treat contaminated water extracted from around the arsenic trioxide chambers and stopes during and immediately after the ground freezing. Contaminated surface water will also be collected and treated until monitoring data clearly show that the arsenic levels are low enough to allow direct discharge. Over the longer term, it is expected that water from the underground mine areas outside the frozen zones may continue to need treatment, and the new water treatment plant will remain in operation as required.

Effluent from the treatment plant will be discharged via a diffuser system into Yellowknife Bay. Discharge to the bay, rather than to Baker Creek, will allow year-round treatment of the extracted minewater. The year-round treatment will remove the current requirement to store large amounts of contaminated water on surface. It will also allow operation and maintenance of the water treatment and ground freezing systems to be carried out by a permanent year-round staff.

Baker Creek

Baker Creek has areas of significant sediment contamination. Also, the current alignment poses a risk of flooding into the C1 Pit and the connected underground workings. The Remediation Plan calls for diversion of the creek into a new channel around the areas where it poses a risk to the underground workings. Options for dealing with the contaminated sediments are under further investigation. They include removal of heavily contaminated sediments and diversion of the creek to uncontaminated areas. However, continuing arsenic inputs, primarily from areas upstream of the site, will limit the level to which the sediments can be cleaned.

Contaminated Soils

A number of surficial materials, from natural soils to tailings to mine rock are present variously across the site. An estimated 328,000 cubic metres of material is contaminated with arsenic at levels that exceed the GNWT criterion for industrial land use. Areas of hydrocarbon contamination are also present but largely overlap the arsenic contaminated areas. The Remediation Plan calls for contaminated soils and mine rock to be excavated and disposed of within the frozen portion of B1 Pit, which will subsequently be covered with non-contaminated material. Additional contaminated soils and spilled tailings will be excavated and moved into the most appropriate tailings or sludge impoundment.

Buildings and Waste Disposal

Over 100 buildings, supported by associated infrastructure and utilities, remain on the site. Many of the buildings pose a hazard to the public. The plan calls for all buildings and infrastructure to be removed. Any arsenic-contaminated materials will be removed and placed underground in the empty chamber 15. The public highway through the site will be relocated to keep traffic away from the demolition, soil cleanup and ground freezing activities. Options for the new alignment are being discussed with GNWT Department of Transportation.

Post-Remediation Conditions

After the remediation activities are completed, the site will consist of a small area that will need to remain under active management, and a broader area that is available for other uses. The actively managed area will be centered around the current C-Shaft, and will allow for both maintenance of the ground freezing system and long-term treatment of contaminated minewater. The remainder of the site will include areas along the current highway corridor that will be available for industrial use, open pits surrounded by rock berms or fences, and broad areas of covered tailings. The tailings areas, in particular, are expected to be open to broader uses after the plan has been fully implemented.

The remediation activities will decrease but not completely eliminate arsenic releases from the site. In quantitative terms, the arsenic releases from the site will decrease from the current level of approximately 500 kilograms per year to less than 200 kilograms per year. In the absence of the proposed remediation measures, arsenic releases from the Giant Mine site could increase to many thousands of kilograms per year.

The post-remediation arsenic release from the site and, equally importantly, areas upstream will mean that Baker Creek will remain contaminated with arsenic. Ecological risk assessment calculations show that there will continue to be a potential for adverse effects on bottom-feeding fish and terrestrial animals living in the Baker Creek area. Human health risk assessment calculations indicate that arsenic intakes by humans will remain within the range estimated for other Canadians, and that there will be little risk of adverse health effects. There may, however, need to be some restrictions on future activities at the site until monitoring programs can demonstrate that arsenic levels are within safe levels.

Monitoring and Reporting

A detailed plan for monitoring the site during and after implementation of the Remediation Plan has been developed. It includes sampling and analysis of groundwater and surface water, air quality monitoring, environmental effects monitoring, and monitoring of ground temperatures within and around the frozen arsenic trioxide chambers and stopes. It also includes regular inspections of remaining pit walls, as well as the covers, ditches and spillways associated with the remediated tailings impoundments. The monitoring will be sufficient to allow post remediation performance to be compared to both predictions and license requirements. Monitoring reports will be prepared and submitted to the Mackenzie Valley Land and Water Board.

Implementation

Remediation of the Giant Mine site, as outlined in this plan, will require approval pursuant to the Mackenzie Valley Resource Management Act. It is anticipated that this Remediation Plan will be submitted to the Mackenzie Valley Land and Water Board in 2007, as part of a water license application.

Throughout the licensing process, DIAND intends to continue public consultation on the Remediation Plan. Reviews by the boards and regulatory agencies will also have formal requirements for public input.

Although the schedule of the licensing process will ultimately be determined by the boards and regulatory agencies, it is anticipated that it will take 12 to 18 months from the date of the application for a water license to be issued.

Once the licensing process is complete, the project will be presented to the Treasury Board for final funding approval. Final engineering design of the approved remediation measures will commence at the same time.

Under this schedule, implementation of the Remediation Plan would commence in 2009. The major surface activities would be completed within five years, and the ground freezing would be substantially complete within ten years. Maintenance of the ground freezing system would continue indefinitely, as would minewater treatment and long-term monitoring.

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A Environmental Conditions

A1 The Giant Gold Mine – Our Story: Impact of the Yellowknife Giant Gold Mine on the Yellowknives Dene - A Traditional Knowledge Report (YKDFNLEC, 2005)
A2 Baseline Study Reference List (KHS Environment Management Group Ltd., 2004)
A3 Ecological Investigations at Giant Mine (Jacques Whitford Environment Limited, 2003)
A4 Biological Sampling at Baker Creek 2002 (Dillon Consulting Ltd., 2002)
A5 Biological Sampling at Baker Creek 2003 (Dillon Consulting Ltd., 2004)
A6 Baker Creek Fish Habitat & Rehabilitation Study for Abandonment and Restoration Planning (Dillon Consulting Ltd, 1998)
A7 Fisheries (Golder Associates Ltd., 2001)
A8 Arsenic Concentration and Speciation in Fishes from Back Bay near Yellowknife, NT
A9 Muskrat Sample Collection Program at Baker Creek (Golder Associates Ltd., 2004)
A10 Giant Mine Migratory Bird Survey (Cygnus Environmental, 2005)
A11 Air Quality Monitoring at Giant Mine Site, Yellowknife: A Baseline Study (SENES, 2005)

B Geochemical Characterization

B1 Giant Mine Arsenic Trioxide Project, Structural Geology (SRK, 2002)
B2 Geochemistry of Mine Wastes, Giant Mine Site, Yellowknife, NT (Golder Associates Ltd., 2001)
B3 Tailings Backfill in the Giant Mine (SRK 2002)
B4 Giant Mine – Underground Mine Water Chemistry (SRK, 2005)
B5 Summary of Routine SNP Monitoring Programs (SRK, 2005)
B6 Giant Mine – Surface Water Chemistry (SRK, 2005)
B7 Giant Mine – Geochemical Characterization of Other Sources (SRK, 2005)

C Hydrogeology

C1 Giant Mine Hydrogeology (SRK, 2002)
C2 Update to Supporting Document 2 (SRK, 2004)
C3 Groundwater Monitoring System Installation Report 2004 (SRK, 2005)
C4 Groundwater Monitoring System: November 2004 Monitoring Update (SRK, 2004)
C5 Groundwater Modelling: Model Design and Simulation Results (SRK, 2005)
C6 Groundwater Modelling Update – Giant Mine Remediation Project (SRK, 2005)

D Arsenic Trioxide Dust Chambers & Stopes

D1 Crown Pillar Stability Evaluation: Arsenic Trioxide Dust Storage Chambers and Stopes (SRK, 2005)
D2 Arsenic Trioxide Chamber Drilling and Testing Program 2004 (SRK, 2005)

E Pit Stability

E1 Site Wide Crown Pillar Stability Investigation (SRK, 2006)

E2 Pit Stability Review – Giant Mine (SRK, 2005)

F Historic Foreshore Tailings

F1 Review of Yellowknife Bay Tailings Environmental Assessments (SRK, 2004)

F2 Investigation of the Distribution of Historic Tailings in North Yellowknife Bay (Golder Associates Ltd., 2005)

F3 The Potential for Geochemical and Microbial Remobilization of Arsenic from Sediments in Yellowknife Bay, Great Slave Lake: Progress Report 4 (Queen's University, 2004)

G Baker Creek

G1 Giant Mine Flood Hydrology (SRK, 2004)

G2 Baker Creek Restoration Concepts (nhc, 2005)

G3 Baker Creek and C1 Pit at the Giant Mine (Golder Associates Ltd., 2004)

H Borrow Sources

H1 Giant Mine Borrow Investigation (Golder Associates Ltd., 2004)

H2 Air Photo Interpretation of Potential Borrow Areas North of Giant Mine (Golder Associates Ltd., 2004)

H3 Summary of Potential Borrow Sources on Giant Mine Lease and in the Immediate Area (SRK, 2005)

I Surface Contamination Investigations

I1 Distribution of Arsenic in Surficial Materials: Giant Mine (Golder Associates Ltd., 2005)

I2 Subsurface Environmental Investigation - Petroleum Hydrocarbon Assessment, Giant Mine, Yellowknife, N.W.T (Golder Associates Ltd., 2001)

J Ground Freezing

J1 Conceptual Engineering for Ground Freezing (SRK, 2006)

K Tailings and Sludge Remediation

K1 Tailings and Sludge Containment Areas (SRK, 2005)

K2 Characterization of Soil and Groundwater in the Calcine and Mill Areas, Giant Mine (INAC, 2004)

L Water Treatment

L1 Water Treatment Update (SENES, 2005)

L2 Giant Mine Effluent Dilution Study (Hay & Co., 2005)

M Supporting Calculations of Arsenic Release

M1 Estimates of Flow and Arsenic Releases from Surface and Underground Sources (SRK, 2005)

N Risk Assessment

N1 Tier 2 Risk Assessment, Giant Mine Remediation Plan (SENES, 2006)

P Communications

P1 Giant Mine Remediation Plan Public Consultation and Communications (DIAND, updated 2007)

Q Project Implementation

Q1 Cooperation Agreement Respecting the Giant Mine Remediation Project (INAC-GNWT, March 2005)

Q2 Legislation, Policies and Guidelines

Q3 Withdrawal Order in Council

Q4 Environmental Impact Matrix (SRK, SENES, July 2007)

Q5 Scoping of Potential Cumulative Effects (SENES, 2007)

Q6 Socio-Economic Impact Assessment (INAC, 2007)

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1 Introduction

1.1 Site Location

The Giant Mine is located in Yellowknife, Northwest Territories about five kilometres north of the city centre. For the purposes of this document, the Giant Mine site is considered to include everything within the boundaries of former Lease L-3668T (now designated as Reserve R662T), as shown in Figure 1.1.1. Two impacted areas immediately outside of the lease area are also herein considered to be part of the site. They are the Giant Mine "Townsite", which was removed from the surface lease in 1999 and an area of historic tailings deposition along the shore of north Yellowknife Bay. These areas are also delineated in Figure 1.1.1.

1.2 Primary Concerns

The Giant Mine produced gold from 1948 until 1999, and gold ore for offsite processing from 2000 until 2004. Gold in the Giant Mine ore is associated with an arsenic-bearing mineral known as arsenopyrite. The roasting process used to liberate the gold from the arsenopyrite led to production of arsenic-rich gases. During the period 1951 to 1999, operators of the Giant Mine captured the arsenic-rich gases in the form of arsenic trioxide dust. Approximately 237,000 tonnes of the dust was pumped into sealed underground storage areas. The dust is approximately 60% arsenic, which is hazardous to both people and the environment. Furthermore, the form of arsenic present in the dust is soluble, meaning that it could dissolve in any water that contacts the dust and could then be transported to Baker Creek or Great Slave Lake.

There are many other concerns associated with the Giant Mine. Recovery of gold from the ore produced tailings that contain arsenic, mostly in the form of arsenopyrite but also in more soluble forms. A total of approximately 13.5 million tonnes of tailings are stored in four impoundments, which together cover 95 hectares of the site. Other areas have been contaminated with arsenic by emissions from the processing facilities, tailings spills, and use of mine rock for construction. There are over 100 buildings on the site that need to be removed, many of which are contaminated with arsenic and asbestos. There are eight open pits and 35 openings to the underground mine, all of which present safety hazards. Baker Creek flows through the site in a channel that has been heavily altered to accommodate mining, ore processing, and highway construction, and both its water and sediments are contaminated with arsenic.

1.3 Remediation Objectives

The Remediation Plan presented herein is intended to address all of the above concerns, and several others of lesser importance. The specific objectives of the remediation activities are:

1. To manage the underground arsenic trioxide dust in a manner that will prevent the release of arsenic to the surrounding environment, minimize public and worker health and safety risks during implementation, and be cost effective and robust over the long term;

2. To remediate the surface of the site to the industrial guidelines under the NWT *Environmental Protection Act,* recognizing that portions of the site will be suitable for other land uses with appropriate restrictions;

3. To minimize public and worker health and safety risks associated with buildings, mine openings and other physical hazards at the site;

4. To minimize the release of contaminants from the site to the surrounding environment; and

5. To restore Baker Creek to a condition that is as productive as possible, given the constraints of hydrology and climate.

1.4 Traditional Knowledge

Traditional knowledge studies are typically included in environmental assessments to help determine potential environmental and social impacts of new developments. In the case of Giant Mine, the environment has already been impacted by over 50 years of gold mining and processing activity. Consequently, this plan is focused on the remediation of an abandoned mine. However, as suggested by the Mackenzie Valley Environmental Impact Review Board in their *Guidelines for Incorporating Traditional Knowledge,* July 2005, considerable effort has been made to involve the holders of traditional knowledge in the Yellowknife region throughout the development of every aspect of this Remediation Plan. To the extent possible, traditional knowledge has been incorporated in the design and implementation of many baseline studies that form the foundation of this plan. In particular, traditional knowledge played a significant role in the design of the ecological and human health risk assessment and it was a foremost consideration in the design and implementation of the many information, workshop and consultation sessions.

The efforts to include traditional knowledge within the various components of the Remediation Plan will ultimately be reflected throughout the Giant mine site after the implementation of the remediation activities outlined in the plan have been completed. Furthermore, knowledge obtained from the holders of traditional knowledge in the Yellowknife area will be drawn upon in order to refine the long term monitoring components of the project.

Figure 1.1.1: Site Location

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In recognition of the importance of incorporating traditional knowledge into the Remediation Plan, the Giant Mine Remediation Project interim office entered into a comprehensive funding arrangement with the Yellowknives Dene First Nation to support their preparation of a traditional knowledge report with specific emphasis on documenting their perspective on the relationship that the Yellowknives Dene First Nation has had with the Giant Mine. Information for this study was initially gathered as an oral record and then compiled in the form of a Traditional Knowledge report by the Yellowknives Dene First Nation. With their permission this report is included as Supporting Document A1.

1.5 Legal and Regulatory Status

Environmental requirements for the Giant Mine were until very recently specified by the Type A Water License N1L2-0043. Two key components are the requirements for an "Abandonment and Restoration Plan" and an "Arsenic Trioxide Project Description". This Remediation Plan addresses both of those requirements.

An Abandonment and Restoration Plan was submitted to the Mackenzie Valley Land and Water Board in October 2001 by the licensee of the time, Miramar Giant Mine Ltd. That plan left several questions open, stating that they would be answered by the Arsenic Trioxide Project Description. At the same time, DIAND was working on plans for managing the arsenic trioxide dust, and provided several reports to the Board, notably a final report on the assessment of alternatives submitted in 2003. Once the most appropriate long term management plan for the underground arsenic trioxide was identified, it became clear that its final design and subsequent implementation could not proceed in isolation of the surface remediation. Therefore, this Remediation Plan addresses both the underground arsenic trioxide dust and surface decommissioning, cleanup, and reclamation.

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2 Site History

2.1 Early History

Before the development of mines in the area and the settlement of what is now known as the City of Yellowknife, the land was used by Dene groups, including the Yellowknives and the Dogrib. These people traveled and camped in the area, while harvesting food from the land and the lake. The earliest written records of the area make reference to a semi-permanent Dogrib fishing camp located across Yellowknife Bay, in the area now known as Dettah.

Many histories of the area state that gold colors were first discovered in the Great Slave Lake region in 1896, by miners on their way to the Klondike gold rush. Gold was found by prospectors in the Great Slave Lake area at least as early as 1900, but it was not until the 1930's, with the advent of aircraft travel in the far north, that significant mineral development began. The first mine to open in the present-day Northwest Territories was the Port Radium mine, on Great Bear Lake. It opened in 1933.

The Port Radium development stimulated mineral exploration throughout the area. The first non-native use of the Yellowknife area appears to have been as a semi-permanent float plane base to serve airborne explorers prospecting the surrounding area. However, it wasn't long before gold discoveries were made in the immediate vicinity. Numerous claims were staked around Yellowknife in the 1930's, leading to the opening of the Con Mine in 1938, and the first large-scale gold production in the area. The Yellowknife Administration District was created in 1939.

2.2 Industrial History

The original twenty-one mineral claims on which the Giant Mine is located were staked in 1935. Exploration of the property continued until 1944, at which time the decision was made to develop a mine. The first shaft was sunk in 1945, and mine production began on June 1, 1948.

Major milestones in the mine history are shown on a timeline in Figure 2.2.1. Figure 2.2.2 shows locations of the major site features referred to in the timeline.

The timeline and the following sections on the mine history are based primarily on information obtained from a review of monthly operational reports to the company Board of Directors, which are stored in the archives of the Prince of Wales Northern Heritage Center. Additional information was obtained from published papers (Pitcher 1953, Grogan 1953, McDonald 1953, Mortimer and Tait 1959, Foster 1963), from Royal Oak Mines Inc (1998a), and from selected correspondence in files located at the Giant Mine.

2.2.1 Mine Ownership

The original claims were staked by Burwash Yellowknife Mines Ltd. in 1935. Giant Yellowknife Gold Mines Ltd. (GYML) was incorporated in August 1937, as a joint subsidiary of Bear Exploration and Radium Ltd. and Yellowknife Gold Mines Ltd., after the latter acquired the assets of Burwash.

During the early 1940's, GYML and Frobisher Exploration Company Ltd. examined the possible geological relationship between the Con and Giant ground via the West Bay fault offset. As a result of this work, Frobisher, which was owned by a company called Ventures Ltd., optioned the remaining treasury shares of GYML in July 1943, and took over management control. Ventures Ltd. remained the property owner until 1962, when it merged with Falconbridge Nickel Mines Ltd.

Ownership changed again in 1986 when Pamour Inc., controlled by Giant Resources Ltd. of Sydney, Australia, bought Giant Yellowknife Gold Mines. Pamour was subsequently bought out by Royal Oak Resources in 1990. In the following year, Royal Oak Mines Inc. was formed to consolidate the assets of Pamour and Royal Oak Resources.

Royal Oak Mines Inc. continued operations at Giant Mine until 1999 when it went into receivership. A court-appointed receiver transferred control of the property to the Department of Indian Affairs and Northern Development (DIAND) in December 1999. Immediately, Miramar Giant Mine Ltd. (a subsidiary of Miramar Mining Corporation) purchased the Giant Mine from DIAND. Under the terms of the purchase agreement, DIAND indemnified Miramar Giant Mine Ltd. for existing environmental liabilities at the site. Concurrently, the Government of the Northwest Territories (GNWT) indemnified DIAND for certain liabilities associated with the surface of the mine. Additionally, under the terms of a reclamation security agreement with DIAND, Miramar Giant Mine Ltd. continued to ensure that the mine remained in environmental compliance. Until July 2004, Miramar Giant Mine Ltd. continued to mine ore from the Giant Mine on a greatly reduced scale. The ore was trucked to the Miramar Con Mine, located on the southern edge of Yellowknife. No further processing of ore took place at the Giant Mine and the roaster did not operate after 1999.

When mining ceased in July 2004, Miramar Giant Mine Ltd. gave DIAND the requisite notice that it would terminate its obligations under the reclamation security agreement on January 7, 2005. An extension of time was negotiated to allow DIAND, together with Public Works and Government Services Canada to enter into a contract arrangement for care and maintenance of the site. Following a competitive bidding process, Deton'Cho-Nuna joint venture was awarded the care and maintenance contract and, after a one month handshake period with Miramar Giant Mine Ltd., the joint venture commenced work on July 1, 2005.

The Giant Mine became "orphaned and abandoned" when Miramar Giant Mine Ltd. was assigned into bankruptcy by the NWT court. The trustee managing the bankruptcy surrendered the mineral rights to DIAND and, because the mine is on Commissioner's land, the surface land lease was returned to the GNWT. Mineral rights have been withdrawn.

Figure 2.2.1: Milestones in Site Development

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Figure 2.2.2: Major Site Features

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2.2.2 Mine Development

Underground mine development began in 1945 with the sinking of A-Shaft. A-Shaft was developed to provide access for exploration drilling and to allow development of the East Zone ore body. While the shaft was being developed, surface drilling identified high-grade ore further up the Baker Creek valley. The decision was made to develop the high-grade ore body first and B-Shaft was sunk in 1946 for this purpose. At the same time, the nearby C-Shaft collar was excavated and stabilized prior to mill construction, in anticipation of future development of the South and Central ore zones.

C-Shaft was sunk in 1949 and was connected to A- and B-Shafts via the 750 level by 1952. Once C-Shaft was connected to the major workings, it became the production shaft through which ore was hoisted to surface, and A- and B-Shafts were used primarily as service and ventilation openings.

Three mining methods were initially employed, including cut and fill, shrinkage, and open stoping. The selection of mining method for a particular stope was largely dictated by the shape, size and angle of the ore block. Shrinkage and open stoping were used exclusively until October 1950, at which time cut and fill methods became the preferred mining method. In addition to development waste rock, natural gravel excavated on surface was used as stope fill until 1957, at which time mill tailings became the main backfill material. A new tailings backfill preparation plant was commissioned in 1967, and tailings backfilling operations continued until 1978.

Economic ore reserves were practically depleted by the early 1970's. In order to keep the operation going while additional reserves were found, open pit mining began in 1974, with the excavation of A-1 pit, and continued through the 1970's with the development of the A-2, B-2 and B-1 pits. The B-1 pit, which lies close to several of the arsenic storage stopes, was worked from 1976 to 1978. Baker Creek was diverted in 1983 to allow the excavation of the C-1 pit. A total of eight pits were developed until open pit mining ceased in 1990. Since then, ore has been extracted only from underground workings.

2.2.3 Ore Processing

The Giant Mine ore has a complex mineralogy. Most of the gold occurs as extremely fine-grained particles that are "refractory", *i.e.* encased within larger grains of sulphide minerals, principally arsenopyrite and pyrite. An oxidation process is required to convert the dense sulphide grains into porous structures and expose the gold to cyanide leaching solutions. Roasting was the only efficient oxidation process available when the Giant Mine was developed. The ore processing system was therefore designed to concentrate the gold-bearing sulphide minerals using froth flotation, and then to roast the sulphide concentrate in preparation for cyanide leaching.

Ore processing operations began on May 12, 1948, with circuits for ore crushing, grinding, froth flotation, and mercury amalgamation. Initially, the flotation concentrates were stockpiled to await the completion of the roaster facility. Some free gold (gold not encased within sulphides) was recovered by mercury amalgamation during the period before the first roaster began operation.

An Edwards type multiple-hearth roaster, built by Allis-Chalmers, began operation in January 1949. The roaster calcine (oxidized product) was leached with cyanide solution. The gold was recovered from solution by precipitation onto zinc, and the zinc-gold product was smelted in a furnace to produce gold bullion. Gold was recovered using both mercury amalgamation and cyanidation methods until 1959, at which time amalgamation was discontinued.

The Allis-Chalmers roaster had a low capacity and was difficult to operate. Variability in feed rate and sulphide concentration caused major problems, and frequently required the roaster to be shut down and cleaned out. Additional difficulties were experienced with the calcine cyclone collectors. The temperatures at the exit point from the roaster were low enough that arsenic gases condensed, forming arsenic trioxide deposits that tended to plug the collector. Arsenic trioxide condensation also created difficulties in the roaster emission stack, where dust build-up caused operating problems.

Soon after roasting operations began, fluo-solids roasters were introduced to the market. Testing of Giant ore with the new roaster technology demonstrated that the best gold recovery could be achieved using a two-stage roast, where arsenic is eliminated in the first stage under reducing conditions, followed by an oxidation stage at a higher temperature. A two-stage fluo-solids roaster (known as the No. 1 Dorrco) was commissioned and put into operation in May 1952, when mill tonnage was increased from 425 tons per day to 700 tons per day. The No. 1 Dorrco initially operated in parallel with the Allis-Chalmers roaster. The company experimented with operating parameters for the No. 1 Dorrco for a couple of years in an effort to obtain a good compromise between gold extraction and electrostatic precipitator efficiency. This experimentation ended in 1954, when the roaster was operated to optimize extraction, and arsenic dust collection was addressed as a separate issue (see Section 2.3.1 for further information on arsenic fume management).

Mill tonnage was increased again in 1958, to 1000 tons per day. At the same time, the ore being mined became increasingly refractory. To cope with both of these changes, a new fluo-solids roaster (known as the No. 2 Dorrco) went into operation in November 1958, replacing the two other roasters. After an initial optimization period, the No. 2 Dorrco proved to be a much more efficient and reliable roaster. The No. 2 Dorrco roaster remained in operation until ore processing ceased at the end of 1999.

2.2.4 Tailings and Water Management

Tailings disposal began in 1948 with discharge directly into Back Bay. Beginning in February 1951, calcine and flotation tailings were deposited in Bow Lake, located in the area of the current North Pond. Dam construction began in 1955 with Dam 1, and continued through the early 1960’s with Dams 2 and 3. Together these dams formed the North Pond, and the original tailings disposal area now underlying the Settling and Polishing Ponds. Construction of Dams 4 and 5 began in the late 1960’s, closing off the south end of the area now known as the Central Pond.

The first documented engineering of tailings dams began in the mid-1970's, with designs for raising Dams 1, 2 and 3 (Geocon Ltd. 1975). Dam 6 was constructed in 1976, as a simple rockfill structure separating the North and Central Ponds. Dam 7 was built in the same year to contain seepage from Dams 4 and 5 on the Central Pond. Dams 9, 10, and 11 were constructed in 1983, and further raised in 1984, to create additional storage. The construction of Dam 11 created the South Pond, on the downstream side of Dams 4 and 5.

The Northwest Pond was created by the construction of Dams 21 and 22 in 1987 to serve as an impoundment for tailings recovered from the North and Central Ponds and processed in the Tailings Retreatment Plant (TRP), as well as new tailings from conventional ore processing. The relocation of tailings from the old storage area was discontinued in 1990 when the TRP shut down, while the deposition of new tailings in the Northwest Pond continued until milling operations ceased in 1999.

A storage pond was built in 1969 to store calcine tailings for summer re-processing in a kiln plant. The calcine pond is located west of the B-1 Pit, in an area now covered with soil removed from the pit.

Arsenic removal from the tailings effluent apparently began in 1957, when mine records indicate that a precipitation circuit was put into service. A new water treatment circuit was commissioned in June 1967, using lime to precipitate arsenic from the mill tailings stream before it was discharged to the active tailings pond. The precipitated arsenic was co-disposed with the mill tailings in the active tailings pond.

In 1978, as a condition of a new Water License, the mine owner was committed to improving the quality of effluent released to the environment. After conducting pilot testing in collaboration with Environment Canada, a new tailings effluent treatment plant started operating in August 1981. The new plant destroyed cyanide by alkaline chlorination, precipitated arsenic through the addition of ferric iron, and precipitated heavy metals with lime. Gold recovery from tailings effluent with carbon adsorption began in 1984. The chlorination stage of the treatment process was replaced by hydrogen peroxide oxidation in 1990.

Up until 1981, water pumped from the mine was discharged directly to Baker Creek near C-Shaft. Minewater was not used in the mill process, since the water quality had a negative effect on froth flotation efficiency. A 1981 requirement to treat minewater in the tailings effluent treatment plant led to the practice of storing minewater in the tailings ponds prior to treatment. The addition of minewater to the tailings ponds significantly reduced the available tailings storage capacity. To help avoid this problem, in 1985 the NWT Water Board approved the treatment and discharge of minewater directly to Baker Creek via the mill, but this option was never implemented. In 1997, a minewater treatment circuit was installed in the mill, allowing the treated water to be used in the mill process, and reducing the consumption of fresh water. Since 1999, when the processing of ore at the site was discontinued, minewater has been pumped to the South, North and Northwest Ponds for storage, and then treated in the existing water treatment plant prior to discharge to Baker Creek during the summer months.

2.3 Arsenic Trioxide Management History

As previously described, most of the gold in the Giant Mine ore is encased within larger grains of sulphide minerals, principally arsenopyrite and pyrite. The roasting process, used to oxidize the sulphide minerals and expose the gold prior to cyanide leaching, produced two major off-gases; sulphur dioxide and arsenic vapour. Initially, the roaster off-gases were vented directly to the atmosphere, with no recovery of arsenic, but since 1951 several generations of gas cleaning technology have been applied, leading to the production and disposal of arsenic trioxide dust as a waste by-product. Sulphur dioxide emissions were not reduced by any of the gas cleaning circuits installed. Major developments in the management of roaster off-gas and arsenic trioxide are summarized in Figure 2.2.1, and discussed in the following sub-sections.

2.3.1 Arsenic Fume Management

At the start of roasting operations in 1949, off-gas management was limited to the provision of a stack for release of gases and particulates to the atmosphere, where it was dispersed. The operation initially had regular problems handling the fumes. Fumes entered the roaster building, and numerous worker health problems were reported.

The first study of the effects of arsenic pollution in the Yellowknife area was initiated in May 1949. The results of this study, along with occupational health concerns and roaster operating problems associated with arsenic trioxide condensation, led mine management to the conclusion that arsenic fume emissions needed to be controlled. For this purpose, an electrostatic precipitator (an ESP, known as the "Cottrell Precipitator") was commissioned in October 1951, and the first large-scale arsenic trioxide collection began. The ESP initially operated as a "cold" unit, in which the inlet gas temperature was low enough that the arsenic was present as particulate arsenic trioxide, and was recovered from the gas by attraction to charged electrodes, along with very fine calcine dust carried over from the roaster.

The efficiency of the cold ESP dropped dramatically when the first fluo-solids roaster (the No. 1 Dorrco) was installed in May 1952. The fumes from the new roaster had an acid deficiency, which reduced the electrostatic charge on the dust particles and reduced the ESP collection efficiency. The new roaster also produced a greater load of fine calcine dust in the off-gas. The calcine dust not only overloaded the ESP, leading to higher arsenic trioxide emissions, but also resulted in significant loss of gold.

In an effort to recover the calcine dust separately from the arsenic trioxide, a second ESP was installed in February 1955. This "hot" unit operated above the temperature at which arsenic trioxide would condense, and was placed in front of the cold ESP. The system of passing roaster off-gas through the hot ESP, where calcine dust was recovered, and then the cold ESP, where condensed arsenic trioxide was recovered, worked quite well. However, the collection efficiency of the cold ESP decreased further due to the additional removal of acid in the hot ESP. Sulphuric acid and water vapour were added to the roaster off-gas in an attempt to increase the acidity in the fumes entering the cold ESP, with limited success. Eventually both ESP's were operated as cold units to improve the arsenic collection efficiency while additional research was undertaken.

When the second fluo-solids roaster (the No. 2 Dorrco) was commissioned in 1958, and the mill feed was increased to 1000 tons per day, a baghouse (known as the "Dracco Baghouse") was installed to handle the added arsenic trioxide burden. The baghouse began operating in November 1958, as the sole dust collection device in the system. Once the new roaster was operating efficiently, one ESP was put on-stream as a hot unit, to remove fine calcine dust in advance of the baghouse. After much experimentation aimed at optimizing the operation of the roaster and dust collection system, which was finally completed in 1963, the original cold ESP was converted to a hot unit and was put on-stream in parallel with the other hot ESP. This system, consisting of two hot ESP's operating in parallel, followed by a baghouse, was used until roasting operations ceased in 1999.

2.3.2 Arsenic Trioxide Dust Disposal

Arsenic trioxide dust formation was not anticipated during the initial development of the mine. When dust build-up in the stack became a problem, the material was periodically cleaned out and, according to mine records, was disposed of "in a suitable area in the north of the property". According to the records, surface disposal of arsenic trioxide dust occurred in July 1949 and February 1950, but the disposal locations are not recorded in any of the documents reviewed for this project. Recent investigations, described in Section 3.10 and Supporting Document I1, have found an area of arsenic contaminated mill wastes such as scrap wood, metal, glass, cloth and insulation. No other surface disposal areas have been identified.

With the first arsenic trioxide dust collection equipment scheduled to be on-line in 1951, the mine operators looked at options for storing the dust. Initial investigations focused on the sand plain west of the Yellowknife airport, and on Veronica Lake (now known as Pocket Lake), northwest of the process plant. The sand plain option was abandoned due to a high water table, and the Department of National Health and Welfare would not consider the Veronica Lake option until much more information was available. The time restrictions were such that sufficient environmental data for the proposed disposal area could not be collected before the arsenic trioxide recovery plant went into operation.

Other options being explored at the time included surface storage tanks and underground storage. In a letter dated July 21, 1950, the Department of National Health and Welfare stated that they regarded the use of concrete vats on surface as the safest method of storage. They also stated, however, they did not want to put mining companies to unnecessary expense and therefore would agree to other storage proposals provided certain criteria were met. The criteria were that the storage would last indefinitely and that a large capacity could be obtained at an economic cost.

Surface storage methods that were considered included wood, steel and concrete tanks. Wood and steel failed to meet the requirement of an indefinite life span. Concrete tanks were long lasting but the required storage capacity was such that a continuous construction program would be required to keep up with the anticipated dust production. It was felt that the amount of form lumber, steel and cement would be an excessively high cost.

An area of ground near the new arsenic recovery plant was selected as a potential underground arsenic disposal area, and was tested for stability and the presence of permafrost. Although it is not stated explicitly in the documents available from that time, it is clear that permafrost was to be the principal means by which the arsenic storage areas were to be kept dry, and prevent the dissolution of arsenic in groundwater. Testing of the ground was conducted by drilling exploratory holes from the 250 Level and from surface. From this drilling, it was determined that permafrost was present from above the 100 Level to below the 250 Level, that is, from 100 feet below surface to more than 250 feet below surface. Temperatures in two holes at the 250 Level were -0.5 and -0.4^{o}C. The drilling program also showed that there was not excessive fracturing in the rock.

In a February 1951 letter from the Mine Manager to the federal Department of Resources and Development, in which all the storage options were reviewed and permission was requested to use underground storage for the arsenic trioxide dust, the Manager stated that the proposed storage area was located in permafrost. In addition, he stated that active mining tended to thaw the surrounding walls, but frozen conditions returned within a few hours after work was completed. Ice conditions in the closest working stope (B208) were presented as supporting evidence.

The first arsenic storage chambers were located close to the arsenic recovery plant, in the horizon from 100 feet through 250 feet below surface, identified as the permafrost zone. This area contained low-grade ore and was mined for gold recovery. Arsenic trioxide disposal began in this area in October 1951 and continued until 1962, by which time five storage chambers had been excavated and there was little space left for new excavations located close to the baghouse, in permafrost ground.

Arsenic trioxide disposal then switched to the early ore production stopes that met the storage criteria, and were now empty, beginning with the B208 stope. Mined-out stopes had the advantage of requiring less preparation time than purpose-built dust storage chambers, and therefore had a lower development cost. In applying for approval to use the mined-out stopes, B208 and B212, B213 and B214, the mine company emphasized that these areas were dry and located in the same horizon as the existing disposal stopes. Ice crystals were observed in B208, but not in B212. To counter the argument that the warm dust would make any permafrost recede, freezing air was to be circulated in all arsenic storage stopes during the winter months to maintain permafrost in the surface crown pillar, thereby preventing water inflows to the stopes.

In 1966, while considering a proposal for the development of new storage capacity, DIAND mining inspectors recognized that permafrost had receded in mine areas that were well ventilated. DIAND questioned whether permafrost was still present at the upper stope level, noting that the proposed new storage area close to C-Shaft was located under Baker Creek, and some of the insulating material had been removed by earlier development. DIAND agreed that the mined-out C212 stope appeared to be a suitable area for arsenic trioxide disposal (it was within the permafrost zone), but requested that rock temperature data be collected to verify that the stope was in permafrost. DIAND objected to the disposal of the dust in stopes located below the lower level of the permafrost zone. Although the mine claimed that these stopes were dry, DIAND questioned whether they would remain dry, if the permafrost in the surface bedrock and overburden became fragmented.

In an internal memorandum of May 1973, the Mining Inspector expressed concern regarding the potential for arsenic pollution from the Giant Mine, if it were to be flooded after a shut-down proposed for 1975, and permafrost was not present. The Inspector presented evidence of permafrost thawing in other mine workings to depths of at least 50 feet, and clearly questioned the continued presence of a permafrost zone at the Giant Mine. He recommended that the mine should not be allowed to flood until the extent and permanency of the permafrost was established through a long-term rock temperature monitoring program. Such a program was not established until the mid-1990’s, when temperature measurement devices were installed in several new drillholes.

In 1977, the Canadian Public Health Association (CPHA, 1977) Task Force on Arsenic was established, to assess the effects of arsenic emissions on the population of Yellowknife. The Task Force was charged with examining the issue of “whether or not there is a serious health hazard to the community of Yellowknife as a result of possible arsenic poisoning”. The terms of reference for the Task Force included the review of existing data, the identification of any additional data required, and the task of ensuring that such data were obtained. The Task Force was to recommend any remedial action required to address the issue. The task force report, published in December 1977, looked at potential effects in the Yellowknife population of arsenic exposure from soil, water, food and air, as well as occupational exposure (CPHA 1977). The report made recommendations on issues ranging from food hygiene practices to industrial emissions control measures. With respect to arsenic trioxide management, the report recommended that underground storage of the arsenic trioxide dust at the Giant Mine should continue, pursuant to requirements specified by the Mining Inspection Branch.

By the end of the 1970’s, there was strong observational evidence that permafrost in the arsenic storage areas was receding and the movement of groundwater in these areas was increasing. The loss of originally present permafrost may have been caused by the progressive development of mine workings near the storage areas and the movement of warm ventilation air. This would have been accelerated by the development of open pits in the area, which removed insulating overburden from the surface.

All former production stopes suitable for arsenic trioxide disposal were filled by 1976. During the 1970’s greater emphasis was placed on maximizing the amount of dust storage in existing stopes, to avoid developing new storage areas. Older storage stopes were “topped up” as the dust consolidated over time. The possibility of mechanically compacting the material before it was placed in the stopes was investigated. It was also anticipated that future production of dust could be sold, and the mine investigated the purification of arsenic trioxide for sale. In fact, the sale of dust did not begin until 1981. More efficient use of existing storage space did not stop the development of new storage.

A new purpose-built chamber, chamber 9, had to be rapidly excavated in 1976 to keep up with dust production.

Raw arsenic trioxide dust from the baghouse was sold to Koppers, a manufacturer of pesticides located in Georgia, USA, from 1981 to 1986. The amount of dust sold was less than the ongoing dust production and underground storage continued throughout the 1980's, with the development of chamber 10, near C-Shaft, and later chambers 11 and 12 in a new area adjacent to the B2 Pit. A downturn in the arsenic trioxide market, and introduction of stricter waste disposal regulations in the USA in the mid-1980's, led to the termination of sales of low-grade arsenic trioxide dust produced by the baghouse.

At this point, it became clear that the arsenic trioxide baghouse dust could only be sold in the future if it was purified, which would require a new process. This option was actively pursued and investigated by the mine owner in the late 1980's, culminating in the detailed feasibility study of an upgrading project, known as the WAROX Project (named after the acronym for the registered trade-name White ARsenic OXide). The WAROX Project would use a fuming process to purify dust from the underground storage areas to greater than 95% arsenic trioxide, and recover gold from the fuming residue. Interest in implementing the project was lost when the property was sold to Royal Oak Resources in 1990. Chambers 14 and 15 were excavated for arsenic trioxide disposal in the 1990's. Chamber 15 had not been commissioned by the time on-site ore processing ceased in October 1999, and remains empty.

Until the 1980's, standard procedure in the development of dust storage areas was to cut off ventilation of warm air, and to blow cold air through the chamber or stope during the winter prior to first use, to re-establish the permafrost. It was concluded that permafrost was in place if ice or frost was visible on the walls. From the mid 1980's onward, the criteria for selecting suitable areas for development of storage chambers no longer included the presence of permafrost. An area was considered suitable if the rock was competent, the area could be effectively sealed off from other mine workings, and the excavation was generally dry before dust storage commenced. The last four chambers (11, 12, 14 and 15) were excavated partially above the elevation of the original permafrost zone. In the minutes of a meeting held in December 1995, the Mine Captain noted that in the regular inspections he conducted since 1986, ice was never observed in any of the arsenic chambers or stopes.

All of the underground excavations used for storage of arsenic trioxide dust are listed in Table 2.1, along with the year of their commissioning. The excavations are identified either as purpose-built chambers or mined-out stopes.

Table 2.1: Underground Arsenic Trioxide Dust Storage Excavations

Excavation Identification	Excavation Type	Year of Commissioning
B230	Chamber	1951
B233	Chamber	1952
B234	Chamber	1956
B235 / 236	Chambers	1958
B208	Stope	1962
B212 / 213 / 214	Stopes	1965
C212	Stope	1973
9	Chamber	1976
10	Chamber	1982
11	Chamber	1986
12	Chamber	1988
14	Chamber	1995
15	Chamber	Not used

Prepared by: srs
Checked by: mdr

2.4 Recent Site Management

2.4.1 DIAND and MGML

As discussed in Section 2.2.1, Miramar Giant Mine Limited (MGML) was responsible for the management of all site activities relating to ore production and environmental protection from the end of 1999 until June 2005. Ore production ceased in 2004, and the Deton'Cho-Nuna joint venture now provides care and maintenance under contract to the federal government. Routine environmental protection activities have included pumping water from the underground mine to the surface storage ponds, monitoring and maintaining the tailings dams, operating the water treatment system and discharging treated water during the open water season, and monitoring environmental quality. In addition to the routine activities, numerous projects have been undertaken since 1999 to assess site conditions and conduct progressive remediation. Progressive remediation projects conducted since 1999 include the disposal of lead-acid batteries, disposal of transformers containing PCB fluids, disposal of waste oils and fuels, disposal of asbestos waste, secure storage of arsenic contaminated waste, disposal of non-hazardous waste, improvements to surface drainage, and demolition of fuel storage tanks and small buildings.

2.4.2 Studies of the Giant Mine Site

Since the bankruptcy of Royal Oak Mines in 1999, DIAND has commissioned numerous studies of the mine site, either directly or through contractors and consultants. Specifically in 2000, DIAND contracted a Technical Advisor to thoroughly evaluate possible alternatives for the management of the arsenic trioxide dust stored underground at the mine and to recommend a preferred alternative. After taking into account the recommendations by the Technical Advisor and an Independent Peer Review Panel, as well as public input gathered at workshops and other information sessions, DIAND announced in February 2004 that it planned to proceed with the “Frozen Block” alternative for the management of the arsenic trioxide dust stored underground.

Once this decision had been made, it became clear that the existing Abandonment and Restoration Plan for the surface of the mine would have to be modified because of many interrelationships and linkages between surface and underground components of the mine. This led to the conclusion that it would be necessary to prepare an integrated plan describing both surface and underground remediation activities planned for this mine site. The decision to prepare this integrated Giant Mine Remediation Plan was supported by a recommendation from the Independent Peer Review Panel.

In addition to the comprehensive and wide ranging studies on arsenic dust management options undertaken by the Technical Advisor, many other baseline environmental studies were completed at the mine to further quantify existing conditions. A complete list of these and other previous studies is included in Supporting Document A2.

2.4.3 Public Consultation

Communicating accurately with and getting input from the public in Yellowknife, Ndilo and Dettah is a keystone of DIAND’s approach to the Giant Mine project. DIAND’s commitment is substantiated by the fact that 63 communication and consultation activities directly related to Giant Mine, have been undertaken by the Giant Mine Remediation Project Team since 1999. The main goals of these efforts to date have been to inform the public of the current situation and conditions of the site, the options for long-term management of the arsenic trioxide dust and to solicit input from the public on these options.

In addition to the direct initiatives of DIAND, the project has a second avenue of communication through the Giant Mine Community Alliance (GMCA), a group of Yellowknife residents, representing various stakeholders with interests in the Giant Mine Remediation Project. The Alliance’s mandate is to act as liaison between the public and DIAND, by relaying to DIAND public concerns and issues regarding the Giant Mine Remediation Project and also by assisting DIAND by communicating their activities on the site to the public, thereby improving the public’s understanding of the project. The GMCA regularly comments on DIAND consultation initiatives and offers suggestions. The GMCA has undertaken public outreach work, including hosting public info sessions and conducting surveys. The Alliance meets regularly with the GMRP team for project updates and to voice questions and concerns on behalf of the public.

Soon after Royal Oak Mines went into receivership, DIAND convened a technical workshop in July 1999 to initiate public discussion and review of potential alternatives or options for the management of the large amount of arsenic trioxide dust stored underground at Giant Mine. Subsequently in September of the same year, DIAND held a public information event with an open house and evening presentations.

After extensive analysis by the Technical Advisor, review by the Independent Peer Review Panel, and taking into account public input, 56 options were reduced to 12 alternatives which were then narrowed down to two preferred alternatives: leave the arsenic underground and freeze it or take it out and store it on surface. A great effort was made to explain these two alternatives to the public, and to gather input on the selection of one alternative. These options were presented at a two day public workshop held in January 2003.

At the January, 2003 workshop, the public informed DIAND that it required more information and more time regarding the choice of the most appropriate management alternative for the arsenic trioxide dust in underground storage. Consequently, DIAND extended its communications activities by four months and provided an additional 20 public information sessions and events from March through May, 2003. This communication effort culminated in a two day public workshop in May, 2003. At this workshop, attendees were in a better position to understand the presented material and to express a preference for one of the two long term management alternatives brought forward, in part, due to the extensive communication efforts preceding the workshop.

After taking into account the considerable feedback received from the public and other stakeholders during the public workshops and information sessions, and based on the recommendations of the Technical Advisor and the Independent Peer Review Panel, DIAND announced in February, 2004, its decision to proceed with the in situ Frozen Block Method as the preferred management alternative for the arsenic trioxide stored at Giant Mine. At approximately the same time the GMRPT began integrating remediation plans for the underground with those required for the surface. Ongoing communications efforts are focussed on working with the community to further inform them and to respond to their questions and concerns regarding all aspects of the integrated Giant Mine Remediation Plan.

2.4.4 Other Communication Initiatives

Website

DIAND's Giant Mine Remediation Project website first unveiled in 2002, was re-designed in May, 2004 and provides current, accurate information on the project. The website is now easier to use, and provides clear links to both DIAND's Giant Mine Remediation Team and the Giant Mine Community Alliance. The website address is www.giant.gc.ca.

Media

DIAND's Giant Mine Remediation Project team makes a point of being available to respond to all media inquiries. This is a key part of the team's commitment to being open and honest with the public. GMRP spokespeople have responded to many media requests from both local and national media, including the Yellowknifer, News North, L'Aquilon, CBC North, CBC's Country Canada, the Globe and Mail, the National Post, Edmonton Journal, Global Television, The Nature of Things, and The Fifth Estate. Media have also been regularly taken on tours of the Giant Mine site, both surface and underground. The media typically receive invitations to technical briefing sessions prior to or during all major communication events.

Public Registry

DIAND created the Giant Mine Public Registry in 2000. This registry currently contains 74 documents regarding Giant Mine, both historical and current, and provides the public with the opportunity to review technical project information. The registry is located in the Giant Mine Remediation Project Office in Yellowknife.

Ongoing public interactions

DIAND's GMRP team remains accessible to the public to answer questions and field public input. This openness has been a key feature of this office since 1999, and members of the public regularly contact the GMRP team. For example, since January 2003, the Giant Mine Remediation Project Team have held 25 information sessions and stakeholder briefings and approximately 15 Giant Mine site tours to help inform and educate the public, and to respond to their questions and concerns.

The public is encouraged to visit the GMRP office, to call or email the team regarding any aspect of the project. DIAND and the GMRP team well understand the importance of this project in the communities of Yellowknife, Dettah and Ndilo, as well as the ongoing need for public dissemination of current, accurate information. Alternatively, members of the Giant Mine Community Alliance may be contacted for information regarding the project. The Giant Mine Remediation Project team will continue to provide tours, presentations, as required.

Supporting Document P1 contains more specific details and information regarding DIAND's communications activities and products. Also included in this supporting document are all available reports on workshops and information sessions that DIAND has held since 1999.

2.4.5 DIAND-GNWT Cooperation Agreement

The federal and territorial governments entered into a Cooperation Agreement respecting the Giant Mine Remediation Project on March 15, 2005. The agreement calls for both parties to coordinate care and maintenance activities and to finalize a Remediation Plan for the site that is cost effective and will ensure continued protection of human health, public safety and the environment. The agreement also outlines the financial responsibilities of the parties relative to care and maintenance, the cost share for surface remediation and the acknowledgement by the federal government of long term responsibility for the arsenic trioxide stored underground at the site. The agreement does not transfer jurisdictional responsibilities or liabilities that each party otherwise may have with respect to the site.

Under the Cooperation Agreement the federal and territorial governments have agreed to establish and implement a protocol for communications on all aspects of the Giant Mine Remediation Project. Within this protocol the parties will work together to share information with the public.

3 Current Site Conditions

3.1 Arsenic Trioxide Dust Storage Areas

3.1.1 Dust Inventory

Arsenic trioxide dust has been stored underground at Giant Mine since 1951. As discussed in Section 2.3, the dust was collected in the baghouse and pneumatically placed in purpose built chambers and mined out stopes.

The estimated inventory of arsenic trioxide dust stored in each of the chambers and stopes is shown in Table 3.1. These estimates were compiled by the mine operators throughout the period of dust production, from 1951 through 1999. The inventories of dust in chambers B230, B233 and B234, up to 1958, were estimated based on the chamber dimensions and the estimated bulk density of the dust. After 1958, dust production was calculated by the mine on a daily basis, using mass balance methods.

Table 3.1: Inventory of Arsenic Trioxide Dust Stored Underground at Giant Mine

Chamber / Stope	Dust Inventory (dry tonnes)	Primary Filling Period
B230	2,835	1951 to 1952
B233	11,426	1952 to 1956
B234	12,048	1956 to 1958
B235 / 236	32,945	1958 to 1962
B208	29,364	1962 to 1964
B212 / 213 / 214	59,289	1965 to 1973
C212	16,946	1973 to 1982
9	18,394	1976 to 1980
10	9,569	1982 to 1985
11	5,860	1986 to 1988
12	26,243	1988 to 1994
14	12,257	1995 to 1999
15	0 (empty)	na
Total	237,176	1951 to 1999

Prepared by: srs
Checked by: mdr

3.1.2 Dust Properties

Data Sources

The physical and chemical properties of the arsenic trioxide dust have been assessed in several studies conducted over the past twenty years. The most important of these studies are:

- Routine gold and arsenic assays by the mine staff;
- Sampling of underground dust and testing of geotechnical properties (Geocon Inc. 1981);
- Analysis of arsenic and gold content of Geocon (1981) samples (Giant Yellowknife Mines Ltd. 1982);
- Testing of flow properties of Geocon (1981) samples (Jenike & Johanson 1982);
- Chemical and particle size analyses of dust product from the baghouse (New Brunswick RPC 1988, Royal Oak Mines Inc. 1998a);
- Chemical properties and mineralogy of dust product from the baghouse and underground dust samples (CANMET 2000); and
- Physical and chemical properties of later baghouse dust production (Lakefield Research 2002).
- A supplementary investigation was carried out in the winter of 2004 by drilling into selected chambers and stopes to measure in situ physical properties of the dust, collect and analyse samples of the older dust, and install monitoring instruments in selected chambers and stopes.

Results from this program are presented in Supporting Document D2, which includes reports on:

- The drilling, in situ testing and sample collection;
- Chemical analysis and physical testing of the arsenic trioxide dust samples (SGS Lakefield Research 2004);
- A mineralogical investigation of the arsenic trioxide dust samples (CANMET 2004a); and
- Laboratory measurements of the thermal properties of the dust (CANMET 2004b).

Physical Properties

Table 3.2 provides a summary of physical properties measured in the studies to date. The investigations did not recover undisturbed samples, although direct and indirect *in situ* testing was performed. The recovered dust samples were tested for a wide range of parameters to characterize the physical, chemical and thermal properties. The *in situ* testing provided some indication of the in-place density and strength of the material, through standard penetration tests and cone penetrometer testing. Moist zones were encountered in some of the 2004 drillholes, but the majority of the dust was dry.

In general, the testing showed that although the arsenic dust is very fine-grained, it behaves like a loose granular material when dry. In particular, its strength increases linearly with the confining pressure of the overlying material. The hydraulic and thermal properties shown in Table 3.2 were used in subsequent modeling.

Table 3.2: Physical Properties of Arsenic Trioxide Dust

Parameter	1981 and 2002 Data	2004 Data	Best Estimate Values
Grain Size	92 – 97% <0.0045mm	72 - 98 % <0.0045mm	88.5% (<0.0045mm)
Dry Density (kg/m^3)			Avg. = 1402 kg/m^3
Maximum	1107 - 1459 kg/m^3	1414 - 1726 kg/m^3	1726 kg/m^3
Minimum	636 - 891 kg/m^3	1333 - 1369 kg/m^3	654 kg/m^3
Specific Gravity	2.6 – 3.8 (avg. 3.17)	3.3 – 3.8 (avg. 3.48)	3.38
Atterberg Limits			
Liquid limit	inconclusive	25.0 – 41.7%	32 %
Plastic limit	19% - 24%	Non-plastic and 28.5% – 35.3%	30 %
Angle of Repose	46° - 58°	nt	46° - 58°
Angle of Internal Friction	33° - 35°	nt	33° - 35°
Hydraulic Conductivity (at 1150.1 kg/m3)	7 x 10^{-7} m/s	nt	7 x 10^{-7} m/s
Thermal Conductivity		0.47 - 2.02 W/(mk)	0.47 - 2.02 W/(mk)
Frozen	0.093 W/(mk)		0.093 W/(mk)
Unfrozen	0.100 W/(mk)		0.100 W/(mk)
Freezing point of saturated solution	-0.7°C	nt	-0.7°C

Notes: nt - not tested

Prepared by: mdr
Checked by: mrl

Arsenic and Gold Content

The arsenic trioxide dust was assayed for arsenic and gold on a routine basis, generally daily, throughout the dust production period, from 1951 through 1999. The weighted averages of these assays for the entire inventory of each chamber and stope are shown in Table 3.3. Although many samples of dust have also been chemically analyzed for the various studies conducted since 1981, the mine production assays provide the most reliable estimates of the arsenic and gold contents of the dust, since the estimated average for each chamber and stope is based on the assays of hundreds, or even thousands, of dust samples.

The roasting and gas cleaning circuits of the plant saw a number of changes during the early production period, the most significant of which were changes to the "Cotrell" electrostatic precipitator circuits and the installation of a baghouse. The major changes affecting the quality of the arsenic trioxide dust were made in the period from 1958 through 1963, while the B235 and B236 chambers were being filled. The average production assays in Table 3.3 show significantly lower arsenic concentrations and higher gold concentrations in the dust produced before these changes were completed. The estimated total inventory of gold in the dust is approximately 4.3 million grams, and about 60% of the gold is contained in the five oldest chambers, which hold just 25% of the total dust inventory.

The average arsenic content of the dust produced after the major plant changes were completed is generally above 65%, which is equivalent to about 86% arsenic trioxide. Loss of gold to the arsenic trioxide dust product was reduced to very low levels by the 1970's, and the average gold content of the later dust production is actually less than the grade of ore being mined at the time.

Table 3.3: Arsenic and Gold Content of Arsenic Trioxide Dust

Chamber / Stope	Production Assays 1951-1999	
	Arsenic (%)	Gold (grams/tonnes)
B230	45.3	24.8
B233	36.9	57.3
B234	36.1	80.0
B235 / 236	53.7	26.3
B208	65.7	12.1
B212 / 213 / 214	61.7	15.5
C212	65.6	5.9
9	67.5	4.3
10	66.8	4.6
11	67.4	4.8
12	65.9	5.9
14	65.5	5.5
Averages	60.1	18.1

Prepared by: srs
Checked by: mdr

Other Chemical Components

The drilling program conducted in 2004 provided an opportunity to sample dust produced over an extensive period of the mine history, from the 1950's through the 1970's, and to analyze the samples for a complete suite of chemical components. The results of these analyses are shown in Table 3.4. The data indicate that the material collected from chamber B233, the oldest dust, is distinctly different from the other materials. The oldest material has significantly higher concentrations of all the elements measured above the method detection limits, with the exception of arsenic and antimony. In particular, the silver, copper, iron, lead and zinc contents of the oldest dust are much higher than found in the dust produced later. These differences reflect the inefficiency of the plant, during the 1950's, in separating arsenic trioxide from other components of the dust produced by the roaster.

The sample collected from chamber B235 has chemical characteristics that are similar to the material collected from the chambers and stopes that were filled later. This chamber was filled while major modifications were being made in the plant and the dust properties were changing, from 1958 through 1962. The chamber was also "topped up" with new dust in 1988. The analytical results suggest that the sample collected from B235 probably represents later production.

Table 3.4: Results of Chemical Analyses of Arsenic Trioxide Dust Samples

Chamber / Stope	B233	B235	B208	B212	B214	C212	C212
Primary Filling Period	1952 to 956	1958 to 962	1962 to 1964	1965 to 1973	1965 to 1973	1973 to 1982	1973 to 1982
Sample ID	B233-P9	B235-P13	B208-1 Comp	B212-4 Comp	B214-1 Comp	C212-2 (140'-168')	C212-2 (168'-189')
Ag (mg/kg)	38	9	4	6	9	<2	6
Al (mg/kg)	19000	7700	4300	7300	12000	9300	6700
Ba (mg/kg)	44	24	16	25	30	25	16
Be (mg/kg)	<0.2	<0.2	<0.5	<0.5	<0.5	<0.2	<0.2
Bi (mg/kg)	<20	<20	<20	<20	<20	<20	<20
Ca (mg/kg)	9300	2900	2300	3400	5300	6800	2300
Cd (mg/kg)	<25	<25	<8	<8	<8	<25	<25
Co (mg/kg)	110	28	<25	26	43	22	28
Cr (mg/kg)	71	20	16	22	36	30	23
Cu (mg/kg)	810	240	100	160	230	130	230
Fe (mg/kg)	150000	20000	18000	25000	42000	23000	21000
K (mg/kg)	5200	2000	1200	2200	3600	2600	1900
Li (mg/kg)	<40	<40	<40	<40	<40	<40	<40
Mg (mg/kg)g	5900	2900	1600	2200	3600	5500	500
Mn (mg/kg)	300	100	74	85	130	170	88
Mo (mg/kg)	<20	<20	<20	<20	<20	<20	<20
Na (mg/kg)	960	600	230	370	560	270	230
Ni (mg/kg)	230	48	40	50	83	42	53
P (mg/kg)	<100	<100	<100	<100	<100	<100	<100
Pb (mg/kg)	4300	440	470	810	1200	240	550
Sb (mg/kg)	18000	3700	11000	17000	16000	2100	3600
Se (mg/kg)	<60	<60	<60	<60	<60	<60	<60
Sn (mg/kg)	<40	<40	<40	<40	<40	<40	<40
Sr (mg/kg)	14.0	5.8	3.2	6.0	9.4	8.1	5.7
Ti (mg/kg)	2000	610	160	310	330	840	510
Tl (mg/kg)	<60	<60	<60	<60	<60	<60	<60
V (mg/kg)	73	30	18	28	44	39	26
Y (mg/kg)	2.1	1.0	0.7	1.0	1.6	0.9	0.9
Zn (mg/kg)	2100	290	300	420	640	220	250
As (%)	39.5	66.0	66.5	60.2	57.8	62.7	66.3
Grain Size um (80%<)	45	10.4	36.8	18.4	15.2	55	51

Note: "Comp" refers to composite sample from different depths. Other samples are from depth range listed.

Prepared by: srs
Checked by: mrl

Arsenic Solubility

The water solubility of arsenic from several samples of dust, produced from the 1960's through the 1990's, was determined as part of a study conducted in 1999 (CANMET 2000). The tests were conducted at temperatures typical of the present minewater. The results are summarized in Table 3.5.

The ranges in the table indicate the variability in arsenic solubility. The variability appears to be correlated with the antimony content of the samples. Samples with higher antimony content tend to show a lower arsenic solubility.

Table 3.5: Solubility of Arsenic Trioxide Dust

Solution Temperature	Soluble Concentration (g/L)	
	as Arsenic Trioxide	as Arsenic
5° C	6.0 – 11.9	4.6 – 9.0
10° C	6.9 – 12.4	5.2 – 9.4

Note: Data from Canmet 2000

Prepared by: srs
Checked by: mdr

3.1.3 Storage Chambers and Stopes

Locations

The locations of the underground arsenic trioxide dust storage areas are shown in relation to surface features in the central mine area in Figure 3.1.1. As discussed in Section 2.3.2, the dust is stored in both purpose-built chambers and mined out stopes. For ease of discussion, the chambers and stopes are often referred to as being in four areas, referred to as AR1 through AR4, and also shown on Figure 3.1.1, and in detail in Figures 3.1.2 through 3.1.6.

A total of ten purpose-built chambers and five mined-out stopes were used to store the dust, although the stopes B212, B213 and B214 are joined together and can be considered as one excavation. All of the chambers and stopes are located in the central area of the mine, close to the processing plant where the dust was produced. The chambers and stopes are relatively close to the surface, with most of the excavations extending from about 20 metres to about 75 metres below the ground surface. All of the chambers and stopes are sealed by concrete bulkheads, which isolate the dust storage areas from the other mine workings.

Arsenic dust was distributed pneumatically through a series of pipes from surface. Most of the pipes are still in place and may contain residual arsenic trioxide dust. Distribution pipes are shown in Figure 3.1.7.

Figure 3.1.1: Dust Storage Chambers and Stopes

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Figure 3.1.2: 3D View of AR1 Chambers

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Figure 3.1.3: 3D View of AR2 Chambers and Stopes

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Figure 3.1.4: 3D View of AR3 Chambers (without B208)

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Figure 3.1.5: 3D View of Stope B208

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Figure 3.1.6: 3D View of AR4 Stopes

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Figure 3.1.7: Location of Arsenic Distribution Pipes

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Geology of the Storage Areas

Supporting Document C1 provides an overview of the structural geology of the mine area in general, and the arsenic storage areas in particular. Further details can be found in Supporting Document C3. In brief, the arsenic chambers and stopes are located in a volume of rock that is bounded by three major faults. The major faults do not intersect any of the arsenic storage chambers or stopes, with the possible exception of chamber 15, which is empty.

In the main ore zones, the rock is of two types, known as sericite schist and chlorite schist. The sericite schist rocks have particularly well-developed small scale fractures, possibly leading to increased hydraulic conductivity and stability problems. The chlorite schist appears to be more ductile, and therefore does not fracture as readily.

The B212, B213 and B214 stopes occupy a hinge in a major fold in the sericite schists. The intensity of the fracturing and its horizontal orientation mean that this area is prone to instability, as evidenced by the presence of several wall failures. The rock surrounding the other stopes and chambers is generally either the less fractured chlorite schist or sericite schist with dominantly vertical fractures. These areas are expected to be more stable.

Chamber and Stope Geometry

Three-dimensional views of the chambers and stopes are presented in Figures 3.1.2 to 3.1.6, and summary dimensions are shown in Table 3.6. The chambers and stopes vary considerably in dimensions, shape and volume. The chambers, which were excavated for the purpose of storing arsenic dust, are generally rectangular shaped cavities, with vertical walls. Figures 3.1.2 and 3.1.4 show the purpose-built chambers in areas AR1 and AR3 respectively.

In contrast, the stopes were originally excavated to follow the ore body and are quite irregular in shape. They are generally narrower than the chambers and have inclined walls. Figures 3.1.3 and 3.1.6 show the mined-out stopes in areas AR2 and AR4 respectively. Figure 3.1.5 shows B208, which is also a mined-out stope, although it is typically grouped with the nearby chambers in AR3. The irregular nature of the stopes means that extensive access workings were developed to allow efficient removal of ore. As a result, there are numerous openings from the stopes into ore chutes, raises and drifts, most of which are probably filled with arsenic trioxide dust.

Water Levels

Water pressures in the dust and overlying rock are monitored by vibrating wire transducers emplaced during the 2004 investigations. In all but B208 and C212, the dust appears to be unsaturated. However, there is certainly seasonal variability in the rate of water inflow to the mine as a whole, so it is possible that the instruments installed in the dust will show saturated zones during future high inflow periods. Monitoring of water pressure on the bulkheads below stope B208 has clearly shown the pressure of a saturated zone, which has increased during previous spring freshets.

Table 3.6: Approximate Chamber and Stope Dimensions

Identification	Excavation Type	Width (m)	Length (m)	Maximum Height (m)	Excavation Volume (m^3)
B230	Chamber	9	23	21	2,800
B233	Chamber	16	35	45	12,300
B234	Chamber	12	35	46	12,000
B235	Chamber	15	35	51	17,900
B236	Chamber	14	35	47	15,200
B208	Stope	24	65	50	22,800
B212	Stope	31	52	57	25,700
B213	Stope	31	17	39	9,400
B214	Stope	31	28	25	12,400
C212	Stope	19	92	49	18,100
9	Chamber	17	35	57	13,300
10	Chamber	11	26	55	5,700
11	Chamber	16	38	23	9,800
12	Chamber	15	70	36	25,500
14	Chamber	14	54	24	12,000
15	Chamber	15	60	30	27,000

Prepared by: bm
Checked by: rc

Temperature

Temperatures in the dust and overlying bedrock and overburden are also being monitored using the instruments strings installed in 2004. The temperatures observed to date range from -4 to +5°C and are consistent with previous temperature monitoring in the immediate area.

3.1.4 Crown Pillar Stability

The mass of bedrock overlying an underground excavation, such as a stope, is known as the crown pillar. Crown pillars can be a long term concern if there is a potential for the rock to collapse, creating a new opening to the surface. The potential for collapse depends on the geometry of the crown pillar, the strength of the rock, and the support provided by any backfilled material inside the excavation.

The geotechnical stability of crown pillars above the arsenic chambers and stopes has been investigated in a series of studies. An initial review (SRK 2001a) found that the chambers all have relatively thick crown pillars, and failures appear to be unlikely. However, the crown pillars above the stopes are not as thick, and their stability may be a concern. In particular, the excavation of the B1 open pit adjacent to stopes B208 and B214 may have created areas where the crown pillars (and stope walls) are thin and fractured. The convoluted shapes of the stope walls could also be a source of instability, because large slabs or wedges of rock on the upper “hanging walls” could collapse into the dust.

In contrast, the chamber walls, being more regular in shape and vertical, are likely to remain stable in the long term. Access workings leading to the chambers are also generally simple, consisting of a small number of regularly spaced draw points at the base and a dust distribution drift across the top.

A supplementary review and a rock mechanics assessment based on holes drilled through selected crown pillars were completed in 2003 and 2004. The objectives of the crown pillar drilling and testing program were as follows:

- Assess the stability of suspect crown pillars; and
- Determine the void space between the dust and the stope backs for use in backfill planning.

Complete results are presented in Supporting Document D1.

The conclusions of the 2004 crown pillar studies are summarised in Table 3.7. The crown pillars above stope B208 and above the group of stopes B212, B213 and B214 were concluded to be at risk of failure. The crown pillar above stope C212 was concluded to be unlikely to fail. However, any disturbance of the C212 crown pillar could result in Baker Creek being funnelled directly into the stope. The C212 crown pillar was therefore concluded to warrant further stabilization.

Table 3.7: Crown Pillar Thickness and Likelihood of Failure

Arsenic Trioxide filled Chamber or Stope	Minimum Thickness of Crown Pillars (m)		Likelihood of Failure
	Background Review	2004 Drill program	
B230	62		Very unlikely
B233	35		Very unlikely
B234	31		Very unlikely
B235	22	21	Very unlikely
B236	28	23.5	Very unlikely
B208	10	11.6	Possible
B212	7	10.4	Possible
B213	8	10.4	Possible
B214	7	7.0	Possible
C212	17	7.9	Very unlikely
9	19		Very unlikely
10	19		Very unlikely
11	19		Very unlikely
12	24		Very unlikely
14	25		Very unlikely
15	25		Very unlikely

Note: See Supporting Document D1

Prepared by: bm
Checked by: rc

3.1.5 Bulkheads

The chambers and stopes used to store the arsenic trioxide dust are secured by engineered bulkheads. Bulkheads were constructed in all access workings leading to each chamber or stope. Upper bulkheads and access hatches generally served as dust injection points or provided access for monitoring the fill levels. Lower bulkheads either hold back the dust directly, or close off access to drifts or cross-cuts into which the dust might have flowed.

A total of 71 bulkheads were designed, but ten of these were either not built or were removed during subsequent mining operations, such as the excavation of the B1 Pit. Consequently, 61 bulkheads remain in service, of which 26 are lower bulkheads. The bulkhead locations are shown in Figures 3.1.8 and 3.1.9. The long-term stability of these bulkheads is questionable and the short-term stability of some of them is also a source of concern. All of the accessible lower bulkheads have been the subject of recent investigations, including non-destructive testing (SRK 2001b, Klohn Crippen Consultants Ltd. 2002), and are included in regular inspections.

An updated version of the stability evaluation on lower bulkheads is summarized in Table 3.8. The table incorporates the findings of recent investigations and ongoing inspections.

The bulkheads of particular concern are:

- Bulkheads 10, 11, and 12: These bulkheads are inaccessible for inspection and are located above the partially filled stope B306. Failure of the bulkheads would lead to uncontrolled release of dust into the underlying workings.
- Bulkhead 36: Year-round seepage has been observed from the north end of stopes B212, 213 and 214. Failure of Bulkhead 36 would lead to uncontrolled release of dust into the underlying workings. Water pressures at Bulkhead 32 are monitored and are believed to reflect conditions at Bulkhead 36.
- Bulkheads 48 and 49: Condition of these bulkheads is unknown. They are located under stope C212 and Baker Creek, and water draining from the creek could cause fluctuating pressures on the bulkheads.
- Bulkhead 68 has been observed to leak water and arsenic sludge every year since 2000.

A monitoring and maintenance program is conducted to ensure that the risk of bulkhead failure does not increase. This program consists of:

- Regular visual inspections of the accessible bulkheads;
- Pressure monitoring at Bulkheads 7, 13, 14, 15, 32;
- Pressure monitoring within chambers and stopes B208, B214, B233 and C212;
- Operation and monitoring of a dewatering system hydraulically connected to stope B208; and
- Operation of a water interception system in B1 pit to reduce inflows to stope B208.

In addition to the above measures, plans are currently being developed to fill stope B306 to provide support for Bulkheads 10, 11 and 12.

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Figure 3.1.8: Upper Bulkheads-All Areas

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Figure 3.1.9: Lower Bulkheads-All Areas

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Table 3.8: Evaluation of Stability for Lower Bulkheads

Current Bulkhead ID	Orientation of Bulkhead	Evidence of Seepage	Risk Rating	Comments
Area AR 3				
1	Vertical	No Access	Low	Any potential failures would be confined by bulkheads 13, 14, and 15
3	Vertical	No Access	Low	
5	Vertical	No Access	Low	
7	Vertical	Yes	Moderate	Seepage of water and, on one occasion, seepage of arsenic sludge. Concrete is competent
10	Horizontal	No Access	High	Inaccessible, but B208 stope has a dewatering system to prevent pressure build-up. Failure would cause dust to enter underlying, partially backfilled stope (B306)
11	Horizontal	No Access	High	
12	Horizontal	No Access	High	
13	Vertical	Yes	Moderate	Bulkheads are at B208 stope, which has a dewatering system to prevent pressure build-up
15	Vertical	Yes	Moderate	
14	Vertical	Yes	Low	New supplementary bulkhead constructed immediately in front of the deteriorated one
Area AR 4				
32	Vertical	Minor	Moderate	Good condition, historically dry or very minor seepage
33	Vertical	No Access	Moderate	
34	Vertical	No Direct Access	Moderate	Historically dry or very minor seepage, as observed from a nearby safe vantage point.
35	Vertical	No Access	Moderate	
36	Vertical	Yes	High	Inadequate flexural strength. Believed to under significant head of water (~30 m). failure would cause dust to block main access to AR2 and AR3 and release to lower workings
Area AR 2				
47	Vertical	No Access	Moderate	Adequate, design strength
48	Vertical	No Access	High	Inaccessible and within the wet area below Baker Creek
49	Horizontal	No Access	High	
50	Vertical	Yes	Moderate	Adequate strength
51	Vertical	Yes	Moderate	Adequate strength
56	Vertical	No Access	Low	
58	Vertical	Yes	Low	
Area AR 1				
64	Vertical	No	Low	Adequate strength
66	Vertical	Yes	Moderate	Adequate strength
68	Vertical	Yes	High	Inadequate flexural strength. Historic high seepage of water and arsenic sludge
70	Vertical	No	None	No arsenic dust in chamber 15

NOTE: "No Access" indicates bulkhead not accessible for inspection or seepage monitoring

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3.2 Other Underground Mine Components

3.2.1 Other Underground Arsenic Sources

In addition to the arsenic trioxide dust stored underground in chambers and stopes, there are other potential sources of arsenic that could affect the quality of minewater when the workings are flooded. These include large quantities of tailings and waste rock that were used to backfill mined out stopes, and lesser quantities of materials such as track ballast in the main drifts and cross-cuts, and fine-grained slimes that have accumulated in various areas of the mine. Mineralized wall rocks throughout the mine could be another arsenic source.

The backfilled tailings are distributed widely in the mine, from the C-Shaft north to the Supercrest area, and from surface down to the 1650 Level. A review of mine records confirmed that calcine tailings were combined with flotation tailings and used for backfill from 1956 to 1967. Tailings backfilling continued until 1978, using only flotation tailings. Approximately 2.3 million tonnes of underground tailings were accounted for in the mine records, about half of which were backfilled before 1967. Therefore it is reasonable to assume that about half of the backfilled tailings contain calcine.

Studies of the geochemical characteristics of backfilled tailings and other mine materials were conducted in 2001, 2002 and 2004 (Supporting Document B6). Samples of the materials were collected for laboratory testing, which included mineralogical analyses, metal analyses, acid base accounting tests, and several tests designed to assess the potential for leaching of arsenic and metals from the materials.

The 2001 to 2004 test results indicate that the backfilled tailings would not generate acidic drainage. Samples containing only flotation tailings had trace amounts of sulphides and low metal contents. Samples that also contained calcine tailings had somewhat higher amounts of sulphide and elevated metal levels. The leach extraction tests indicated that the flotation tailings release elevated concentrations of soluble arsenic and antimony. Although the samples containing calcine tailings released less arsenic and antimony, they released slightly elevated concentrations of cadmium, cobalt, copper, manganese, nickel and zinc. The calcine tailings contained large amounts of arsenic bearing iron oxide minerals, which have the potential to release arsenic if the material is flooded and chemically reducing conditions develop.

Testing of the backfilled waste rock indicated that this material is also unlikely to generate acidic drainage, but the samples did contain variable amounts of sulphide and metals. Leach extraction tests indicated substantial amounts of soluble sulphate, and there were somewhat elevated metal concentrations in the leachate. Mineralogical tests indicate that iron oxides are only a minor constituent of the waste rock and, therefore, long-term release of arsenic is not expected to be significant. The wall rock and track ballast samples were similar in character to the waste rock.

The slimes samples contained iron oxides that strongly resemble the calcine observed in many of the backfilled tailings samples, suggesting that at least some of the slimes are comprised of tailings spilled in the mine access workings. The geochemical behaviour of this material is expected to be similar to the backfilled tailings containing calcine.

Additional laboratory testing of tailings backfill was conducted in 2004, using samples collected underground during the 2002 program. The objectives of the 2004 program were to conduct extractions tests on a larger number of samples than had previously been tested, to ensure that the samples adequately represented variability in the tailings backfill, and to include tests intended to simulate mildly reducing conditions that could develop in the underground mine when it is flooded. The test results are presented in Supporting Document B6. The arsenic releases from both types of backfill samples, flotation tailings and calcine tailings, were generally consistent with the results of previous testing described above. The tests to simulate mildly reducing conditions did not successfully promote reducing conditions; however, they did provide further demonstration of the redox buffering capacity of the backfill, and of the limited potential for arsenic release under oxidizing conditions.

The results of the laboratory studies were used to estimate the arsenic concentrations that could arise when these materials are flooded, and the arsenic loads released to the minewater in the long term. These estimates are discussed in detail in Section 3.7.1 and Section 6.2.

3.2.2 Underground Infrastructure

The underground infrastructure includes all of the equipment and systems used to mine the rock and bring ore to the surface, while maintaining a safe working environment in the mine. This includes ore and waste rock handling systems, ventilation systems, mine dewatering systems, and distribution systems for fresh water, compressed air and electricity. Most of this infrastructure is constructed of steel, wood and concrete, and presents no environmental concerns.

Environmental concerns may be associated with underground facilities in which hazardous materials were used or handled. These include work shops used to maintain mine equipment, storage areas for fuels, oils and explosive materials, and the electrical distribution system. The following sections describe this infrastructure and highlight potential remediation concerns.

Maintenance Shops

The mining equipment used underground has been powered by compressed air, electrical batteries, and diesel fuel. This equipment has been maintained in work shops located near major access points on most of the mine levels.

Scoop trams, jumbo drills and other diesel powered equipment have been maintained recently in five different shops located on the 575, 750, 1500 and 1650 Levels. Several additional shops, previously used to maintain diesel powered equipment, have been inactive in recent years. Removal of equipment and hazardous materials from the inactive shops is ongoing at the time of writing.

The active maintenance shops have not yet been assessed and may contain unused hazardous materials, such as small quantities of diesel fuel, lubricating and hydraulic oils, greases, cylinders of compressed gases, solvents, and chemicals such as cleaners and additives. Hazardous waste materials stored in the shops could include small quantities of used oils, oil absorbent materials, used solvents, and lead-acid batteries.

Maintenance shops for battery powered equipment are located close to C-Shaft on many of the mine levels, although only a few have been active recently. These shops may contain small supplies of sulphuric acid, and new and used lead-acid batteries.

Fuel and Oil Storage Areas

Two diesel storage facilities have been in recent use underground, located on the 750 and 1500 Levels. These consist of single-walled steel tanks (4,500 litre capacity) standing inside concrete spill containment berms. Fuel has been trucked to these tanks from storage facilities on surface. Several other diesel storage facilities have been used underground in the past, but are now inactive. In most cases, these storage tanks have been moved to new locations underground or brought to surface, although some unused tanks remain in place.

Lubricating and hydraulic oils have been stored in dedicated facilities adjacent to the maintenance shops for diesel powered equipment. Drums of oil have been stored inside concrete spill containment berms at these facilities.

Explosives Storage Areas

Every active mining area underground had designated explosive storage facilities nearby, and there are numerous such facilities throughout the mine. These consist of fenced off mine workings or caverns, fitted with shelves for storing explosives. Detonation explosives (blasting caps) have been stored separately from bulk explosives (ANFO, dynamite). Only a few of these facilities have been recently active, and could still contain explosive materials. Explosives have been removed from inactive storage areas, as a matter of safety policy.

Electrical Systems

Active electrical substations are currently located on the 750, 950 and 1250 Levels, where transformers reduce the voltage for electric powered equipment such as lights, ventilation fans, pumps, and the underground crusher. All of the transformers at these locations are of the dry type, and do not contain oil.

In the early 1990's, several transformers that contained PCB bearing oils were removed from the mine and transported to a disposal facility in Alberta. Most of the underground PCB materials were removed from the site in this period. Since much of the remaining underground electrical system dates from the period when PCB compounds were extensively used, small electrical components may be expected to contain PCB's. For example, most of the lighting in the maintenance shops is provided by fluorescent strip lights. Depending on the date of installation, the light ballasts may contain small amounts of PCB compounds in solid forms.

3.2.3 Openings to Surface

A total of 35 openings from the underground workings to surface are currently open, sealed with temporary measures, or require further assessment to determine if they are adequately sealed. The locations, types and current status of these openings are shown in Figure 3.2.1.

Five of the openings are vertical shafts, which are today, or were at one time, used to lift workers and equipment in and out of the mine, or bring ore and waste rock to surface. These are known as the A-now used for ventilation purposes rather than mine access. All of the shafts are currently open, and access is controlled by buildings and doors.

There are seven openings known as portals, leading to horizontal adits or inclined ramps. These provided access to the mine for workers and mobile equipment, and were also used to bring waste rock to surface. Most of these are located in the open pits and are currently secured with temporary measures, such as doors and gates, which are locked when not in use.

The remaining twenty-three openings are vertical or inclined raises. These were used for ventilation, ore and waste rock handling, arsenic trioxide dust distribution, and emergency access to surface. Many of these openings are currently secured with locked doors and gates, or temporarily sealed with wooden covers. Others are backfilled with waste rock and require further assessment to determine if the backfill is adequate as a permanent seal.

3.2.4 Other Crown Pillars

The long term stability of the crown pillars associated with the arsenic trioxide storage areas is discussed in Section 3.1.4 and in Supporting Document E1. Other mine excavations located near the ground surface are generally found in the pit areas, where ore zones that were originally mined from underground stopes were later mined with open pit methods. The stability of crown pillars located within the pits is discussed in Section 3.3.3. All near surface crown pillars located outside the pits and arsenic storage areas have been assessed. None were identified as high risk but more detailed review is underway on some.

3.3 Open Pits

3.3.1 Dimensions and Access

The physical dimensions of the eight open pits are listed in Table 3.9. Pit depths and volumes have been calculated based on recently completed digital terrain mapping. The volumes listed in the table are to the "spill point" of each pit. The spill point is defined as the lowest section of the pit rim, where water would overflow if the pit was flooded.

Table 3.9: Open Pit Dimensions and Approximate Volumes

Pit	Length & Width (m)	Depth (m)	Mined Volume (m^3)
A1	319 x 136	50	766,000
A2	355 x 152	38	498,000
B1	193 x 148	35	327,000
B2	277 x 110	26	223,000
B3	170 x 65	11	40,000
B4	69 x 50	7	12,000
Brock	104 x 34	10	6,000
C1	276 x 127	28	395,000
Total:			2,267,000

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Checked by: rc

Currently, it is possible to access the A1, A2, B1, B2, and B3 pits by means of the existing access ramps. These ramps are not maintained, with the exception of those in the B2 and B3 pits, which are used for underground access via the UBC and 1-38 portals.

3.3.2 Interaction with Underground Workings

Numerous intersections with mined out stopes, tunnels, and other openings (raises, etc) occur along the bottoms and sides of the pits. Access adits were constructed in several of the pits in order to enter the first level of the mine without an additional ramp. Currently, the only active adits are the UBC portal in the B2 Pit, and portal 1-38 in the B3 Pit.

All of the identified openings to the surface are discussed in Section 3.2.3. Further details on those specific to the open pits are discussed in detail in Supporting Document E2. The openings consist of intercepted raises, tunnels, man-ways, and purpose built adits. Many of the smaller ones are currently either open or have been capped or blocked using engineered structures. Of more significance for remedial planning are the historic stopes that connect to the pits. These stopes were backfilled prior to open pit mining to provide for stable crown pillar conditions when excavating the pits, and would have been topped up if voids were detected when breakthrough occurred. Because they were not capped, the stability of the opening is questionable.

There are subsidence areas in the C1 pit where the pit bottom intersects several backfilled stopes. These are thought to have occurred due to water infiltrating from Baker Creek through a cut-off dam at the north end of the pit, or under the wall through the historic creek channel. Efforts were made to cut off inflow from the creek in 2004. This work is described in Supporting Document G3. Further discussion of the subsidence zones is provided in Supporting Document E1.

Figure 3.2.1: Locations of Underground Mine Openings to Surface

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3.3.3 Pit Walls and Stability Issues

The stability of the pit walls was investigated in 2001, with a review of data and site inspections (Golder Assoc. 2001). The investigation indicated that a thawed overburden in the northwest wall of the A1 Pit had experienced some sloughing, but no movement was observed in any of the other pit walls.

Access to the pit walls constitutes a hazard to the general public, especially due to the proximity to Yellowknife city limits and the adjacent highway. Currently, access to the pit walls is controlled by mine operations security.

Tension cracks are evident at some of the pit edges and within the pits, notably the A1, A2 and C1 pits. Additionally, subsidence areas are occurring in the C1 Pit. These are being actively monitored and are discussed in detail in Supporting Document E1.

The B2 Pit dyke was identified as a high failure consequence dam during a dam safety review carried out by BGC Engineering Inc in 2004. This dyke will be further assessed and any required remedial measures carried out as part of ongoing care and maintenance. Dam 1 above the B3 Pit will also be investigated as part of this assessment program.

3.3.4 Pit Wall Geochemistry

Acid rock drainage potential in the pit wall rock was investigated by Royal Oak Mines (ROM, 1994) and Golder Associates (Golder, 2001). Test results showed that 85% of the samples collected were acid consuming. Given the large percentage of carbonate minerals within the ore zone lithology, any acid produced by discrete acid generating sections of high sulphide concentration would be neutralized. Static leach testing also showed only limited potential for arsenic release from the wall rock (Golder 2001). Pit wall geochemistry is discussed in more detail in Supporting Document B1.

3.3.5 Borrow Material in Open Pits

A significant quantity of backfill material is located in the A1, A2, and C1 Pits, as listed in Table 3.10. Tension cracks and subsidence areas are evident, and the material not considered to be stable over the long term. Supporting Document E1 provides further details.

Table 3.10: Backfill Material Currently in Pits

Pit	Estimated Volume of Backfill (m^3)		
	Till	Waste rock	Till & waste rock
A1			66,000
A2		29,500	
C1	123,500	58,500	
Total	123,500	88,000	66,000

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3.4 Waste Rock

Most of the waste rock produced by open pit mining, and brought to surface from the underground mine, was utilized as construction material in tailings dams and site roads. There are currently just three small waste rock piles immediately south of B2 pit, containing approximately 12,000 tonnes of rock.

The geochemical characteristics of the waste rock are detailed in Supporting Document B1 and summarized in Table 3.11. Analytical data show that the waste rock is non-acid generating, and the arsenic and metal content of the rock is relatively low. Leach extraction tests indicate that arsenic and metal concentrations in waste rock leachate are low.

Table 3.11: Summary of Waste Rock Geochemistry Characteristics

Parameter	Range in Solids (mg/kg)	Range in Leachate (mg/L)
NP:AP ratio	2.2 – 38.9	n/a
Arsenic	11 – 8,960	0.0077 – 0.11
Antimony	4 – 74	<0.2
Chromium	105 – 494	<0.01
Copper	54 – 276	<0.01 – 0.01
Nickel	54 – 117	<0.05
Lead	<2 – 82	<0.05
Zinc	66 – 238	<0.005 – 0.013

NP:AP = ratio of neutralization potential to acid generation potential *Prepared by: kss*
Notes: Twenty three samples were analyzed for ABA and metal content in solids *Checked by: kss*
Eight samples were submitted for leachate extraction testing. Tests were conducted at 20:1 dilution

3.5 Tailings and Sludge Containment Areas

3.5.1 North, Central and South Ponds

Tailings Disposal

Approximately 9.5 million dry tonnes of tailings were originally deposited in the North, Central and South Ponds. From 1988 through 1990, 2.5 million tonnes of these tailings were processed in the Tailings Retreatment Plant and transferred to the Northwest Pond. Today, about 7 million tonnes of tailings remain in the North, Central and South Ponds. The tailings were deposited by a combination of sub-aqueous and sub-aerial methods. The tailings in these ponds cover a combined surface area of 51 hectares, with a maximum tailings depth of about 22 metres in the Central Pond. The geochemical characteristics of the tailings are discussed in Section 3.5.5.

Containment Structures

The tailings are impounded by a series of dams. The design objectives for all of the dams were to contain tailings and to minimize seepage of pore water. Seepage collection systems were designed and constructed at all of the perimeter dams where seepage did occur.

Dams 1, 2 and 3 were the first tailings dams constructed, and together form the North Pond, as well as the original tailings disposal area now underlying the Settling and Polishing Ponds. The locations of these structures are shown in Figure 3.5.1. The original three dams consist of mine waste rock placed in stages on top of previously deposited tailings. Tailings were beached on the upstream sides of the dams, limiting seepage through the dams from the pond water accumulated upstream.

When Dams 1, 2 and 3 were raised in the 1970's, the rockfill was extended in the downstream direction and a sloping clay zone was constructed upstream. The raised sections of the dams incorporated a filter zone of sand and gravel between the clay and the downstream rockfill, and the clay core was extended onto the tailings beach to create a horizontal upstream clay blanket as an additional barrier to seepage through the lower sections of the dams.

Dams 4 and 5, which close off the south end of the Central Pond, were constructed above the rising tailings level so that, unlike the first three dams, the foundations do not include tailings. Dams 4 and 5 have zones of clay on the upstream side to reduce seepage through the structures.

Dam 6 is a simple rockfill structure separating the North and Central Ponds, and does not incorporate a low permeability zone. Dam 11, which forms the southern boundary of the South Pond, was designed as a water retaining dam. It has a rock fill downstream section, a central core of low permeability clay material, and a rock fill upstream shell. Sand and gravel filter zones are present upstream and downstream of the clay core. Tailings placed on the upstream side form a beach in front of the dam. A similar design configuration was later used for the dams of the Northwest Pond.

The dams that contain tailings and water in the North, Central and South Ponds have been inspected annually by a professional geotechnical engineer since 1979, to assess their performance and maintenance requirements. The performance and safety of these dams was reviewed in September 2004 (BGC Engineering Inc. 2004). The detailed review identified no immediate safety concerns, but made recommendations to assess dam performance in more detail, and improve operating, maintenance and surveillance procedures, in the event that these dams continue to perform their current function.

Dam Seepage

In the history of development of the North, Central and South Ponds, several of the dams have produced significant volumes of seepage, which passed either under the dams, or through the structures themselves. Today, seepage at Dams 2, 3 and 11 remains a water management concern.

Dam 2 is founded partly on tailings, which covered low lying ground between Dam 1 and the North Pond before the dam was built. In recent years, seepage from the North Pond to the Settling and Polishing Ponds has occasionally been evident from poor water quality in these ponds, with higher arsenic concentrations than found in the discharge from the ETP. Because of this, an informal operating criterion is now applied, keeping the North Pond water level no more than 1.7 metres higher than the level of the Polishing Pond. This practise effectively controls the seepage through Dam 2 within acceptable limits.

Seepage through or under Dam 3 has been a significant concern in the past. Two small dams, known as 3C and 3D, were constructed to contain the seepage downstream of Dam 3 and allow it to be pumped back to the North Pond. In recent years, the North Pond water level has been kept low in relation to Dam 3 and seepage at this dam has been a relatively minor concern. A small volume of contaminated water collects at Dam 3C, and is periodically pumped back into the North Pond. Dam 3D no longer collects a significant volume of seepage.

Seepage emerges at the downstream toe of Dam 11, on the South Pond, and is contained by Dam 7. The contained water is pumped back into the South Pond, and the volume of seepage is monitored with a flow meter. The seepage flow rate has decreased since tailings discharge to the South Pond ceased in 1999. The annual average seepage flow rate is currently 3 to 5 cubic metres per day, typically containing 1 to 3 mg/L arsenic.

Water Management

During periods of high mine inflow in the spring and summer seasons, minewater is periodically pumped to surface through the C-Shaft and discharged to the South Pond. A decant pipeline carries water directly from the South Pond to the North Pond, and little water can be stored in the South Pond. The total water storage capacity of the North Pond, to the maximum operating level, is about 160,000 cubic metres, and the maximum pond depth is 5 metres. The arsenic concentration in the North Pond water is typically between 7 and 11 mg/L.

Figure 3.5.1: Original Tailings Containment Area

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3.5.2 Northwest Pond

Tailings Disposal

About 6.5 million dry tonnes of tailings are stored in the Northwest Pond (Figure 3.5.2), of which 2.5 million tonnes were transferred from the original tailings containment area. The remainder of the tailings came from conventional mill production. Tailings slurry was discharged near the crests of the dams to form shallow beaches sloping toward a pond of supernatant water. The tailings cover an area of 44 hectares, to a maximum depth of about 15 metres. The geochemical characteristics of the tailings are discussed in Section 3.5.5.

Containment Structures

The Northwest Pond is contained by Dams 21A, B, C and D, and Dams 22A and B. These dams were designed to meet water retention dam standards in accordance with the accepted practice at the time of construction. The dams are composed of rockfill, with a sloping core of silty clay keyed into bedrock or frozen soils in the foundation, forming a zone of low permeability to control seepage. The clay core is underlain by a two stage granular filter zone, and is protected by an upstream rockfill shell.

The tailings dams of the Northwest Pond have been inspected annually by a professional geotechnical engineer, as requirement of the former water licence and the current care and maintenance contract. The dam safety review completed in 2004 recommended more detailed assessment of the dam performance, and improvements in operating, maintenance and surveillance procedures, as long as the dams continue to perform their current function. The review identified no immediate safety concerns.

Dam Seepage

Seepage from the dams on the Northwest Pond has been indicated historically by the results of water sampling outside the impoundment. Only Dam 22B has produced enough seepage to make containment practical. A seepage containment and pumping system is located downstream of the dam. The seepage volume has been reduced in recent years, due to lower pond water levels and improvements in seepage management, although contaminated water continues to report to the collection system. This water is pumped back to the Northwest Pond, and the volume is monitored with a flow meter. The annual average flow rate is currently 7 to 9 cubic metres per day, typically containing 1 to 3 mg/L arsenic.

Water Management

The Northwest Pond currently plays a major role in site water management. Water is pumped from the mine throughout the year and is stored in the pond before treatment and discharge to the environment. The Northwest Pond provides the majority of the capacity for storing contaminated water on site, holding about 900,000 cubic metres to the maximum operating level, at a maximum pond depth of 5 metres. Arsenic concentrations in the pond water are typically around 15 mg/L, and can vary from 10 to 20 mg/L. The role played by the Northwest Pond in site water management is discussed further in Section 3.7.2.

3.5.3 Settling Pond and Polishing Ponds

The Settling and Polishing Ponds form part of the current water treatment system. The ponds have had this function since 1981, when the first comprehensive treatment of tailings water began. Before this, the pond formed between Dam 1 and Dam 2 was initially used for tailings disposal, and later for clarifying tailings water decanted from the North Pond before its discharge to Baker Creek.

The area is divided into the Settling and Polishing Ponds by a rockfill dyke constructed on top of the previously deposited tailings. The dyke serves to retain sludge produced by the Effluent Treatment Plant in the Settling Pond, while allowing relatively clear water to seep into the Polishing Pond. Over the years of operation, some sludge has passed through the dyke and settled in the Polishing Pond, although the majority remains contained in the Settling Pond. The water quality in the Polishing Pond is normally within the limits specified for effluent discharge to the environment, with total arsenic concentrations below 0.4 mg/L. The function of the Settling and Polishing Ponds in the water treatment system is described further in Section 3.7.2.

The volume of sludge currently stored in the Settling and Polishing Ponds has been estimated from measured changes in the pond bathymetry since sludge deposition began. The sludge volume is estimated to be between 250,000 and 450,000 cubic metres (Supporting Document K1).

During normal operation of the Effluent Treatment Plant, the Settling Pond is shallow and holds a relatively small volume of water. The Polishing Pond contains approximately 230,000 cubic metres of water, with a maximum depth of approximately 9 metres.

3.5.4 Calcine Pond

The former calcine storage pond is located east of the B1 Pit, adjacent to Baker Creek. The pond was used to store roaster calcine before further treatment to recover the contained gold. Some of the material deposited in the pond proved difficult to treat for gold recovery and was left in place. The pond was eventually drained and the remaining calcine was covered over with soils excavated from the B1 Pit.

A physical and geochemical investigation of the former calcine pond was conducted in 2003 (Supporting Document K2). An auger drill was used to test the dimensions of the remaining calcine deposit, collect samples, and install groundwater monitoring wells. The volume of calcine was estimated to be 960 cubic metres, based on the thickness determined by drilling, and the lateral extent of the calcine pond indicated by historical aerial photographs. The investigation indicated that the remaining calcine deposit varies in thickness from 1 to 3 metres, and is covered with clay material varying from 1 to 11 metres thick. The calcine is also underlain by fine-grained soils. The geochemical characteristics of the calcine are described in section 3.5.5.

Figure 3.5.2: Northwest Tailings Containment Area

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3.5.5 Tailings, Sludge, and Calcine Geochemistry

Tailings

The chemical characteristics of the tailings and tailings pore water have been assessed in several studies. In 1994, near-surface tailings solids from the North, Central, South and Northwest Ponds were sampled for acid base accounting test work (Royal Oak Mines Inc. 1994). The results indicated relatively low total sulphur contents (less than 1%), and generally high net neutralization capacities. The study indicated that the tailings would not be expected to generate acidic drainage.

Further assessment of the tailings was conducted in 2001 (Golder Associates 2001). Near surface tailings were sampled throughout the North, Central and South Ponds, and from various depths in a borehole drilled in the Northwest Ponds. Samples collected by Miramar Giant Mines Limited in 2000, from various depths in the North, Central and South Ponds, were also analyzed as part of the same study. The test work conducted on these samples included mineralogical analysis, acid base accounting, whole rock chemistry, and analysis of water soluble constituents.

The study found that the tailings consist principally of fine-grained material containing quartz and carbonate minerals, with a small proportion of sulphides, including arsenopyrite, which are generally not altered or oxidized. The roaster products, or calcines, are also abundant in most of the tailings samples. The soluble arsenic in the tailings is most likely associated with the calcine, in which arsenic likely occurs adsorbed onto hematite particles.

The 2001 study confirmed that the tailings in all of the impoundments are net acid consuming. The ratios of neutralizing potential to acid generating potential in the tailings samples generally decrease with depth, and sulphate is found in the near surface tailings, indicating that oxidation is occurring at the surface. Evidence of oxidation at surface was not found in areas where the tailings are typically covered by water throughout most of the year, such as the central part of the Northwest Pond.

The 2001 study indicated typical arsenic concentrations of about 2000 to 4000 mg/kg, with a few samples in the range of 5000 mg/kg. The test work indicated that only a small portion of the arsenic in solid form is water-soluble (average of 0.2% by weight), however the presence of dissolved arsenic in tailings pore water and potential additional release of soluble arsenic from solid forms could generate runoff or seepage from the tailings that exceeds effluent quality criteria.

Water Treatment Sludge

The chemical characteristics of the water treatment sludge were also assessed in 2001 (Golder Associates , 2001). Two samples of the sludge were collected for laboratory test work, one from the sludge deposit in the Settling Pond, the other from the Effluent Treatment Plant discharge. The work included analysis of major and trace constituents, and sequential leach extractions.

The arsenic contents of the two sludge samples were 1% and 4.2% (by weight), and the iron contents were 6% and 30% (by weight). The higher arsenic and iron contents were found in the material from the ETP discharge. The iron to arsenic molar ratios of 8 and 9 indicate that the arsenic is likely to be very effectively retained in the sludge.

The sequential leach extractions were designed to simulate exposure of the sludge to ambient conditions. The results indicated that a very small proportion of the arsenic in the sludge is water-soluble (up to 0.006% by weight).

Calcine

The chemical characteristics of roaster calcine located in the former storage pond adjacent to Baker Creek were assessed in 2003 (Supporting Document K2). The purpose of the study was to assess the potential for the release of arsenic or other contaminants from the calcine to the creek. Samples of the material were collected by drilling through the soils lying over the calcine deposit. Laboratory testing of the samples included analysis of metals, acid base accounting tests, and leach extraction tests. Groundwater monitoring wells were installed in the drilled holes.

The study concluded that, although this material is a potential source for arsenic and antimony, the soluble concentrations of these elements are moderate, and seepage flows to Baker Creek are expected to be low due to the low permeability of the surrounding soils. The acid base accounting indicates that the calcines are unlikely to be acid generating, and that significant future changes to the chemistry are unlikely. Therefore, the calcines are not considered a major current or future source of arsenic loading to the creek.

3.6 Historic Foreshore Tailings

Mine production records indicate that approximately 300,000 tonnes of tailings were deposited on the foreshore of north Yellowknife Bay. About 35% of the tailings are on the beach with the remaining in Back Bay. Submerged tailings have been dispersed along the western shore of north Yellowknife Bay by lake currents; however, the bulk of the tailings remain near the original disposal site. Sediment sampling carried out in 2004 has allowed better definition of the extent of tailings dispersion in north Yellowknife Bay. More detailed information on the historic foreshore tailings is provided in Supporting Document F2. The key results of that program are shown in Figure 3.6.1.

Remedial works have been done on the beached tailings. The beach was recontoured to a 4H:1V (horizontal to vertical) slope and covered with geotextile overlain with gravel and coarse rock to prevent erosion of the solids into north Yellowknife Bay. To minimize the amount of surface water flowing through the tailings, drainage ditches were constructed to direct drainage to north Yellowknife Bay along a pathway south of the beach.

The tailings have a very low potential to generate acidic drainage. The tailings solids have low concentrations of metals with the exception of arsenic, antimony, lead and zinc. Tailings porewater contain elevated concentrations of arsenic, antimony and zinc only.

Figure 3.6.1: Approximate Limit of Tailings and Arsenic in Lake Sediments

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Assessment of the submerged tailings indicates that arsenic concentrations in lake sediment porewater appear to be proportional to the arsenic concentrations in sediments and the amount of tailings in the lake sediment. Elevated arsenic concentrations were found in samples located near the mouth of Baker Creek and in north Yellowknife Bay near the historic tailings disposal site. However, of the arsenic load entering Yellowknife Bay from the historic foreshore tailings area, roughly 90% originates from surface sources. This figure was estimated from field data collected from groundwater wells installed in the beach area. The water column above the submerged tailings meets the Canadian Council of Ministers of the Environment water quality guidelines for protection of aquatic life.

Impacts on the receiving environment in Yellowknife Bay are low. However, where the lake sediments are high in arsenic, either from tailings or from historical arsenic loadings, the benthic invertebrate population differs from that of the surrounding areas.

3.7 Site Water Management

3.7.1 Underground Minewater

Minewater Management

The major sources of water entering the underground mine include seepage from groundwater around the mine, infiltration through soils and bedrock in the mine area, runoff flowing into the open pits, seepage from Baker Creek, and seepage from the tailings containment areas. Of the tailings containment areas, the Northwest Pond is the principal source of seepage into the mine. Several of these sources are controlled by climatic conditions, and the total inflow to the mine varies greatly during the year.

All water entering the mine ultimately drains into the main dewatering systems located at C-Shaft and the area known as Supercrest, in the northern part of the mine. Most of the water is handled by gravity flow through ditches in the main drifts, as well as the ramps, raises and drainage holes that connect the main drifts. In areas where drainage by gravity is not possible, small sumps and pumps transfer water to the gravity drainage system. The underground drainage and dewatering systems are shown in Figure 3.7.1.

Drainage towards C-Shaft from the southern part of the mine includes major inflows originating from the A2, A1 and C1 Pits during the freshet and heavy rainfall periods. Drainage from the northern part of the mine includes a large inflow of water from the Northwest Pond, which flows throughout the year, and seepage from other areas that increases significantly during the freshet, and when the water level in Baker Creek is high. In the C-Shaft area, flows from the ditches in the main drifts above the 1300 Level are directed through drainage holes and drainage pipes into the main dewatering sump. At Supercrest, a portion of the seepage from the Northwest Pond drains directly into another dewatering sump on the 750 Level.

Flooding of the lower levels of the mine was initiated in July 2005, when the pumps on the 2000 Level at the bottom of the mine were shut down and removed. The dewatering sump on the 1300 Level is currently the only active sump at the shaft. Water is pumped from the 1300 Level up the shaft to the 750 Level, where it flows through a 2,000 metre long pipeline to the 750 Level Supercrest sump. From there it is pumped directly to surface and is discharged into the Northwest Pond.

Before flooding of the lower mine levels commenced, the dewatering rate required to keep the mine dry was typically about 2,000 cubic metres per day in winter, increasing to 4,000 cubic metres or more during the freshet period.

Minewater Quality

Monitoring of water flows and chemistry within the mine has been carried out in several programs since 1999. The objectives of the programs were to identify and characterize the principal sources of arsenic within the mine, and to develop water and arsenic balances for the minewater system. A detailed discussion of the minewater sampling programs and minewater chemistry is presented in Supporting Document B3.

The results of the sampling programs indicate that the main sources of water entering the mine are direct infiltration of snowmelt and precipitation, infiltration from Baker Creek, and seepage from the Northwest Pond. Although deep saline groundwater enters the lower levels of the mine, the isotopic composition of minewater samples indicates that the majority of water comes from the surface.

As water percolates downwards through the mine, it interacts with the mine walls and surrounding bedrock. Water samples collected from boreholes and fractures at the extremities of the mine have relatively low arsenic concentrations, ranging from 0.018 to 0.063 mg/L. Interaction with the mine workings nearer the ore zones leads to further increases in arsenic concentrations, in the range of 0.5 mg/L.

Water that contacts the arsenic trioxide dust is characterized by very high arsenic and antimony concentrations, slightly acidic pH, and high magnesium, sulphate and ammonia concentrations. Arsenic concentrations in seeps close to dust-filled chambers are in the range of 4000 mg/L. The isotope data indicate that most of the seepage from the chambers originates from snowmelt and rainwater. However, a sample collected below chamber C212, which lies under Baker Creek, was more characteristic of creek water.

Water from the tailings ponds and polishing pond also enters the mine via direct infiltration. The tailings seepage tends to have arsenic concentrations in the range of 4 to 6 mg/L, as well as elevated concentrations of sodium, chloride, ammonia and nitrate.

Figure 3.7.1: Current Underground Dewatering System

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Some of the mine stopes are backfilled with waste rock and tailings, as described in Section 3.2.1. Seepage from stopes that are backfilled with tailings typically has arsenic concentrations ranging from 0.1 to 6.8 mg/L (with one outlier of 20 mg/L), while seepage from stopes that contain waste rock have arsenic concentrations ranging from 0.2 to 1.6 mg/L.

The deep groundwater is characterized by very high total dissolved salts content, and high calcium, sodium and chloride concentrations. The deep groundwater appears to contribute significantly to the sodium/chloride release from the mine, but is a relatively minor source of arsenic.

Typical concentrations of arsenic in water from each of the above sources are summarized in Table 3.12.

Table 3.12: Arsenic Concentrations in Underground Water from Different Sources

Source	Arsenic Concentrations (mg/L)
Soils, Bedrock, and Mine Walls	0.05
Northwest Tailings Pond Seepage	7
Tailings Backfill	5
Waste Rock Backfill	1.5
Arsenic Chambers & Stopes	4000

Prepared by: kss
Checked by: mdr

Results of monthly sampling of the underground mine flows and underground water and load balances reflecting winter and freshet sampling are presented in Supporting Document B3. The results indicate that flows of approximately 2400 cubic metres per day, and arsenic loads of approximately 56 kilograms per day are discharged from the mine. Approximately 90 to 95% of the arsenic enters the mine drainage system between C-Shaft and 1000 feet north of B-Shaft (1000 North), which is the area of the mine beneath the arsenic chambers. An additional 5 to 10% is from further north of the arsenic dust storage areas, and can be attributed primarily to seepage from the Northwest Tailings Pond. A negligible proportion of arsenic load originates from south of C-Shaft.

The underground mine workings form a network of connected voids, including horizontal drifts, inclined raises, vertical shafts, ramps, chutes and ore stopes. In addition, many thousands of exploration drill holes intersect the workings, creating an extensive drainage system for the rock in the mine area. Because the drainage system extends to the bottom of the deepest shaft, 610 metres below the surface, the local groundwater table is artificially lowered in the area of the mine. This has the effect of continuously drawing groundwater towards the workings and preventing the escape of contaminated minewater.

3.7.2 Surface Water

Fresh Water, Grey Water and Sewage

Fresh water is currently used for sanitary and fire suppression purposes at the active mine buildings near C-Shaft, as well as for heating purposes at the active boilers. Historically, fresh water was also used at the Townsite for domestic and fire suppression purposes, but this system was shut down in 2005.

All of the fresh water used for boilers, fire suppression and sanitary purposes at the active mine buildings is potable water obtained from the City of Yellowknife, and is currently trucked to storage tanks on site. All waste water generated from surface uses, including grey water and sewage, is currently directed into the underground water management system through a pipe in the C-Shaft. The waste water joins the main mine dewatering line on the 750 Level and is eventually discharged into the Northwest Pond.

Control of Surface Runoff

Runoff into the open pits is controlled to reduce the volume of water that would require pumping from the mine and eventual treatment. For this purpose, three runoff diversion systems were constructed to collect and divert runoff around the A1 and A2 Pits. The A1 North diversion ditch collects runoff from the west of the A1 Pit and directs it into Baker Creek, to the northeast of the pit. The A2 North ditch collects runoff from the west of the A2 Pit, and discharges into Baker Creek north of the pit. The A2 South diversion system consists of a small dam on high ground south of the A2 Pit, and a plastic pipeline that carries water from the dam to the drainage system adjacent to Highway No. 4. Clean runoff is also collected in the C1, B1 and B2 Pits, and is periodically pumped from the pits directly into Baker Creek.

Surface runoff in the shallow valley just north of the Roaster Complex is typically contaminated with arsenic at concentrations above the discharge limits specified in the Water Licence (0.5 mg/L arsenic), due to the high levels of soil contamination found in this area. In recent years, the contaminated runoff has been contained in a shallow sump at the bottom of the valley and pumped to the South Pond, for storage and eventual treatment. Similarly, contaminated runoff in the immediate area of the Mill complex is now collected in a series of ditches and sumps, and pumped to the South Pond.

Contaminated Water Storage

The tailings containment areas are used to store contaminated water on surface before it is treated. As discussed in Section 3.7.1, minewater is pumped from the 750 Level of the mine to the Northwest Pond throughout the year. Historically, minewater has also been pumped to the South Pond via C-Shaft, during periods of high mine inflow in the spring and summer. Small volumes of water are also returned to the Northwest Pond from the seepage collection system at Dam 22B, and to the South Pond from Dam 11.

Apart from pumped discharges from the mine and the dam seepage collection systems, the tailings ponds also receive inputs of water from direct precipitation and runoff. Losses of water from the ponds include diffuse seepage through and under the dams, seepage into the mine workings, and evaporation.

The Water Licence requires that a minimum of 0.5 metres of freeboard is maintained at the lowest water retaining structures in the tailings containment areas, to provide emergency water storage for extreme precipitation events, and to prevent overtopping of the dams due to wave action. The water storage capacity of the Northwest Pond to the maximum permitted level is approximately 900,000 cubic metres.

The South Pond has been almost completely filled with tailings, and little capacity remains for water storage. A decant pipeline carries water by gravity flow from the South Pond directly to the North Pond. The inlet to the pipeline lies just above the minimum tailings elevation, so that the pond is almost empty when the pipeline is drained. When the South Pond was accepting minewater discharge, a small pond developed to provide the hydraulic gradient required to push water through the pipeline to the North Pond. The pond volume was typically less than 20,000 cubic metres.

As discussed in Section 3.5.1, the level of the North Pond is controlled to minimize the potential for seepage of contaminated water into the adjacent Polishing Pond. The total capacity of the North Pond, to the maximum operating level, is approximately 160,000 cubic metres. However, the water reclaim system in use at the North Pond can only draw the water level down by a few metres, and only about 70,000 cubic metres of this capacity can be actively used.

Water Treatment and Discharge

Water is reclaimed from the Northwest and North Ponds for treatment in the Effluent Treatment Plant (ETP) during the open water season, usually from June through September. The ETP is equipped with two parallel treatment circuits, each consisting of three agitated tanks in series. The tank elevations are stepped so that gravity flow carries the water from one tank to the next. When water is being reclaimed from both the Northwest and North Ponds, the influent flows are usually combined before division of the flow between the two parallel circuits. Both circuits are often used together to treat water drawn only from the Northwest Pond.

A solution of hydrogen peroxide is added to the first tank in the series, to ensure that all of the arsenic in the water is oxidized to the pentavalent state, ensuring efficient precipitation in the following stages. A solution of ferric sulphate is added to the second tank. The ferric iron combines with the arsenic to form amorphous ferric arsenate precipitates. Arsenic species are also removed from solution by adsorption on amorphous ferrihydrite (iron-hydroxide) precipitates.

In the last tank, lime slurry is added to neutralize the acid generated by hydrolysis of the iron and maintain an optimal pH for arsenic precipitation. A polymeric flocculant is also added to increase the efficiency of solids settling. The overflow from the last of the three tanks in each circuit, containing water and precipitates, drains through a short pipeline to the north end of the Settling

Pond. The lime slurry and flocculant solution are prepared from dry reagents in a building next to the tanks. The hydrogen peroxide and ferric sulphate are normally received at the site as solutions ready for addition to the circuit, and are stored in large tanks adjacent to the ETP.

The Settling Pond provides quiescent conditions to allow precipitates to settle out of the water. The pond is separated from the downstream Polishing Pond by a permeable rock-fill dyke, which retains precipitates within the Settling Pond, while allowing the clarified water to seep through. Settling efficiency is greatly improved by the addition of flocculent in the ETP. Efficient settling within the pond reduces the build-up of precipitates on the upstream face of the dyke, thus reducing the hydraulic gradient required across the dyke to push water from the Settling Pond to the Polishing Pond. A larger hydraulic gradient encourages the break-through of precipitates to the Polishing Pond, which can result in unacceptably high concentrations of arsenic in the final effluent. The potential for this effect controls the maximum practical treatment rate of about 7,000 cubic metres per day.

The Polishing Pond has a large capacity (230,000 cubic metres) and residence time. The pond provides the last opportunity for settling any precipitates carried over from the Settling Pond. The Polishing Pond also allows some mixing of the water, smoothing out variations in the water quality, and allowing brief ETP process upsets to occur without producing water that is unacceptable for discharge. In the event of more significant treatment problems, the large capacity of the basin also allows an opportunity to contain water that does not meet the discharge limits and, if necessary, to pump the water back to the North Pond.

Final effluent is discharged through a siphon line from the south end of the Polishing Pond to a drainage ditch south of the B3 Pit. The treated water drains through a series of culverts under mine access roads and Highway No. 4, and discharges into Baker Creek.

3.8 Baker Creek

The current and original alignment of Baker Creek is illustrated in Figure 3.8.1. The diversions around specific mining areas are also shown. Much of the diverted channel has been relegated to narrow confined channels, some completely in bedrock, with limited fish habitat potential. The channel sediments do not resemble those upstream of the mine site. There is more fine material and the larger material is composed of more angular rock (*i.e.*: recent fill) not at all similar to the rounded *in situ* bed material above the mine site. Tailings that settled in Baker Creek Pond (pond at inlet of Trapper Creek) likely comprise most of the fine sediments found within the wetted perimeter of the existing channel.

A large proportion of the channel is without a functional riparian area. It is subject to scour and high velocities during freshet, and shows very little floodplain development. Natural channel processes are inactive, and this will limit future ability to develop and sustain in-stream and riparian habitats.

Figure 3.8.1: Baker Creek Historical Alignments

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The current channel is traversed by approximately seven structures that limit the natural behaviour of the system. These include old mine infrastructure, highways and mine road crossings, in-channel structures and debris. The construction of the pits also required extensive relocation of the channel. A minor dam close to the B-shaft compressor causes a pooling of water, a chute and small drop over bedrock. In recent years fish have returned to Baker Creek, and although fish have been observed traversing the chute at high flows, no successful spawning has yet been documented.

Underground observations suggested that Baker Creek does not infiltrate into the underground mine across most of the site, although it is underlain by mine workings. The exception is at the north end of the C1 Pit where flow from the creek is observed to infiltrate the upper fill section into the pit during high water periods (*i.e.*: during spring freshet and periods when ice blockage causes water levels to rise).

The hydrology, water quality, sediment quality, and aquatic life in Baker Creek are discussed in Chapter 4.

3.9 Quarries, Borrow Areas and Overburden Piles

Construction activities on the site, such as building tailings dams, roads and laydown areas, utilized mine development rock as much as possible. The Northwest Pond dams were constructed using material quarried from the current footprint of this facility. Consequently, there are few exposed quarries on the Giant Mine site. A clay and till borrow pit was opened south of the propane bulk storage facility during the construction of the NW Tailings Pond and is now filled with water. Two small quarries have been incorporated into the eastern side of the Northwest Pond and currently have exposed rock walls.

There are two overburden stockpiles on the site, located immediately north of A1 pit and immediately south of C1 pit. The material appears to be overburden stripped from the pit areas when they were opened in the 1970s and early 1980s. Seep samples collected from the stockpile north of A1 pit show that the overburden does not contribute arsenic to the surface water. Water quality data is provided in Supporting Document B6.

3.10 Contaminated Surficial Materials

Surficial materials around the mine infrastructure show impacts of fifty years of industrial activity. Areas of arsenic and other metals (notably antimony, chromium, copper, lead, nickel, vanadium and zinc) as well as hydrocarbons have been delineated by detailed selective and random sampling across the site. The areas identified as contaminated are shown in Figures 3.10.1 and 3.10.2. A detailed discussion of the investigation programs are provided in Supporting Documents I1 and I2. A summary of the investigation results is presented in the following sections.

The contaminated materials found on the surface of the site generally consist of:

- "Contaminated soil" – Natural soil deposits or fill, other than waste rock or tailings, with arsenic and/or hydrocarbon contamination. In accordance with the objective set out in Section 1.3, only material that is above the industrial land use remediation criterion (GNWT 2003) is included in the "contaminated soil" category herein.
- "Tailings" – Tailings that have been spilled or deposited outside of the impoundments, and containing arsenic dominantly in the form of arsenopyrite minerals.
- "Waste rock" – Mine rock used as fill on surface and containing arsenic dominantly in the form of arsenopyrite minerals.

It should be noted that the tailings impoundment, the historic foreshore tailings and the calcine pond are not indicated as contaminated areas on Figures 3.10.1 and 3.10.2, but that materials in these areas have the same or higher total arsenic levels.

3.10.1 Arsenic and Other Inorganics

The primary soil contaminant of concern is arsenic. Areas of soil containing arsenic concentrations greater than the Northwest Territories industrial criteria of 340 mg/kg arsenic were identified in nine areas of the mine lease area, as shown in Figure 3.10.1. The figure presents the locations where samples have been collected during several investigations. These samples were analysed for total metals, as reported in Supporting Document I1.

Arsenic concentrations range as high as 25,500 mg/kg. The highest arsenic concentrations are found in the Mill and Roaster areas (Area 1) and in the area west of the Polishing Pond (Area 4). These areas appear to contain large amounts of arsenic trioxide dust and spilled tailings, respectively.

Selected samples were tested to determine how much of the arsenic is in a readily soluble form. The proportion of water soluble arsenic ranged from 0.4% to 58%, with most soluble material located in the Mill and Roaster areas. This is likely due to the presence of arsenic trioxide dust around the roaster, baghouse and emissions stack. Arsenic concentrations in leachates from soils containing more than 340 mg/kg arsenic range from 0.7 mg/L to 231 mg/L. In soils containing less than 340 mg/kg arsenic, the arsenic concentration in leachates were less than or equal to 0.1 mg/L with one exception being at 7.3 mg/L.

Samples were analysed for constituents other than arsenic. Antimony, chromium, copper, lead, nickel, vanadium and zinc concentrations in a small number of samples exceeded the Northwest Territories industrial criteria. Most metal exceedances occurred in the Mill and Roaster areas. All exceedances of the industrial criteria for other metals occurred concurrently with arsenic exceedances. Consequently, arsenic was selected as the indicator constituent to delineate contaminated areas.

The volume of contaminated material in each area was estimated and the results are summarized in Table 3.13 below. Details are given in Supporting Document I1.

Figure 3.10.1: Location of Arsenic in Surficial Materials

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Figure 3.10.2: Location of Hydrocarbon Contaminated Soils

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Table 3.13: Estimated Volumes of Material with Arsenic above NWT Industrial Level

Areas	Contaminated Soil (m^3)	Tailings (m^3)	Waste Rock (m^3)	Total Estimated Volume Greater than 340 mg/kg Arsenic (m^3)
Area 1 – Mill and Roaster areas	170,000			170,000
Area 2 – West of Central TCA	4,800			4,800
Area 3 – West of TRP	200			200
Area 4 – West of Polishing Pond		110,000		110,000
Area 5 – Propane tank farm	2,000			
Area 6 – Townsite			37,000	37,000
Area 7 – Townsite road			1,100	1,100
Area 8 – Dam 7 to Yellowknife Bay		2,300		2,300
Area 9 – East of Dam 3		800		800
Total	**177,000**	**113,100**	**38,100**	**328,200**

Note: Volumes have been rounded

Prepared by: mdr
Checked by: srs

As discussed in Section 2.3.2, it was reported that arsenic trioxide dust was disposed of in 1949 and 1950 in a suitable area north of the property. Based on the property lines and site roadways identified from a review of historical air photos, it is likely that the area of high arsenic waste, near the Polishing Pond, is the disposal site discussed in the earlier records. This area is currently covered by tailings and waste rock. Site wide sampling and reconnaissance have not identified any other areas that appear to have been used for disposal of high arsenic waste.

3.10.2 Hydrocarbons

The potential for hydrocarbon contamination was evaluated in a separate investigation. Contamination by diesel fuel and/or fuel oil was identified in areas where fuel handling has taken place, as shown in Figure 3.10.2. The report detailing the hydrocarbon investigation is included in Supporting Document I2.

The volume of hydrocarbon contaminated material is estimated to be 15,000 cubic metres. The areas of known hydrocarbon contamination generally fall within areas of high arsenic concentrations. Additional investigations will be required to determine the presence of contamination under existing tank foundations, concrete pads and drum storage areas that were inaccessible during the first investigation. It is likely the volume of hydrocarbon contaminated material will increase as a result of these investigations.

3.11 Buildings and Infrastructure

Buildings

The Giant Mine site has over 100 buildings, constructed in several phases of the mine history, using a variety of construction materials. The first buildings were constructed in the mid-1940's in the A-Shaft area, to support underground exploration activity, and in the Townsite area, to provide accommodation and recreation facilities for the miners. The buildings required for full-scale ore production and processing were constructed in the area of the B and C-Shafts in the late 1940's, and were subsequently improved and expanded through the 1950's and 1960's. The Effluent Treatment Plant was constructed in 1981, to comply with new effluent quality standards, and a new gold refinery was built in the same year. In the late 1980's, the Tailings Retreatment Plant, Mobile Equipment Garage, and new C-Dry were built. The locations of the site buildings are shown in Figure 3.11.1.

The site buildings were inspected in 1998 (Royal Oak Mines Inc. 1998b). The purpose of the inspections was to visually identify the types and approximate amounts of hazardous materials associated with each building. The inspections identified asbestos containing materials, lead-based paints, and potential for PCB contaminated materials as remediation concerns. Asbestos containing materials identified included non-friable construction materials, such as the siding and roof shingles found on all of the older site buildings, and friable asbestos materials used for insulation. Large quantities of friable asbestos were found in the process buildings associated with the roaster and roaster-gas handling systems.

Most of the buildings have been painted on exterior and interior surfaces, and since lead was widely used in the manufacture of paints until about 1977, lead-based paints were probably used. Non lead-based paints have been applied over the original paint on most interior and some of the exterior surfaces. The original paint on many exterior surfaces is now peeling, cracked, or flaking, which could result in lead contamination of soils immediately adjacent to the older buildings.

In 2002, a survey of arsenic bearing materials located in the Mill and Roaster complexes was undertaken, including extensive sampling and analysis of process residues in various vessels and ducts (Northwest Consulting Limited 2003). The survey identified approximately 700 tonnes of process residues containing greater than 10,000 mg/kg total arsenic, and likely to contain high levels of soluble arsenic. An additional 1,500 tonnes of process residues in the Mill and Roaster complexes may be expected to contain less than 10,000 mg/kg total arsenic, which would require further assessment to determine if the material is suitable for disposal in the tailings ponds.

The buildings can be grouped into ten complexes, according to their function and location on the site. The ten complexes are listed in Table 3.14, along with the key hazardous material and remediation concerns associated with each complex.

Figure 3.11.1: Locations of Buildings and Infrastructure

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Table 3.14: Summary of Building Complexes and associated Hazardous Material Concerns

Complex	Infrastructure	Hazardous Material Concerns		
		Asbestos Containing Materials	Arsenic Containing Materials	PCB Materials
Townsite	Residences, recreation hall, curling rink, freshwater pumphouse, domestic water pumphouse	Non-friable construction materials	None	Possible (small quantities of solid PCB materials)
A-Shaft Complex	A-Boiler, sewage lift station, core shed, transformer substation, old power house, hoist room, headframe, explosives magazine	Non-friable construction materials, friable insulation materials at A-Boiler	None	Possible (small quantities of solid PCB materials)
C-Shaft Complex	Main office, C-Dry, headframe, hoist room and compressor building, crusher building, machine shop, warehouses, pipe and steel racks, electrical shop, C-Boiler, Mine Equipment Garage, carpenter shop, planer shop, emergency powerhouse	Non-friable construction materials, friable insulation materials at C-Boiler	Small quantities of ore residue in crusher building, conveyor galleries	Possible (small quantities of solid PCB materials)
Mill Complex	Mill, refinery, reagent shed, office and laboratory complex	Non-friable construction materials	Large quantities of process residues	Possible (small quantities of solid PCB materials)
Roaster Complex	Roaster plant, kiln plant, carbon plant, Cottrell plant, baghouse, stack, arsenic trioxide silo, truck loading shed	Non-friable construction materials, large quantities of friable insulation materials	Large quantities of process residues, with high soluble arsenic contents	Possible (small quantities of solid PCB materials)
B-Shaft Ventilation Plant	Ventilation plant, propane tank, old compressor building	Non-friable construction materials	None	Unlikely
Tailings Retreatment Plant	Process plant, water tanks, thickener, leach tanks, warehouse, office trailers	Unlikely	Residual tailings	Unlikely
B3 Ventilation Plant	Ventilation plant, propane tank	Unlikely	None	Unlikely
Effluent Treatment Plant	Process control and reagent prep building, treatment tanks, reagent holding tanks	None	Small quantities of sludge residue	Unlikely
Akaitcho Complex	Headframe, core racks, compressor building, warehouse, recreation hall, bunkhouses	Non-friable construction materials	None	Possible (small quantities of solid PCB materials)
Pipe Systems	Utilidors housing pipe systems, from Townsite and A-Shaft complex to C-Shaft complex. Fresh water and steam heat supply, sewage disposal.	Non-friable pipe wrapping materials	None	None

Prepared by: srs
Checked by: mdr

Fuel Storage and Handling Systems

All above ground fuel and lubricant storage tanks that are no longer in use have been dismantled and are slated for removal from the site. The remaining above ground tank are the fuel tanks for the A, C, and C Dry Boiler heating plants and a mobile equipment diesel fuel tank located adjacent to C Boiler.

Underground storage tanks include heating oil tanks built into some of the buildings in the Townsite, and a gasoline tank adjacent to the main warehouse. The former are slated for removal with the buildings, and the latter is still in use.

Electrical Distribution System

Fluids containing PCB compounds were banned for use in new electrical equipment manufactured after 1977. At one time the Giant site had a significant inventory of PCB's, but the majority of electrical equipment known or suspected to contain PCB fluids was removed from the Giant site in 1993 and 1994, under a federally sponsored program, and transported to a disposal facility in Alberta (Royal Oak Mines Inc. 1998b).

An assessment of the potential for PCB fluids to remain at the site was conducted in 2000 (Deton'Cho Environmental Alliance 2000a). Eight unused transformers were identified as probably or possibly containing PCB fluids, and were removed from the site for disposal at a licensed facility. The assessment also included sampling and analysis of soils adjacent to all of the major electrical transformer stations. The sampling found evidence of limited PCB soil contamination at three of the sub-stations.

Another potential source of PCB's are fluorescent lighting ballasts manufactured before 1979. A large number of the site buildings contain fluorescent lighting systems manufactured in this period and may be expected to contain PCB compounds in solid materials. Small quantities of solid PCB compounds may be associated with other electrical components remaining at the site.

Public Highway

Highway No. 4, (the Ingraham Trail), and the Vee Lake Road run through the Giant Mine site along a 60 metre wide right of way. The road is used by residents of homes on the Ingraham Trail, and by other members of the public for recreational purposes. The road is owned and maintained by the Government of the Northwest Territories. The road passes close to several key site components, such as Baker Creek, the A2 and C1 Pits, and the Roaster Complex. The road also passes close to or directly above several of the underground arsenic trioxide storage chambers and stopes.

3.12 Waste Storage and Disposal Areas

A number of equipment salvage and laydown areas are located across the site. For the purpose of this report, these areas are identified as waste storage sites. There are also several waste disposal sites. Eight principal waste storage and disposal areas have been identified, located as shown in Figure 3.12.1. None of the sites are currently in use. The following sections briefly describe these areas.

Area 1: A-Shaft Road

The mine road leading from the main site to the A-Shaft complex has been used as a waste storage or waste disposal site since the earliest years of operations. Redundant mining and processing equipment has been dumped on ground adjacent to the road over a distance of 300 metres. The majority of the waste is comprised of steel, and does not present any special hazards with respect to waste handling or disposal. In 2000, eight transformers suspected to contain PCB fluids were identified in this area and removed from the site for disposal. Small quantities of other hazardous materials could remain amongst the waste, including asbestos containing materials, and arsenic bearing process residues associated with equipment removed from the Roaster complex.

Area 2: C-Shaft Area Yards

The storage yards east of the C-Shaft area have been used to store redundant equipment, including underground mining equipment and surface mobile equipment. Some of the clean waste has been collected and disposed of at the current non-hazardous waste landfill (Area 8) in recent years, but a large amount of waste remains in the yards. A large inventory of lead-acid batteries was collected from this area in 2000, and transported to lead recycling facilities off site (Deton'Cho Environmental Alliance 2000b). The majority of the remaining waste is non-hazardous, although small quantities of hazardous materials could remain in this area, such as hydrocarbon products associated with vehicles.

Area 3: South Pond Tire Dump

A large inventory of used rubber tires is stored in a flat area south-west of the South Pond.

Area 4: B1 Open Pit

The B1 Pit was designated as a disposal site for non-hazardous wastes in 1993, and was recognized as such by the Government of the Northwest Territories (Royal Oak Mines Inc. 1998b). Some wastes, designated by the mine operator as non-hazardous, were placed near the bottom of the pit, and covered with waste rock and soil. Other waste was later placed on top of the fill, including underground and surface mobile equipment, piping, and tanks. No waste has been placed in this area since 1998, when it was recognized that the placement of waste in the pit could interfere with remediation measures for the arsenic trioxide dust stored in adjacent underground stopes.

Area 5: Central Pond Hazardous Waste Area

A disposal site for hazardous wastes is located on tailings in the northwest corner of the Central Pond, just below the Tailings Retreatment Plant. The wastes deposited there, which are partially buried in tailings, include asbestos containing materials attached to old equipment, and rusted steel drums that may contain asbestos and arsenic contaminated materials.

Area 6: Dam 1 Area

Waste is stored in several locations just east of Dam 1, south of the Polishing Pond. This includes non-hazardous steel waste (old equipment), as well as a large quantity of steel drums that originally contained hydrocarbon products. The drums are believed to be largely empty, although the presence of hydrocarbon staining in this area indicates that residues may remain in the drums.

Area 7: Northwest Pond Hazardous Waste Area

This area was designated by the mine operator for hazardous waste handling soon after the tailings pond was commissioned in 1987. Initially, the area was designated as a disposal site for wastes such as asbestos containing materials and arsenic contaminated materials. The arsenic contaminated materials included steel process equipment with arsenic scale, used bags from the arsenic trioxide baghouse, and personal protective equipment. The intent was to bury the waste with the deposition of tailings, as had previously been the practise for these types of waste. The waste materials were initially dumped at the site, without the intent of recovery for disposal elsewhere. At some point in the early 1990's, the function of the site changed from disposal to storage, after which, sealed drums of waste were placed upright on solid ground so that they could be easily recovered later.

From 2000 through 2004, a substantial clean up of this site was completed in several phases. Drums of waste that were not originally marked with the type of waste contained were opened and inspected. Several waste samples were collected and analysed. Drums containing arsenic contaminated materials (principally baghouse bags, clothing, and scale cleaned from process equipment), were placed in plastic over-pack containers, stacked on pallets at a new site nearby, and covered with plastic. Damaged and corroded drums containing arsenic contaminated materials were also collected and placed in over-pack containers.

Asbestos containing materials were also identified and collected in this process. An asbestos disposal landfill was created nearby by excavating a trench in dry tailings, placing the waste in the trench, and backfilling it with tailings.

Area 8: Northwest Pond Non-Hazardous Waste Area

A disposal site for non-hazardous wastes has been operated at the north end of the Northwest tailings pond since the pond was commissioned in 1987. In the period of active tailings disposal, the waste was covered with tailings discharged from the Mill. In the years since tailings disposal ceased, a large amount of non-hazardous waste has been collected across the mine site and placed on the tailings in this area. Some of this waste has been covered with waste rock, although much of the waste remains exposed. The waste typically disposed of in this area includes steel, wood, rubber, plastics and paper products.

Figure 3.12.1: Locations of Waste Storage and Disposal Areas

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4 Current Environmental Conditions

4.1 Climate

There is an excellent record of climate data from the Yellowknife airport meteorological station, which has collected data since 1943. Air temperature during the monitoring period ranged from a minimum of -51ºC to a maximum of +32ºC. The estimated mean annual air temperature is - 4.5ºC.

The Northwest Territories is one of the drier regions of Canada, with relatively low precipitation and high evaporation. Total annual precipitation recorded at Yellowknife airport has ranged from 160 to 423 millimetres since 1943. The mean annual precipitation recorded at Yellowknife from 1971 to 2000 was 281 millimetres (Canadian Climate Normals, Yellowknife Station ‘A’, 1971 to 2000). In this period the average annual rainfall was 165 millimetres, and the recorded mean annual snowfall water equivalent was 116 millimetres (this snow water equivalent is not adjusted for snowfall measurement errors).

The probable maximum precipitation event for the mine site has been estimated. The calculations (using the Hershfield Method) are described in Supporting Document G1. The estimated maximum rainfall over a twenty-four hour period is 318 millimetres. For comparison, the maximum twenty-four hour rainfall event recorded at Yellowknife airport from 1942 to 1990 was 83 millimetres.

Studies of lake evaporation at Pocket Lake, which lies inside the Giant surface lease boundary, have been underway since 1993 (Reid 2001). The results of this work indicate an average annual lake evaporation of about 415 millimetres at this site from 1994 to 2002, with annual evaporation ranging from 361 to 460 millimetres in this period. Pan evaporation data from the Yellowknife airport suggests that the long-term average annual evaporation may be higher than 415 millimetres, but the data is believed to be less reliable for the estimation of lake evaporation than the results of the Pocket Lake studies.

From 1942 to 1990, the average wind speed recorded at Yellowknife airport was 15 kilometres per hour (Canadian Climate Normals, Yellowknife Station ‘A’, 1942 to 1990). In this period, the monthly average wind speed varied little during the year, ranging from 13 to 16 kilometres per hour. In the fall, winter and spring months, from October to May, the winds are most frequently from the east and northeast. An exception is the month of January, when winds from the northwest are most frequent. In the summer months of June, July and August, southerly winds are most frequent. In September, winds from the southeast are most frequent.

4.2 Surface Water

4.2.1 Hydrology

Baker Creek drains in a generally southward direction and discharges into Yellowknife Bay of Great Slave Lake. The catchment of this stream has two distinctive features that control the stream's runoff response. Firstly, the catchment has a very low relief, with an overall elevation range of about 157 metres to 260 metres. Secondly, the catchment contains a very large number of lakes and wetland areas. The arid climate of the region also plays a significant role in the character of Baker Creek's flows. The mean annual precipitation for the catchment is approximately 340 millimetres (based on the record for Yellowknife airport, corrected for snow measurement errors).

The hydrology of Baker Creek can be characterized with a high degree of accuracy because the Water Survey of Canada (WSC) has monitored the flow of this stream since 1968. The streamflow has been measured at two locations. The initial site was located just upstream of the confluence with Trapper Creek. In 1983, the station was moved about 3 km upstream to its current location at the outlet of Lower Martin Lake. To mark the movement of the station in their database, the WSC assigned different identification numbers to the two locations, the initial one being 07SB009 and the other 07SB013. The official estimates of drainage areas for the two locations are 126 and 121 square kilometres, respectively.

The WSC data were used to characterize the low, average and flood flows of Baker Creek. To improve the accuracy of the characterization, the two flow records were combined to create a single, longer record spanning the period 1968 to 2002, or 35 years. Owing to the small difference in their respective catchment areas, no adjustments were made to the flows of the original station before using them to extend the record of the current station. The long-term average flow at Station 07SB013 works out to approximately 0.215 cubic metres per second or 6,800,000 cubic metres per year, which is equivalent to an average annual yield of 56 millimetres when expressed as a depth of water (*i.e.*, the average annual volume of runoff distributed evenly over the contributing catchment area). Thus, the average annual runoff generated by Baker Creek is only a small fraction (about 16%) of the total precipitation falling on the catchment.

There is some uncertainty in the official estimate of the drainage areas for the WSC streamflow gauging stations and for Baker Creek as a whole. This uncertainty arises because the available topographic maps for much of the catchment do not meet the minimum standard typical of mapping prepared by Natural Resources Canada. A disclaimer on the 1:50,000 map sheets indicates that the maps may have vertical errors that could exceed 20 metres and horizontal errors that could exceed 100 metres. As part of the current study, the catchment boundary of Baker Creek was delineated on the available 1:50,000 maps. Different interpretations of where the drainage boundary should be placed suggested that the catchment area for Station 07SB013 could fall in the range of 121 to 156 square kilometres. The total catchment area for Baker Creek at its mouth falls in the range of 144 to 178 square kilometres. These uncertainties would change the estimates of unit runoff, but not the estimated flood flows or low flows presented below.

The largest recorded flood flow for Baker Creek is 8.5 cubic metres per second. This works out to a unit discharge of 70 litres per second per square kilometre of the watershed, which is very low on the scale of floods experienced elsewhere in Canada.

The measured annual floods on Baker Creek were fitted to a theoretical frequency distribution to estimate instantaneous flood peaks for a range of return periods from 2 years to 200 years. Table 4.1 shows the results of this analysis. The relatively low flood flows can be attributed to the arid climate and the water storage available in the numerous lakes and wetlands in the catchment. Further information on the flood regime of the Baker Creek catchment is contained in Supporting Document G1.

Table 4.1: Estimated Flood Flows for Baker Creek at Outlet of Lower Martin Lake

Return Period (years)	Estimated Flood Discharge	
	(m^3/s)	(L/s)/km^2
2	1.3	11
10	3.8	32
50	8.3	69
100	11.3	93
200	15.2	126

Prepared by: pb
Checked by: qjk

The flow in Baker Creek becomes minimal for some period in winter almost every year. The combined flow record for the two gauging stations contain 29 years of complete data, and the annual low flow fell to zero in 26 of these 29 years.

Despite the high density of lakes in the catchment, Baker Creek flows become very low during the summer. The extended flow record for Baker Creek was subjected to a frequency analysis to estimate summer low flows (June 1 to September 30) for a range of durations and return periods. The results, summarized in Table 4.2, indicate that Baker Creek can dry up during the summer as often as one of every four years.

Table 4.2: Estimated Summer Low Flows for Baker Creek at Outlet of Lower Martin Lake (June 1 to September 30)

Return Period (years)	Duration (days)	Estimated Discharge (m^3/s)
2	1	0.003
	7	0.004
	30	0.007
	122	0.198
3	1	0.001
	7	0.001
	30	0.002
	122	0.125
5	1	0
	7	0
	30	0.001
	122	0.077
10	1	0
	7	0
	30	0
	122	0.044

Prepared by: pb
Checked by: qjk

4.2.2 Water Quality

Routine monitoring of surface flows and arsenic concentrations was carried out by Miramar Giant Mines Ltd. as part of the Surveillance Network Program (SNP) required by the site water license. DIAND is continuing with the SNP. The SNP includes regular monitoring of stations upstream of the mine on Baker Creek, the outlet of Trapper Lake, Trapper Creek, discharges from the underground mine to the Northwest Tailings Pond, discharges from the water treatment plant, and the mouth of Baker Creek. Routine monitoring results are presented in Supporting Document B4.

Arsenic concentrations in Baker Creek immediately upstream of the mine area (SNP 43-11), ranged from 0.01 to 0.07 mg/L, with a flow-weighted average value of 0.028 mg/L.

Trapper Creek is the largest tributary to Baker Creek in the vicinity of the mine, and enters Baker Creek just upstream of the water treatment plant discharge point. Trapper Creek is monitored at two locations, the outlet of Trapper Lake (SNP 43-15), and immediately upstream of Baker Creek (SNP 43-16). Seepage from the Northwest Pond could potentially enter between these two stations. Arsenic concentrations in both stations typically range from 0.05 to 0.2 mg/L, with average concentrations of approximately 0.1 mg/L.

Discharges from the effluent treatment plant are monitored at SNP 43-1. The average arsenic concentration during 2000 and 2004 was 0.38 mg/L. During the summer months, flows from the effluent treatment plant comprise a significant portion of the total flow in Baker Creek.

There is a progressive increase in arsenic concentrations as Baker Creek passes through the mine area. Data from the mouth of Baker Creek (SNP 43-5) provide the most continuous record of downstream concentrations. The results indicate that there is a significant difference in concentrations between samples collected during periods of treated water discharge and samples collected at other times of the year. During the discharge period, arsenic concentrations ranged from 0.060 to 0.40 mg/L, while during periods without discharge, arsenic concentrations ranged from 0.017 to 0.28 mg/L. Flow weighted average arsenic concentrations for the discharge and non-discharge periods were 0.12 mg/L and 0.068 mg/L, respectively. The overall average concentration downstream of the mine was 0.094 mg/L.

Other surface water sampling programs have included detailed seepage surveys in 1994, 2001, 2003 and 2004, and additional sampling of Baker Creek and its tributaries upstream and to the west of the mine. The results of these programs are provided in Supporting Document B5. Concentrations in seepage and runoff ranged from approximately 0.2 mg/L from undisturbed areas near the mine to as high as 68 mg/L in a water collection pond near the mill. However, most samples had concentrations of less than 1 mg/L. The treated water discharge, plus the inputs from runoff from contaminated soils, tailings spills, and relatively undisturbed areas around the mine, account for essentially all of the arsenic loading observed at the mouth of Baker Creek. Creek sediments may also contribute to the arsenic in Baker Creek, but their contribution is not distinguishable in the current data.

4.2.3 Sediment Quality

Table 4.3 provides a summary of contaminant concentrations in aquatic sediments at three separate locations within Baker Creek.

Table 4.3: Mean Contaminant Concentrations in Sediments

Parameter	ISQG 1999	PEL 1999	Upstream of Mine Site (mg/kg)	Creek Channel through Mine site (mg/kg)	Outside the Breakwater (mg/kg)
Arsenic	5.9	17	177	1643	1275
Antimony	n/a	n/a	78.8	106.9	103.3
Cadmium	0.6	3.5	0.20	1.42	0.55
Chromium	37.3	90	29	45	57
Copper	35.7	197	17	451.8	265
Nickel	n/a	49	23	75	81
Selenium	n/a	2.2	0.67	2.63	-
Zinc	123	315	74.6	290	221

Note: Interim Sediment Quality Guidelines (ISQG) and Probable Effects Levels (PEL) Taken from CCME 1999.

Prepared by: rm
Checked by: ml

The table also includes the Interim Sediment Quality Guidelines, (ISQG) and the Draft Probable Effects Levels (PEL) for a number of parameters. The table shows that the historical operations of the Giant mine have impacted the sediment quality in the Baker Creek watershed. For example, the sediment samples collected at the discharge of Baker Creek behind the breakwater have lower arsenic concentrations than from those collected in the area of Yellowknife Bay immediately outside the breakwater.

The Interim Sediment Quality Guidelines (ISQG) provide scientific benchmarks, or reference points, for evaluating the potential for observing adverse biological effects in aquatic systems. The guidelines are derived from the available toxicological information according to the formal protocols established by the Canadian Council of Ministers of the Environment. The Probable Effects Levels (PEL) define the levels above which adverse biological effects are expected to occur frequently. (CCME, 1999).

The average arsenic concentrations in sediments from upstream of the mine site in each of the sampling events exceeded both the ISQG and the PEL with an average concentration of 177 mg/kg compared to the published interim guideline value of 5.9 mg/kg and a Probable Effects Level of 17 mg/kg.

Average copper concentrations measured in the sediment samples collected at the discharge of Baker Creek and outside the breakwater exceed both the ISQG and PEL values. Average cadmium, chromium and zinc concentrations in the sediments at the discharge of Baker Creek and outside the breakwater exceed the ISQG values but are below the PEL value.

4.3 Groundwater

Detailed discussions of recent groundwater investigations around the mine area are included as Supporting Documents C1 to C6. The investigations to date included installations of a monitoring system that is being used to further delineate current groundwater flow conditions and geochemistry. The results will be used as a benchmark for baseline conditions, and as a means of assessing effectiveness of remedial works.

4.3.1 Conceptual Hydrogeological Model

The current understanding of the conceptual model groundwater flow patterns around the mine can be summarized as follows:

- The regional pattern of groundwater flow follows the generally flat topography eastwards towards Great Slave Lake;
- The bedrock surrounding the mine has a relatively low hydraulic conductivity, based on available test data and the low pumping rates that have been observed in the minewater management system;
- The mine is relatively dry now and there is no record in the mine history of encountering natural high inflow zones;
- The West Bay Fault acts as a local barrier to groundwater flow in the southern and northern parts of the site, but appears to be more permeable in the area where Baker Creek crosses the fault;

- The pumping of water out of the mine has lowered the local water table and completely changed groundwater flows near the mine. Deep groundwater between the lake and the mine is flowing towards the mine workings;
- Water that infiltrates through the ground surface anywhere within the local area enters the mine workings; therefore, is captured by the mine dewatering;
- Shallow groundwater (less than 10 to 20m deep) on the eastern perimeter of the site may be flowing towards the lake; and
- No arsenic has escaped the underground workings through groundwater flow.

To date, there is not a significant correlation between groundwater flow and rock type. Variations in the hydraulic conductivity of the rock mass appear to be controlled by faults and fractures rather than by the different rock types and their boundaries. The larger faults in the mine area (*e.g.*, West Bay, Townsite, and Akaitcho) have the potential to markedly influence groundwater flow patterns.

Relatively little hydraulic conductivity data are available for the major faults. Multilevel monitoring systems have been installed through the West Bay (two areas), Townsite and Rudolph Faults as part of the groundwater monitoring system (SRK 2002a and Supporting Document C 3). Installation of S-1857, S-DIAND-021, S-DIAND-001, and S-DIAND-002, through the West Bay, Townsite, and Rudolph Faults, respectively, provided limited geological information from core. Structures were interpreted from core, and generally found to be narrow zones, or multiple planes. Piezometric data indicate that the West Bay and Townsite faults are lateral flow barriers at the location of monitoring wells S-1857 and S-DIAND-001. Pressure data is observed to drop across each fault, from higher values on the side of the fault away from the mine, to lower values on the side of the fault closer to the mine workings. S-DIAND-021 and S-DIAND-002, which penetrate the central section of the West Bay fault under Baker Creek and the Rudolph Fault, suggest that the faults act as neither barriers nor preferential flow paths. Pressure data show no significant variation across the fault, suggesting that either the fault conductivity is not significantly different than bedrock or, possibly, that its orientation precludes it having significant effect on flow.

4.3.2 Groundwater Numerical Model

The site groundwater data were integrated into a mine scale numerical model. The model, used to test the conceptual flow model of the site and future reflood scenarios as part of the planning process, is discussed in detail in Supporting Document C5. Supporting Document C6 provides an update that incorporates data from the enhanced groundwater monitoring system installed in August 2004.

The model was designed to illustrate groundwater flow patterns in the mine workings and surrounding bedrock. The model has been calibrated to available data, but as the mine is currently dewatered, it is not possible to calibrate the model for fully reflooded conditions. The model will be updated as the mine refloods during the remediation program.

4.3.3 Groundwater Quality

A review of groundwater quality in the bedrock surrounding the mine is given in Supporting Document C4. This discussion deals only with background water quality from samples collected using the multilevel groundwater monitoring system installed in 2002 and augmented in 2004.

Results to date show elevated arsenic content in the groundwater when compared to other Canadian Shield groundwater geochemistry, but significantly less than mine or surface sources tested to date. As the groundwater is moving towards the dewatered mine, the source of the arsenic is either the mineralised bedrock or infiltration from surface sources.

4.4 Current Water and Arsenic Balance

A series of calculations were completed to track water flows and to estimate the current rate of arsenic release from the existing surface and underground sources. Details of the calculations are presented in Supporting Document M1.

The calculations indicate that, under current conditions, the total arsenic loading in Baker Creek is approximately 800 kg/year, distributed as follows:

- Sources upstream of the mine comprise approximately 220 kg/year, or 28% of the total arsenic loading to Baker Creek;
- Tributaries upstream of Trapper Lake and to the west of Baker Creek combine to contribute an additional 67 kg/year, or 8% of the loading to Baker Creek;
- Discharge of treated water from the Effluent Treatment Plant contributes 290 kg/year, or 36% of the total arsenic loading to Baker Creek;and
- Other mine site sources contribute approximately 220 kg/year or 28% of the loading to Baker Creek. This is distributed as follows:
  - 55 kg/yr from the Northwest Tailings Pond;
  - 44 kg/yr from the Polishing Pond/Settling Pond Area;
  - 37 kg/yr from upstream of the Mill Area;
  - 21 kg/yr from the Mill Area; and
  - 67 kg/yr in runoff downstream of the mill.

Yellowknife Bay receives an additional 110 kg/year in direct runoff from the mine site catchments that drain to the east. The total loading of arsenic from the Baker Creek and mine site catchments to Yellowknife Bay is therefore approximately 910 kg/year. A summary of arsenic loading from each of these areas is provided in Figure 4.4.1.

Most of the arsenic discharged from the Effluent Treatment Plant originates in the underground mine. A separate water and arsenic balance for the underground mine indicates that infiltration through the Northwest Pond and the arsenic chambers are the largest sources of arsenic. Total flows from the underground mine are on the order of 880,000 m^3/year, and total arsenic loadings are approximately 20,000 kg/year. At present, all of the flows from the underground workings are pumped to the Northwest Pond and stored for seasonal water treatment.

Figure 4.4.1: Summary of Current Arsenic Loadings

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4.5 Terrestrial Biota

4.5.1 Vegetation

The soils and climate of the project area have limited the upland vegetation communities to three upland types, two wetland types, one riparian type and three disturbed types. A detailed discussion of the methodology and a map of survey results is provided in Supporting Document A3. Each of the community types is described briefly below. (Jacques Whitford Limited, 2003).

Upland Vegetation Communities

Mesic Forest - The mesic forest community is found on the deepest soils between the rock outcrops within the study area. Retention of some moisture during the growing season, as well as a relative abundance of nutrients, has allowed for higher species diversity and plant vigour in this community as compared to the scrub forest and rock outcrop communities. This community is comprised of mature white spruce (18% cover) and paper birch (3% cover) with a shrub under story dominated by willow (20% cover) and Labrador tea (14% cover), with a sub-dominance of green alder (3% cover). Common herbaceous species include dwarf scouring rush (10% cover) and trace amounts of common horsetail and mountain goldenrod. The moss and bryophyte layer is usually dominated by glow moss (25% cover) and to a lesser extent by hair-cap mosses (2% cover).

Scrub Forest - The scrub forest community occupies the shallow soils niche of the study area ecologically and geographically between the mesic forest and the rock outcrop communities. The shallow soils results in less moisture and nutrient retention than the soils of the mesic forest community. As a result, the community structure is lower in diversity and vigour as compared with the mesic forest community. The tree layer is typically poorly developed with a total cover ranging from 5 to 10% cover. Paper birch (3% cover) forms the dominant cover with lesser amounts of white spruce. The shrub layer is typically dominated by common juniper (4% cover) with minor amounts of prickly rose, Labrador tea and green alder. The dominant herb is bearberry, often covering up to 20% of the area. Northern bastard toadflax will occasionally co-dominate in this community but averages between 1 and 2% cover in general.

Rock Outcrop - The rock outcrop vegetation community is sparse in terms of ground cover and density. The vegetation in this community exists within the crevices of the exposed bedrock. The lack of moisture and nutrients has restricted this community to one of low shrubs, herbs, mosses and lichens with rare occurrences of tree species. The vegetation within this community typically covers a maximum of 10% of the area with the dominant species varying from site to site. Dominant species include bearberry, common juniper and various grasses.

Wetland Vegetation Communities

Cattail Wetland - The cattail wetland community is dominated by cattail with minor occurrences of various sedge species. This community occurs along the shorelines of the larger lakes and surrounding small water filled depressions within the logged meadow community. These latter sites may be the result of the possible change in hydrology arising from historical logging.

Wetland Sedge - The wetland sedge communities are found in small isolated depressions in the rock outcrops, within the low areas of the meadow communities and along the shoreline of the larger lakes within the study area. The diversity of this community is low and is dominated by water sedge with cover values averaging 75%. The only other common but less dominant species was common horsetail with a cover value averaging 7%. Trace amounts of tall cotton-grass, foxtail barley and tufted moss were also observed.

Riparian Vegetation Communities

Riparian Shrub - The riparian shrub community occurs within the seasonally flooded banks of Baker Creek and is largely restricted to the northern end of the creek upstream from most of the mine activities. The shrub cover in this community approaches complete cover (100%) and is co-dominated by willow and bog birch with minor amounts of sweet gale and trace amounts of prickly rose and shrubby cinquefoil. When present, the herb understory is inhabited by trace amounts of common horsetail, dwarf raspberry, dwarf scouring-rush and Canada blue-joint.

Vegetation Communities in Disturbed Areas

Disturbed Meadow - The disturbed meadow community occupies a similar ecological position as the mesic forest community type (level areas with deeper soils). Historical logging had taken place in all of the meadows sampled and thus it appears as if the disturbed meadow community may be a result of historical logging of mesic forest communities.

Species composition and percent cover varied significantly on a micro scale (*e.g.*, within 10m) but on a macro scale (mapped polygons) the overall species composition was homogenous. The disturbed meadow community is relatively diverse and is generally vegetated with rough hair grass (average cover of 8%), dwarf scouring rush (26% cover), common horsetail (6% cover) and trace amounts of goldenrod, slender wheatgrass, foxtail barley, and glow moss.

Disturbed Vegetated - Areas mapped as disturbed vegetated are those areas throughout the mine area that have been sparsely re-vegetated with pioneer species including foxtail barley, rough hair grass, yarrow, red clover, common dandelion, lamb's quarters, common horsetail and dock. The variability of the species occurrence and cover precluded an estimation of percent cover.

Disturbed Un-vegetated - These areas have undergone severe disturbance where no obvious vegetation exists. Such areas include dry tailings ponds and open pits, roads and other mine infrastructure sites.

Rare Plants

The NWT Species Monitoring Infobase (GNWT, 2000) lists six plant species as being sensitive or possibly at risk. None of the listed plant species were observed within the study area during the field investigations.

4.5.2 Wildlife

Muskrat

A muskrat field survey program within the Baker Creek watershed was carried out in the fall of 2003. Details of the study are presented in Supporting Document A9. A total of 60 muskrat observations, including 12 burrowing systems, were recorded during the field investigations. Approximately 4 km of shoreline was surveyed giving a density of three burrow systems per kilometre of shoreline or one burrow system every 333 m. Based on these observations and assumptions of muskrat reproductive success and mortality, as few as 66 and as many as 197 muskrats may reside within the Baker Creek watershed (Jacques Whitford Environmental Limited, 2003).

A muskrat sampling program was initiated in the fall of 2004 to investigate the concentration of arsenic in the muscle and organs of these mammals.

Other Mammals

During the 2003 field study two red foxes were sighted. Evidence of wolf, fox and black bear were also observed. Sightings of moose, black bear, wolf, and fox have been commonly reported within the study area.

Signs of beaver were observed throughout the Baker Creek watershed and included old lodges and cuttings in the lower portions of the creek and dams in the upper portion of the creek that are currently not maintained.

Sensitive and "At Risk" Species

The City of Yellowknife and the Giant Mine site are situated within the Taiga Shield ecozone. Approximately fifty species of mammals can be found within the Taiga Shield ecozone. Of these, the wood bison is the only species that is considered at risk according to its Committee on the Status of Endangered Wildlife in Canada (COSEWIC). There are several species found within the Taiga Shield that are considered sensitive or possibly at risk. These include the grizzly bear, river otter, fisher and polar bear (GNWT, 2000). None of these have been observed in the Giant Mine area in recent times.

Birds

Field surveys of birds at the Giant Mine site were completed in 2004. Complete results are presented in Supporting Document A10.

The primary goal of the study was to fill these information gaps to help address concerns of local duck hunters and the general public. The secondary goal was to document the use of this area by other bird species to help build an accurate information base for future environmental monitoring studies.

Bird species inventories were completed at selected habitats divided into three main categories: a) “Disturbed Sites” which included areas on the mine property containing tailings effluent and/or sediments; b) “Control Sites” which included a variety of natural water bodies of potential value for waterfowl; and c) “Upland and Wetland Habitats” which are representative of recurring habitats found throughout the mine property. Human structures associated with mining activities, such as buildings, pits and utilities, were also assessed for use by birds. Field observations spanned exactly four months, beginning May 14 and ending October 14, 2004.

The results suggest that disturbed tailings areas and associated water bodies are not utilized extensively by waterfowl. Use by ducks is largely restricted to the spring and fall migration periods when tailings ponds appear to break up sooner and freeze over later than nearby water bodies. Both the Tailings Beach and Northwest Pond are significant gathering sites for gulls and terns, the latter site being of special importance as a breeding area.

Of all the mine property’s relatively natural water bodies surveyed, Trapper Lake stands out as being exceptional both in terms of the abundance and diversity of ducks that use this site throughout the summer and early fall. The Breeding Bird Survey suggests that wetlands are the most diverse and productive bird habitats on the property.

4.6 Aquatic Biota

4.6.1 Baker Creek Benthic Community

Ten studies, dating from 1973, have included investigations of benthic organisms in Baker Creek or North Yellowknife Bay (Supporting Document A2). The most recent data from 2003 show that benthic invertebrate tissue samples collected downstream of the mine site contained higher concentrations arsenic, antimony, copper and nickel than those collected upstream. The report detailing the methodology and the results is provided in Supporting Document A3.

4.6.2 Baker Creek Aquatic Vegetation

A detailed investigation of the aquatic vegetation in Baker Creek was completed in August and September 2003 (Jacques Whitford, 2003). During the course of that investigation the distribution of aquatic vegetation communities were mapped and analyzed throughout the portion of Baker Creek within the lease boundary and the area immediately adjacent to the discharge of Baker Creek into North Yellowknife Bay.

Table 4.4 provides a list of the species of aquatic vegetation identified during the course of that investigation. No rare or endangered aquatic species were observed during the course of the investigation.

Table 4.4: Aquatic Vegetation Observed in the Giant Mine Study Area

Common Name	Scientific Name
Water Plantain	Alisma sp.
Canada Blue Joint	Calamagrostis canadensis
Water Arum	Calla palustris
Richardson’s Water Moss	Calliergon richardsonii
Water sedge	Carex aquatalis
Bladder sedge	Carex intumescens
Sedge species	Carex spp.
Common Horsetail	Equisetum arvense
Swamp Horsetail	Equisetum fluviatile
Tall Cotton grass	Eriophorum augustifolium
Common Mare’s Tail	Hippuris vulgaris
Cow Lily	Nuphar variegatum
Sago Pondweed	Potamogeton pectinatus
Richardson’s Pondweed	Potamogeton richardsonii
Bullrush	Scirpus lacustris ssp. validus
Narrow-leaf Burreed	Sparganium angustifolium
Cattail	Typha latifolia
Flatleaf Bladderwort	Utricularia intermedia

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Checked by: mrl

Emergent vegetation was observed in varying amounts along the length of Baker Creek. In some areas cattails lined approximately 80% of the shoreline while in other areas only trace amounts of emergent vegetation were observed. Submergent vegetation was not observed south of the point of Baker Creek opposite the mill site. Submergent vegetation in the creek north of that point was rare with minor amounts of sago pondweed and Richardson pondweed. Sections of Baker Creek that have been physically modified as a result of mining activity (*i.e.* channel relocation) exhibited a lesser density of aquatic vegetation. Cattails were the most common emergent vegetation species observed and were typically restricted to the edges of the creek. Other commonly observed emergent aquatic species included common mare’s tail and swamp horsetail.

The North Yellowknife Bay area is dynamic with respect to ecological niches (water depth and flow patterns), however due to its relatively small size the outflow area can be considered a single vegetative community. Swamp horsetail dominates the community with an average cover of 29%. Sporadic distributions of Canada blue-joint, common horsetail and Richardson’s water moss were also observed. Open water covers approximately 70% of the area.

A more detailed discussion of the distribution of each of the observed species is provided in Supporting Document A3.

4.6.3 Fish

Past studies have observed several fish species within Baker Creek, although primarily before the annual summer discharge of treated minewater. The species identified include northern pike (*Esox lucius*), white sucker (*Catostomus commersoni*), longnose sucker (*Catostomus catostomus*), trout perch (*Percopsis ominscomauycus*), nine spine stickleback (*Pungitius pungitius*), lake chub (*Couesius plumbeus*), spottail shiner (*Nottropis hudsonius*), emerald shiner (*Notropis atherinoides*), and juvenile Artic grayling (*Thymallus articus*) (Dillon Consulting Limited, 1998).

A survey of fish habitat throughout the length of Baker Creek, from North Yellowknife Bay to the areas immediately upstream of the mine site, was completed in 1998 (Dillon Consulting Limited, 1998). Generally the survey concluded that limited fish habitats exist in the lower reaches of Baker Creek, due in large part to the alterations resulting from mining activities and the construction of roads, including Highway 4. The lack of habitat is further exacerbated by the wide variability in Baker Creek stream flows resulting from periods of treated minewater discharge.

Nine studies have investigated fish in Back Bay and Yellowknife Bay. Since the first report in 1973, well over 700 fish have been sampled for tissue analysis. The most extensive set of results are presented in Jackson et al (1996). The most recent work included determination of the form of arsenic in fish sampled from North Yellowknife Bay, and is included as Supporting Document A4.

4.7 Air Quality

The Environmental Protection Division of the Department of Environment and Natural Resources (ENR) monitors air quality in the Northwest Territories. In Yellowknife, dust (Total Suspended Particulate or TSP) levels have been monitored since 1974, sulphur dioxide (SO_2) since 1992, and fine particulates (PM_{10} and $PM_{2.5}$) since December 1999.

4.7.1 Air Quality in Yellowknife

Since 1985, total airborne arsenic levels in Yellowknife over a 24-hour period have only twice risen above the Ontario standard of 0.3 µg per cubic metres. There is no NWT standard for airborne arsenic. Both events occurred in 1988 and coincided with baghouse malfunctions at the Giant Mine. The closure of Giant Mine roaster in 1999 had a direct impact on arsenic levels. The 1999 and 2000 results showed that arsenic levels had decreased to less than, or close to, detectable levels.

An air quality guideline, under the Northwest Territories' Environmental Protection Act, sets a standard for acceptable levels of sulphur dioxide in ambient air. The standards have not been exceeded since 1999 and the annual averages indicate only background levels.

4.7.2 Giant Mine Air Quality

An ambient air quality monitoring program at the Giant Mine site was designed and implemented during 2004. One high-volume sampler and four "MiniVol" samplers were installed at locations downwind of the tailings ponds. The locations were selected after a review of average wind speed and wind direction in the Yellowknife area over a five year period.

The high volume sampler was stationed at the Giant townsite in the location shown on Figure 4.7.1 to collect TSP. The four portable MiniVol samplers were placed in areas where electrical power was not easily accessed. The MiniVol samplers collected TSP at three locations: the South Pond, the Mill/Roaster Complex, and an area near the intersection of the Vee Lake Road and the Ingraham Trail. The other MiniVol sampler was installed at the South Pond location to collect PM_{10}. Samples were collected over a period of 24 hours, at six-day intervals to coincide with Environment Canada's National Air Pollution Surveillance Network sampling program. Additional samples were also collected between the six-day intervals, using the MiniVol samplers only. These samples were collected over a 48 hour period to ensure sufficient material was being deposited on the MiniVol filters for elemental analysis.

The air quality monitoring is ongoing and results are being used to develop baseline air quality estimates for the site. A report on the 2004 sampling program is included as Supporting Document A11. The highest arsenic concentration measured in 2004 was 60% lower than the ambient air quality criterion developed by the Ontario Ministry of the Environment. No other Canadian jurisdictions have an ambient air quality criterion for arsenic.

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Figure 4.7.1: Location of Air Quality Monitoring Sites

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5 Remediation Plan

5.1 Arsenic Trioxide Dust Storage Areas

5.1.1 Key Concerns

Current conditions in the arsenic trioxide dust storage areas are described in Section 3.1. The key issue associated with the dust is the potential for uncontrolled release of arsenic following reflooding of the mine.

A second and more immediate concern is the physical stability of the dust storage areas. Several of the crown pillars and bulkheads around the chambers and stopes, have been identified as having moderate to high failure risks, potentially resulting in the release of dust to the lower mine workings or the surface environment.

5.1.2 Method Selection

The selection of a method to remediate the arsenic trioxide dust storage areas has been a long and careful process, involving dozens of scientific and engineering studies as well as extensive consultation with local shareholders. The following paragraphs give a short overview. A more detailed discussion of the many alternatives considered can be found in SRK (2002b) and Independent Peer Review Panel (2003).

Technical Advisor Studies

In late 1999, when Royal Oak Mines Inc. went into receivership, DIAND took on the task of developing a long-term management plan for the arsenic trioxide dust. This led to a decision to contract an independent "Technical Advisor". During the period from January 2000 to December 2002, the Technical Advisor team:

- Compiled a detailed history of arsenic trioxide production and storage at the Giant Mine;
- Reviewed all available information about the arsenic trioxide dust and the chambers and stopes in which it is stored;
- Carried out or directed investigations to further characterize the properties of the dust and the storage areas, and to determine the current and possible future releases of arsenic to the receiving environment;
- Completed assessments of the ecological and human health risks associated with the current and possible future releases of arsenic;
- Assessed over 56 methods that were potentially applicable to the long term management of the arsenic trioxide dust, and evaluated the feasibility, risk and costs of four groups of alternatives;

- Prepared a comprehensive report, with seventeen supporting technical documents, presenting the results of the initial evaluations (SRK, 2001c);
- Carried out further, detailed evaluation of twelve specific alternatives selected on the basis of the technical merits and public response to the initial report;
- Prepared a second comprehensive report, this one including nineteen supporting technical documents, to present results of the detailed evaluations (SRK, 2002b); and
- Participated in three major public workshops as well as presentations to interested community groups.

Results of the Technical Advisor's assessment of the risks associated with the arsenic trioxide dust and the remedial alternatives were presented in SRK (2002b). In brief, the risk assessment characterized possible human health and ecological risks associated with arsenic releases from the underground arsenic trioxide. After taking into account uncertainties in the assessment, the Technical Advisor concluded that 2,000 kg per year would be an appropriate target for the maximum arsenic releases from the Giant Mine. That level of arsenic release will result in human health risks below the applicable thresholds, and will keep the arsenic concentrations in North Yellowknife Bay at or below the CCME criterion for freshwater aquatic life.

The twelve remedial alternatives considered included seven *in situ* alternatives that would keep the dust underground, and five *ex situ* alternatives that would take it to surface for disposal or re-processing. One of the *in situ* alternatives (Alternative C – Deep Disposal) and one of the *ex situ* alternatives (Alternative D – Removal and Surface Disposal) were included as a result of requests from the public. The other *in situ* alternatives included three variants of perpetual water management and three variants of re-freezing the ground around the dust. The remaining *ex situ* alternatives included reprocessing of the dust to recover gold and high purity arsenic trioxide, reprocessing of the dust to recover gold and stabilize the arsenic, and reprocessing to encapsulate the dust in either cement or bitumen.

All twelve alternatives were initially evaluated to determine if they could meet the objective of keeping arsenic releases below 2,000 kg per year. Nine alternatives that were concluded to be capable of meeting that objective were then assessed on the basis of risks and costs. Three types of risk were considered: the risk of arsenic release during implementation of the alternative, the risk of arsenic release after the alternative was completed, and the risk to worker health and safety. Cost estimates were developed for each alternative and included preparation and implementation costs as well as long-term monitoring and maintenance costs.

Table 5.1 below summarizes the results of the second round of assessments. Alternatives A through C would keep the dust underground, and therefore were classified as *in situ* alternatives. The report concluded that the best *in situ* alternative was Alternative B3, isolating the arsenic trioxide dust in its current location by creating a block of frozen dust and rock, monitoring in perpetuity, and if necessary maintaining isolation by periodic re-freezing. The water treatment alternatives, A1, A2 and A3, would require long-term operation of an active pumping and treatment system, and therefore were concluded to present higher risks of arsenic release over the long term. Alternative C, mining the dust from its current locations and disposing it in new caverns at the base of the mine, was predicted to result in very low long-term risks. However, the significant increase in worker health and safety risks during mining of the dust would outweigh the slight reduction in long-term risks.

Alternatives D through G would require that the dust be brought to surface, and were therefore considered *ex situ* alternatives. Alternative G1, comprising mining the dust, mixing it with cement, and storing it in a secure on-site landfill, was recommended as the best *ex situ* alternative. Alternative D, removing the dust and trucking it to a hazardous waste disposal site in Alberta, was concluded to present too high a risk of arsenic release. Alternative F, mining the dust and re-processing it to recover gold and stabilize the arsenic, was concluded to have a similar risk profile to Alternative G1. Given that the risks were similar, the Technical Advisor recommended the much less costly Alternative G1 as the best *ex situ* alternative.

The SRK (2002b) report also noted that, in the public consultation carried out during the studies, individuals had expressed reservations about options that would leave the dust in place, whereas others expressed concern about those that would bring the dust to surface. Therefore, the Technical Advisor recommended that both the best *in situ* alternative and the best *ex situ* alternative be carried through to the final round of public discussion.

Table 5.1: Summary of Methods to Remediate Arsenic Trioxide Dust

Alternative	Risk of Arsenic Release		Worker Health & Safety Risk	Cost Range ($ Million)
	Short Term	Long Term		
A1. Water Treatment with Minimum Control	Low	High	Low	30-70
A2. Water Treatment with Drawdown	Low	Moderate	Low	80-110
A3. Water Treatment with Seepage Control	Low	Moderate	Low	80-120
B2. Frozen Shell	Very Low	Low	Low	90-110
B3. Frozen Block	Very Low	Low	Low	90-120
C. Deep Disposal	Low	Very Low[(b)]	Moderate[(b)]	190-230
D. Removal & Surface Disposal	High	Very Low	Moderate	600-1000
F. Removal, Gold Recovery & Arsenic Stabilization	Moderate	Very Low	Moderate	400-500
G1. Removal & Cement Encapsulation	Moderate	Low	Moderate	230-280

Notes: (a) Alternatives B1, E and G2 were concluded to be infeasible and therefore were not further evaluated.
(b) Subsequent review by the IPRP concluded that the ratings shown here (IPRP 2003) probably underestimate both the long-term risks and the worker health and safety risks associated with Alternative C.

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Checked by: mdr

Independent Peer Review Panel Reviews

The SRK (2002b) report was comprehensively reviewed by an Independent Peer Review Panel (IPRP) consisting of nine of the country's top engineers and scientists and covering all of the disciplines involved in the project. In March 2003, the IPRP issued its report, which concluded:

> "The IPRP considers that the December 2002 SRK Report is appropriate for the presently planned level of the studies (*i.e.* comparison and assessment of management alternatives). The IPRP agrees with SRK's selection of these two basic management alternatives."

Public Discussion of *In Situ* and *Ex Situ* Methods

The public discussion of the two alternatives recommended in the December 2002 report began in January 2003 and included approximately twenty presentations to groups in Yellowknife, Ndilo and Dettah. In addition, the Community Alliance, a group of interested citizens, who act as a liaison between the local public and the Giant Mine Remediation Project Team. The public discussion period culminated in a workshop held in Yellowknife, May 26-27, 2003.

During the public discussion period, there were many expressions of concern about the *ex situ* alternative. These include statements from four Yellowknife Members of the Legislative Assembly and from GNWT staff rejecting the *ex situ* alternative. In contrast, while there were questions about, suggestions for improvements to, and requests for more study of the *in situ* alternative, direct opposition was limited.

In response to questions raised at a May 2003 workshop, both the IPRP and the Technical Advisor completed a further review of Alternative C, Deep Disposal. Both reviews concluded that more detailed consideration only increased the preference for Alternatives B3 and G1, and that further consideration of deep disposal was not warranted.

After considering the public feedback and the follow-up studies, the Technical Advisor made the following recommendation to DIAND:

> "The *in situ* alternative recommended in the December 2002 report, namely Alternative B3 – Ground Freezing as a Frozen Block, should be adopted as the preferred approach for managing the arsenic trioxide dust stored underground at the Giant Mine. Elements of the alternative should be modified to take into account suggestions made by the general public, the Yellowknives Dene, and the GNWT. The modified alternative should be described within a Project Description that presents a complete plan for final closure and reclamation of the Giant Mine site, including surface works. The Project Description should then be submitted for formal environmental review, licensing and subsequent implementation."

5.1.3 Ground Freezing Method

Figure 5.1.1 shows the general concepts behind the recommended method and Supporting Document J1 provides details. Under the "frozen block" method, the ground under and around the arsenic trioxide dust stopes and chambers would be frozen to prevent any escape of arsenic. The interior of the frozen shell would then be flooded and also frozen. Freezing of the flooded dust will take several years, primarily due to the latent heat released by the water as it changes to ice. It will then be possible to maintain the frozen conditions around the arsenic dust by periodic or partial operation of the freezing system. The large volume of ice in the rock and dust pores will delay any thawing of the ground, and extend the time available to respond to warming conditions.

Several variants of the method have been evaluated. The primary choice to be made was between active and passive freezing. Active freezing requires the input of power to maintain frozen conditions. It is the most common ground freezing method and has been used to freeze ground around mine shafts for decades. It has also been used to create frozen underground walls that prevent water from entering mines. The passive freezing variant would make use of thermosyphons, which in effect extract cold from the air and deliver it into the ground, without the need for external power. Thermosyphons have been used for about 30 years to maintain permafrost at shallow depths, and have recently been applied to create frozen walls around shallow contamination. The use of a thermosyphon over the much greater depths typical of the arsenic trioxide chambers and stopes was successfully tested at Giant Mine.

After considering the advantages and disadvantages of each approach, it was clear that the best option for freezing the arsenic chambers and stopes would be a "hybrid" combination of active and passive methods. The hybrid system would allow the passive removal of heat during the cold winter months, but also allow external power to continue cooling the ground even in summer. It is also expected that the hybrid approach would reduce power consumption and, more importantly, allow a smooth transition to a long-term system that requires only periodic inspections and maintenance.

The choice of the hybrid frozen block method necessitated many other decisions about underground access, crown pillar stabilization, and bulkhead stabilization. The results are discussed in the subsequent sections.

5.1.4 Stabilization of Bulkheads and Crown Pillars

Implementation of the ground freezing is expected to take 5 to 10 years. During this time, the high risk bulkheads and crown pillars may pose a significant risk for arsenic release. The locations of the high risk bulkheads and crown pillars are shown in Figure 5.1.2.

Bulkheads

As discussed in Section 3.1.5, measures to monitor and where necessary stabilize the bulkheads containing the arsenic dust have already been implemented or are in planning. All bulkheads will ultimately be supported by backfill plugs and incorporated within the frozen zones around each chamber and stope. The backfill plugs will be situated between the freeze pipes and the bulkheads, and will freeze towards the bulkheads, thus providing support during the freezing process.

Crown Pillars

Remedial options to control potential crown pillar instability are discussed in detail in Supporting Document D1. For the chambers and stopes that require short-term stabilization (B208 and B212-213-214), backfilling the void below the crown pillar was determined to be the best alternative. This task will be undertaken prior to implementation of the Remediation Plan Following freezing, all pillars will be supported by the frozen dust, fill or ice.

5.1.5 Freeze System Construction

Underground Preparation

All arsenic distribution pipes outside of the frozen blocks, shown in Figures 5.1.3 to 5.1.6, will be removed and handled as hazardous waste, as described in Section 5.1.2. All accessible spills of arsenic dust will be cleaned up and deposited in the nearest accessible arsenic chamber or stope.

All tunnels leading to the frozen block will be sealed with backfill. Any tunnel sections that will be intercepted by freeze pipe installation holes will also be backfilled.

Underground Access

To carry out the initial ground freezing, a series of freeze pipes will be installed along the bottom and perimeter of the chambers and stopes. Access for some of the lower freeze pipes will require new tunnel development. Figures 5.1.3 through 5.1.6 illustrate the conceptual pipe layouts and proposed underground access. The total length of new access tunnels and the number and length of drillholes and freeze-pipes are listed in Table 5.2 below.

Table 5.2: Access, Drilling and Pipe Details for Freeze Wall Installation

	Surface holes	U/G holes	Surface pipes (m)	U/G pipes (m)	U/G Development (m^3)	U/G Development length (m)
Area 1	180	63	11,139	1,970	6,500	446
Area 2	135	57	12,773	2,066	5,980	374
Area 3	206	57	18,673	2,560	6,340	396
Area 4	87	27	8,829	1,009	2,260	142
Total (with 15)	608	204	51,414	7,605	21,080	1,358

Note: Chamber 15 has been included in the installation requirements for AR1, although it currently does not contain any arsenic trioxide dust. Chamber 15 has been included as a contingency for storing other high arsenic waste on site as discussed in Section 5.1.2.

Prepared by: mnn
Checked by: rc

Quantities do not include contingencies for possible extra drillholes and pipes needed at final engineering stage or for problems encountered during installation (drillhole deviation, etc.) These factors are discussed in detail in Supporting Document J1.

Figure 5.1.1: Schematic of the Criteria for Ground Freezing

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Figure 5.1.2: Location of High Short Term Risk Bulkheads and Crown Pillars

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Figure 5.1.3: Underground Access in Area AR1

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Figure 5.1.4: Underground Access in Area AR2

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Figure 5.1.5: Underground Access in Area AR3

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Figure 5.1.6: Underground Access Area AR4

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Surface Access

The perimeter freeze pipes will be installed from the surface. The number of surface holes, and the total length are also listed in Table 5.2. Preparatory works required for the surface installations are listed in Table 5.3 and illustrated in Figure 5.1.7.

Table 5.3: Surface Installation Preparation Requirements

Area	Surface Preparation
AR1	- Build access road for drill on rock hillock
AR2	- Backfill section of Baker Creek above C212 to provide drill platform for installing freeze pipes - Relocate highway for installation of C212 freeze pipe - Demolish buildings for #10 freeze pipe installation
AR3	- Relocate highway to east of AR3 for installation of B230, B233, and B234 freeze pipes - Fill B1 Pit for drill platform for B208 installation
AR4	- Fill B1 Pit for drill platform for B212, B213, and B214 installation

Prepared by: mnn
Checked by: mdr

Freeze Pipes

Installation activities in each storage area will follow a similar sequence:

- Underground access tunnels will be developed for drill access for installing horizontal freeze pipes for each area;
- Horizontal holes will be drilled and grouted to fill voids, and the freeze pipes will be installed;
- Surface access, drill setup and laydown areas will be prepared;
- Surface holes will be drilled and grouted, surface freeze pipes will be installed; and
- Coolant distribution pipes will be installed and connected to each freeze pipe.

Regular steel pipes are normally used for freeze pipes in active freezing systems. The corrosion of the steel by the coolant, in particular brine, is prevented by introducing additives and by controlling the pH of the coolant. The freeze pipes will consist of 100 mm (4 inch) steel pipe combined with an inner 50 mm (2 inch) PVC pipes.

Thermosyphons are constructed with welded high pressure steel pipes that are connected to a radiator at the surface. The hybrid thermosyphons assumed in this conceptual design also require a heat exchanger between the pipe coming from the ground and the radiator. The heat exchanger is to enable the coolant from the freeze plant to cool the thermosyphon during the warm seasons.

Thermosyphons are often constructed with 100 mm (4 inch) steel pipes. The radiator will likely be a 150 mm (6 inch) steel pipe, 12.2 m (40 ft) long and covered with a 25.4 mm (1 inch) wide steel coil that acts as the radiator. The coil provides the surface area required for the heat exchange between the thermosyphon and the ambient air. The exposed steel above the ground surface and down to about 1 m below grade will be aluminized and painted white to increase heat losses and to protect the exposed steel against corrosion.

Freeze Plant

The freeze plant will have compressors and heat exchangers to cool the primary coolant within the plant. The cooled primary coolant is circulated, usually at high pressure, through heat exchangers to extract heat from a secondary coolant that is circulated at low pressures through the distribution and the ground freezing pipes.

The secondary coolant is distributed by a series of supply lines that feeds pipe headers at each of the freeze pipe locations. Each freeze pipe consists of a narrow plastic tube surrounded by a steel cylinder. The secondary coolant first flows through the plastic tube down to the bottom of the steel pipe and then returns up the annulus of the outer steel and inner plastic tube.

The freeze plant will house the refrigeration units for the primary coolant, the heat exchangers between the primary and secondary coolants, the maintenance and storage areas, the control room for the operations of the freeze plant and the monitoring system, and the power system. The plant will require a supply of fresh water for condensing the primary coolant and a discharge for the warmed water. The proposed plant will require industrial grade power installations of up to 2.7 megawatts capacity.

The freeze plant will be sited in the approximate centre of the four freezing areas, in close proximity to the water treatment plant. Locating the two facilities together will allow for simplifying security requirements, as well as the possibility of using waste heat from the freeze plant in the water treatment plant.

Figure 5.1.7: Location of Freeze Pipes and Freeze Plant at Surface

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5.1.6 Ground Freezing

The ground freezing in each area will be accomplished in four steps:

- Actively freezing the ground around each chamber and stope to create a completely frozen shell;
- Saturating the dust and flooding the remaining void space within each frozen shell;
- Actively and passively freezing the flooded zone to create each frozen block; and
- Maintaining long-term frozen conditions by passive freezing.

The objective of the first step will be to create a zone of frozen rock that is wide enough to prevent any escape of water when the chamber or stope is flooded. The design criterion selected to reflect that objective is a temperature colder than -10°C over a distance of at least 10 m around and below all mine workings where the arsenic trioxide dust is present. Once that criterion is met, water will be added to saturate all of the dust within the chamber or stope, and the process of freezing the saturated dust will begin. The proposed design criterion for that step is to reduce the temperature within the saturated dust to -5°C or colder.

The freeze plant has been sized to allow the frozen shell around the largest area to be completed within two years. To minimize the power requirements, installation and start-up in the four areas will be sequenced over a five year period. This will also allow for drilling and installation of the freeze pipes to be sequenced from area to area over roughly the same period. Temperatures in the frozen wall will be monitored throughout the initial freezing to ensure that the design criteria are met prior to saturating and freezing the contained dust.

Techniques for saturating the dust have not been finalized at this time. Several options are available, ranging from simply flooding the dust and waiting for the water to distribute itself, to the use of high pressure jets.

The freeze plant will be operated until the saturated dust reaches the criterion of -5°C. The modelling presented in Supporting Document J1 indicates that it will take up to an additional ten years for all of the dust in the largest stopes to reach the -5°C criterion.

Temperatures in the frozen wall will be monitored throughout the initial freezing to ensure that the design criteria are met prior to turning off the active freezing system. Monitoring systems, for both temperature and groundwater flow, are discussed in Section 7 of this report.

5.1.7 Long Term Operation and Maintenance

Long term operation of the system will rely on passive thermosyphons installed in the vertical drillholes to maintain the frozen conditions. Modeling in Supporting Document J1 shows that vertical thermosyphons will be able to maintain the target low temperatures throughout the frozen blocks. The vertical freeze pipe system will extend below the base of the dust storage chambers and stopes to ensure that the thermosyphons will be capable of maintaining frozen conditions at the bottom of the frozen blocks.

System maintenance requirements will be dictated by the final design of the thermosyphon headers. Exposure to weather conditions and the risk of vandalism require that the thermosyphons be monitored to ensure that they continue to function properly.

5.1.8 Contingency

The program for monitoring the ground freezing system is described in Chapter 7. If the monitoring indicates that the frozen blocks are not meeting design criteria, then a series of contingency measures are available:

- Modifying the ground surface to provide additional insulation or cooling;
- Extending the time of active freezing;
- Maintain active or passive freezing in the horizontal underground pipe system;
- Installing extra freeze pipes along the initial alignment; and
- Installing additional freeze pipes into dust mass to increase freezing capacity.

5.2 Other Underground Mine Components

5.2.1 Key Concerns

The mine has a large inventory of materials, located outside the arsenic trioxide dust storage areas, which contain soluble arsenic compounds, including tailings and waste rock backfill in mined out stopes, and the mine wall rocks. Flooding the mine workings will release arsenic from these materials, making the minewater unacceptable for discharge to the environment without treatment. Over time, the concentration of arsenic in the minewater will decrease, as soluble arsenic is flushed from these materials, but the minewater may have to be contained and treated for an extended period.

Some of the underground infrastructure, such as the maintenance shops, fuel and oil storage areas, and explosives storage areas, contain materials that could contaminate the minewater when the underground workings are flooded. These contaminants would be difficult to remove from the water by conventional treatment.

The many openings into the underground workings from surface, including shafts, raises and portals leading to adits and ramps, present physical hazards to humans and wildlife through inadvertent or deliberate access. The measures currently in place to prevent unauthorized access are temporary and would deteriorate over time. Several openings are currently accessed through buildings that will eventually be demolished.

The following sections outline the methods proposed to address the above concerns.

5.2.2 Other Underground Arsenic Sources

Method Selection

The ground freezing method described in Section 5.1 will effectively isolate the underground arsenic trioxide dust from minewater, by permanently freezing the dust storage chambers and stopes, as well as the rock around them. There are no practical methods to remove or stabilize the other underground materials that contain significant but much lower concentrations of soluble arsenic. This is primarily because of the volumes of these materials and their wide distribution throughout the mine. The only practical method to manage arsenic releases from most of these sources is to contain the contaminated water within the mine workings and treat it before it is discharged to the environment. Details of the proposed methods to collect and treat contaminated minewater are described in Section 5.7.

Clean-up and Isolation of Concentrated Sources

Measures to reduce the release of arsenic from some of the concentrated underground sources may be taken. For example, fine-grained materials in some areas located outside the proposed frozen zones are known or suspected to contain high levels of soluble arsenic, due to historical seepage from the dust storage areas. Where these materials are located in stable workings, such as the main tunnels, they can be safely accessed by workers and equipment. To reduce the potential release of arsenic into the minewater, heavily contaminated materials from these areas will be removed to a secure disposal site. Potential disposal sites include mine excavations that require backfill and would be frozen, such as the empty spaces remaining within the frozen zones and in the existing empty chamber 15

5.2.3 Underground Infrastructure

Method Selection

Contaminants other than arsenic that could be released from the underground infrastructure would be difficult to remove by the proposed water treatment system. Therefore, the preferred remediation method is to remove the sources of these contaminants, before the mine is flooded.

Removal of Potential Contaminants

Materials to be removed from the mine will include all significant quantities of hydrocarbon products located in the maintenance shops or designated hydrocarbon storage areas, and all significant quantities of explosives. These materials will be brought to surface and disposed of according to procedures appropriate to the material type. The disposal could involve containment or stabilization on site, destruction on site, or disposal at an approved facility. Proposed methods for hazardous waste disposal are described further in Section 5.11. Hazardous materials were removed from all underground areas below the 750 Level prior to the commencement of flooding in 2005.

Since all of the underground electrical transformers are dry (not oil-filled) and do not contain PCB compounds, they would remain underground unless recovered for their salvage value. Small electrical components that are expected to contain small amounts of PCB bearing solid materials, such as light ballasts, will be removed from the mine for appropriate disposal at an approved facility.

Water in the flooded mine will be relatively low in oxygen and not acidic. Therefore, leaching of metals from abandoned equipment, such as the copper components of the electrical system, will not be a concern. Easily removable components, such as batteries, will be removed and recycled.

5.2.4 Openings to Surface

Method Selection

The Northwest Territories Mine Health and Safety Regulations specify that all underground openings to surface must be sealed before a mine is permanently closed, and provide basic design criteria for the capping of shafts and raises. The selection of methods is primarily an engineering exercise to ensure that each opening is sealed in a manner that meets the regulations, and achieves objectives for strength and durability, while remaining cost-effective. Several methods that could be applied to the Giant Mine openings are described below.

Sealing of Surface Openings

Mine openings to surface will be sealed with structures requiring minimal maintenance to remain stable and effective in the long term. Each opening will be permanently sealed once no further use is required for mine access or ventilation. While a particular mine opening still serves a purpose, access will be controlled with a lockable gate or door.

The appropriate method for permanently sealing a particular opening depends on the location, inclination, size, and geometry of the opening, as well as the quality of rock around the opening. Examples of various types of seals that could be used at Giant are shown in Figure 5.2.1.

Most of the horizontal openings, such as the portals located in the open pits, will be backfilled with broken rock. The depth of the plug, size of the rock, and slopes of the rock faces, will ensure that the plug is physically stable in the long term and discourage any future opening of the seal.

Inclined or vertical openings, such as the raises and shafts, will be permanently sealed either by backfilling the excavation with broken rock, or by constructing a concrete cap over or inside the opening.

Several provincial jurisdictions in Canada provide detailed guidelines for the design of concrete caps. They specify that reinforced concrete caps overlying openings must be constructed directly on, or otherwise supported by sound bedrock surfaces around the opening. Where the bedrock around the opening is weak, due to heavy fracturing or weathering, a reinforced concrete bulkhead may have to be located some distance inside the opening, recessed into sound bedrock below the surface. These types of caps can be covered with soil and, since they are relatively impermeable, will normally be provided with a vent pipe to allow exchange of air between the mine workings and surface.

In some situations, where a small inclined mine opening is wider at the mouth than it is inside, a simple concrete plug, without steel reinforcement, could be installed. Depending on the required load capacity, additional shear resistance could be provided by installing steel dowels between the rock and the plug.

Figure 5.2.1: Typical Permanent Seals for Underground Mine Openings

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5.3 Open Pits

5.3.1 Key Concerns

Current conditions in the pits are described in Section 3.3. Long-term stability of the backfilled stopes below some of the pits is a concern and the pit walls represent a physical hazard to people using the site in future. Two other concerns are related to water management. Water from the underground mine, if the level is not controlled, would form contaminated ponds within the pits. Baker Creek, if not controlled could flow into the pits and disappear into the underground mine.

5.3.2 Method Selection

Assessment of remediation measures for the major surface issues at the site has largely been through internal meetings of the Giant Mine Remediation Project Team and technical specialists. The surface remediation measures proposed were also reviewed at a meeting with representatives of the GNWT.

Specifically, a series of meetings in September 2003 and 2004 reviewed the remediation measures proposed in the previous Abandonment and Restoration Plan (Golder Associates Ltd, 2001), listed all other options, assessed several combinations of those options and identified those worthy of more detailed review. The results for the pits are summarized below and other results are presented where relevant in Section 5.4 through 5.12.

The remediation options that were considered for the pits are:

- Backfilling and covering;
- Allowing flooding to form full depth pit lakes; and
- Partially backfilling and flooding to form shallow pit lakes or wetlands.

Backfilling and covering the pits would produce a surface that could allow a variety of future land uses. The main question is the availability of backfill material. The available amount of clean backfill is limited and is also in demand for other remediation activities. Two sources of material for backfilling the pits are the tailings and the contaminated soils from elsewhere on site. Both of these materials contain high levels of arsenic. Measures to limit release of that arsenic would need to be included in the backfill design.

Establishing pit lakes might provide additional aquatic habitat. However, the pits are connected to the underground mine workings. Therefore, the water in the pits will be contaminated at least as long as the minewater itself is contaminated.

Partially backfilling the pits could minimize the contact between the contaminated minewater and the shallow pit lakes or wetlands. However, any leakage through the backfill could result in Baker Creek drying up during low flow periods. The lack of clean backfill is also a problem for this option.

After consideration of these options, it was decided to proceed with a combination that makes use of available backfill, reduces physical hazards associated with mine openings and pit walls, and prevents the formation of contaminated pit lakes.

5.3.3 Specific Pit Remedial Works

B1 Pit

The B1 Pit is partially over top of the B208 and B212-213-214 arsenic stopes, and will need to be backfilled to allow installation of the required freeze pipes. The volume of backfill required to provide grade surface drill platform for installation of freeze pipes is approximately 330,000 m3. The backfill will be compacted to prevent differential settlement, which could damage the freeze pipes, and to reduce hydraulic conductivity of the material.

This pit will be used to dispose of the contaminated soil and waste rock on site. The contaminated soil will be placed in a cell behind the freeze pipes and so be incorporated into the frozen zone. The volume of the B1 Pit that will be maintained at -5°C or lower is limited to approximately 60,000 cubic metres, as shown in Figure 5.3.1.

Contaminated backfill will be excavated from other areas of the site (see Section 3.10) and trucked to the pit. Where practical, contaminated soils will be segregated from waste rock or less contaminated soils, and incorporated within the frozen zone of the B1 Pit. The rest of the pit will be backfilled with waste or quarry rock, stable clean demolition waste such as concrete rubble, and other clean fill. A cover similar to that proposed for the tailings will be constructed on the backfill to promote surface runoff.

C1 Pit

The C1 Pit will be left open. Baker Creek will be relocated. Partial backfilling of the C1 Pit to form a stable stope below the re-routed Baker Creek may be required. Further investigations are ongoing as discussed in Section 5.8.

Other Pits

Overburden in and around the A1, A2, and C1 Pits is considered to be a resource for use elsewhere on the site. Estimated volumes are discussed in Supporting Document H3.

The B3 Pit will be used as the inflow point to the mine for surface runoff until these flows are acceptable for direct release to Baker Creek. At that time, the slopes of the pit will be pushed in to partially fill the excavation. The northern rock wall will be left as is to form a natural escarpment.

The walls of the B4 Pit will be re-graded to shallower slopes using the available material currently at the location. The slopes will be covered with growth medium and revegetated.

The entrance adit in Brock Pit will be blocked. Crushed rock, soil and/or clean demolition debris will be used to backfill the pit.

All other pits will be left open. All openings to the underground will be sealed, as discussed in Section 5.2. Access to the pits will be controlled using an appropriate combination of signage, earthen berms and boulders, and fencing. Details will be determined once the final alignments of Baker Creek and the highway are defined.

5.3.4 Contingencies

Differential settlement in the B1 Pit could cause damage to the top cover. This could be remediated by regular maintenance. It may also be necessary to replace freeze pipes if the settlement causes damage.

All remaining pit walls will be monitored and damage to berms or fences will be repaired.

5.4 Waste Rock

As discussed in Section 3.4, the only waste rock that is expected to remain on surface has been used in construction, primarily of roads, yards and tailings dams. The rock is expected to maintain neutral drainage and to meet the water quality criteria for non-point discharges.

The mine road between C1 pit and B1 pit, on the west bank of the current Baker Creek location, will be excavated and developed into a new channel for Baker Creek. Selected sections of other mine roads and yards would be retained to maintain access to the B1 pit area, the B3 pit area and the north side of the Northwest Pond. Roads that are expected to remain in service after closure activities are completed are shown in Figure 5.4.1.

The remaining mine roads would not be required after closure activities have been completed. The current plan is to reclaim the roads for use as fill where significant volumes exist. Abandoned road sections that do not contain significant amounts of fill will be scarified and revegetated. Culverts would be removed and swales would be cut across the roads at appropriate intervals to facilitate surface water drainage. Roads that would be reclaimed are also shown in Figure 5.4.1. The selection could be modified to meet access requirements associated with future land uses.

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Figure 5.3.1: Frozen Contaminated Soil Placed in B1 Pit

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Figure 5.4.1: Road Decommissioning

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5.5 Tailings and Sludge

5.5.1 Key Concerns

Current conditions in the tailings and sludge containment areas are described in Section 3.5. The key concerns are seepage from Dams 3, 11 and 22B, surface overflow quality, dusting from the tailings surfaces and the potential for physical contact with the tailings by humans and wildlife. Supporting Document K1 presents details of the remediation design for these areas, and includes appendices that compile the available engineering data on the tailings, the sludge and the containment structures.

5.5.2 Method Selection

The selection of remediation methods for the tailings was driven by the objectives stated in Section 1.3, specifically minimizing public health and safety risks, and minimizing the future release of contaminants to the surrounding environment. Exposed tailings would present a potential for direct physical contact by people or wildlife. They would also generate dust and allow runoff to become contaminated with arsenic. To address these problems, it was decided to cover the tailings. To facilitate covering and to prevent water ponding on the surface, regrading of sections of the tailings and construction of surface water run-off channels will be necessary.

Standard construction techniques will be used to construct the tailings covers and diversions. These will include provisions to control sediment release into the local waterways both during construction and while vegetation is being established on the covers to provide long term erosion control.

5.5.3 South, Central and North Pond Earthworks

The South, Central and North Pond surfaces will be regraded to direct runoff towards a spillway cut into the bedrock south of Dam 2.

The South Pond will require minimal regrading to enhance the existing slope towards the Central Pond. Natural ground juts into the South Pond at its north end. A ditch will be constructed through that area to direct flow into the Central Pond via a spillway between Dams 4A and 4B. The location of these ditches is shown in Figure 5.5.1.

The Central Pond also has a gradual slope towards the North Pond, with two gullies running in a southwest/northeast direction. The eastern gully is relatively shallow and will be regraded into a shallow swale with side slopes of 5 horizontal to 1 vertical. The west slope of the western gully would be resloped to 5 horizontal to 1 vertical. The bottom grade of both gullies would be kept at close to the current levels and would direct surface overflow into spillways that will be cut through Dyke 6. The general arrangement at the Central Pond is shown in Figure 5.5.2.

The North Pond will cease to be a water storage facility. The existing ponded water will be pumped, treated and discharged. The surface will be cut and filled to direct surface overflow towards a spillway that would be constructed around the south end of Dam 2. The outlet ditch invert will be at an elevation that will prevent water from pooling in the North Pond. The spillway will be constructed entirely in bedrock and will discharge approximately 100 m downstream of Dam 1. As long as the surface runoff water remains contaminated, outflow from the spillway will be directed to the B3 Pit, where it will enter the minewater treatment system. Once water quality meets discharge criteria, the outflow will be re-directed to Baker Creek. The location of the spillway is shown in Figure 5.5.3.

5.5.4 Northwest Pond Earthworks

Water currently stored in the Northwest Pond will be pumped, treated and discharged. The tailings surface will be cut and filled to direct runoff to the west where a spillway will be constructed through the bedrock outcrop between Dams 22A and 21D, as shown in Figure 5.5.4. Short-term discharge will be directed to a runoff collection sump and pumped to the Achaitcho shaft where it will enter the minewater collection system.

The Northwest Pond is also a potential location for non-hazardous waste. The disposal of non-hazardous waste is described in Section 5.12.

5.5.5 Tailings Covers

The design proposes a two-layer cover, as shown in Figure 5.5.5:

- The bottom layer will consist of crushed material from a local quarry and will serve three functions; (1) act as a robust physical barrier to prevent human or animal contact with tailings in the event that the overlying layer is evolved or damaged, (2) prevent upwards wicking of arsenic salts through the cover, and (3) prevent roots from penetrating into the tailings.
- The upper layer, will consist of locally borrowed silt and silty clay and serve four functions; (1) act as a clean surface that would shed runoff, (2) allow vegetation to establish, (3) reduce infiltration, and (4) in future allow the area to be used for traditional and/or recreational purposes.

The desire to allow the reclaimed surfaces to eventually be used for traditional and recreational uses implies the establishment of vegetation. Therefore, the upper layer must be of sufficient quality and depth to allow vegetation to establish. The available material that is most appropriate for this layer is the silt and silty clays identified within the mine lease boundaries. As a minimum to allow vegetation to establish, this layer should be 30 cm thick. However, using a variable thickness would allow for a wider range of vegetation species. Based on the amounts of fine-grained soils identified to date, it would be possible to cover all the tailings and sludge ponds with an average 70 cm depth.

A cost-benefit analysis will be needed to determine the optimum among the alternatives for the bottom layer, including:

- 100 cm thick layer of run-of-quarry material (<100 cm in size)
- 30 – 60 cm thick layer of screened run-of quarry material (<50 cm in size) with geotextile separation layers above and /or below
- 15- 30 cm thick layer of crushed gravel (<2.5 cm in size) with geotextile separation layers above and/or below.

Depending on how the cover material is prepared, it may be necessary to include geotextile layers to prevent fine tailings from mixing upwards into the bottom layer, or fine material from the top layer from mixing downwards. Both of those effects would compromise the function of the bottom layer.

Studies planned for late 2005 and the winter of 2005-06 will provide a basis for determining the amount and type of crushed rock that will be required to accommodate potential settlement into the tailings, and the requirements for phased construction. The final design will define all cover materials and depths, and such details as access, monitoring, and sediment control during construction. Studies to select vegetation species and define seeding and fertilization requirements are still needed.

5.5.6 Settling and Polishing Ponds

Under the proposed remediation, the current settling and polishing ponds would not be required in the post-closure period. These facilities would be closed in place.

The settling and polishing ponds are included in the winter 2005-06 studies and the closure design will be finalized thereafter. The current concept, described in Supporting Document K1, includes construction of a spillway through the bedrock outcrop south of Dam 1, and construction of a cover similar to that proposed for the tailings, as shown in Figure 5.5.6. To minimize settlement damage to the cover, it would be underlain with a filter cloth placed directly on the sludges. The option of using contaminated soils to consolidate the sludge is also under consideration. The surface of the cover would be graded to direct surface overflow towards Baker Creek.

There is an elevation difference between the solids in the settling pond and in the polishing pond. Further investigation is required to determine the long-term stability of the dyke. If necessary, the dyke will be buttressed.

The chemical stability of the sludge will be monitored. In the short term, both the chemical conditions within the sludge and the water quality of any seeps will be monitored for signs of increased arsenic leaching. Seeps from the settling and polishing ponds would continue to be monitored in the long term.

5.5.7 Calcine Pond

As discussed in Section 3.5.5, the bulk of the calcine pond and its contents were removed several decades ago. What remains is a layer of calcine, approximately 1 to 2 m thick, about 1.4 to 11 m below the ground surface. The calcine appears to be confined to the footprint of the old pond.

At present the calcine layer is covered with fine-grained clayey silt material that is effectively isolating the calcine. It is proposed that this material remain in place. Should it be determined during closure activities that the overburden material is required elsewhere on the site, the calcine layer would be excavated and disposed with other soils identified as contaminated.

5.5.8 Contingencies

It is anticipated that there will be a need for cover maintenance and repair. In the first years of construction, repairs of settled areas may be extensive. The sediment control works built for cover construction will need to be maintained and operated until the vegetation is established and erosion is reduced to levels typical of natural areas. Plans for handling runoff and seepage from the tailings area are discussed in Section 5.7, and include provision for dealing with water quality that is better or poorer than expected.

5.6 Historic Foreshore Tailings

As discussed in Section 3.6, tailings submerged in Yellowknife Bay appear to have minimal effect on the environment. The key issues associated with the historic foreshore tailings is the potential for continued erosion of the beached tailings into Yellowknife Bay.

The proposed Remediation Plan is to further stabilize the beached tailings by extending the existing geotextile and rip-rap cover below the lake surface to cover the tailings where they occur in littoral zone. This will minimize the potential of an erosion scarp developing due to wave action, as well as reduce migration of the tailings by lake currents and wave action. It would also likely stimulate benthic invertebrate production and create fish rearing feeding and spawning habitats. Remediation measures at the South and Central ponds are expected to reduce the amount of contaminated water that flows through the beached tailings, thereby reducing the loading of arsenic into Yellowknife Bay.

Figure 5.5.1: South Pond Re-grading and Water Management

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Figure 5.5.2: Central Pond Re-grading and Water Management

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Figure 5.5.3: North Pond Re-grading and Water Management

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Figure 5.5.4: Northwest Pond Re-grading and Water Management

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Figure 5.5.5: Tailings Cover Conceptual Design

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Figure 5.5.6: Sludge Cover Conceptual Design

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5.7 Site Water Management

5.7.1 Key Concerns

Minewater is expected to remain contaminated with arsenic and unacceptable for direct discharge to the environment for an extended period. In this period, contaminated water will have to be contained within the mine workings and treated prior to discharge.

Remediation measures proposed for the tailings, involving regrading and placing covers on the tailings, are expected to improve the quality of surface runoff and eventually allow direct discharge to the environment. The remediation activities are also expected to reduce the volume of contaminated seepage from the tailings containment areas to low levels in the long term. However, during an interim period after the covers are placed, runoff and dam seepage could require collection and treatment before discharge.

Water is currently treated and discharged only during the open water season, although contaminated water is generated throughout the year, which means that a large volume of contaminated water must be stored over winter. Water is currently stored in the Northwest Pond, which suffers from a high rate of seepage into mine workings below. Furthermore, humans and wildlife could be exposed to any contaminated water stored on surface.

Although two of the pits will be backfilled, most will remain open. If contaminated minewater were allowed to rise above the bottom of the pits, humans and wildlife could be exposed to the pools of contaminated water that would result.

5.7.2 Method Selection

The selection of a water treatment schedule, and the requirement to store contaminated water on site, is the main issue affecting control of future water levels within the mine. Seasonal treatment, as currently practised, requires a large storage capacity which is currently found in the Northwest Pond. This pond would be an inefficient storage location in the long term, since water would be continuously recirculated into the mine through seepage, and would have to be pumped out more than once. The Northwest Pond and other surface ponds are also unattractive as storage locations, due to the potential for exposure of humans and wildlife to the contaminated water.

The alternative to surface storage is to store contaminated water in the underground workings. However, the combination of seasonal water treatment and underground storage would require large fluctuations in the minewater level during the year, repeatedly flooding and draining mine workings on several levels. Large fluctuations in the water level are likely to increase the release of arsenic from sources such as the tailings backfill, and could even cause movement of the backfill.

Issues affecting the selection of water treatment and sludge disposal methods include the preferred location of the treatment system, the available technologies, and the schedule of water treatment and discharge. Continued use of the existing treatment plant and sludge separation and disposal system was considered, and several alternative technologies were evaluated in SRK (2002b). An update to that work is provided in Supporting Document L1. The optimum technology for this application is precipitation of arsenic with iron, separation and dewatering of the sludge by thickening and filtration, and disposal of the dewatered sludge in an engineered landfill.

The choice of treatment and discharge schedule, either seasonal or year-round, is closely related to the requirement to store water on site. Year-round treatment would require year-round discharge of water to the environment. Discharge of treated water to Baker Creek, as currently practised in summer only, would be very difficult in winter, whereas discharge to Yellowknife Bay would be possible year-round. Eliminating the release of treated water to Baker Creek would also improve water quality in the creek.

The desire to avoid a contaminated pond on surface drives the decision towards storing water underground. Concerns about large fluctuations in the mine water level leads to the selection of year-round treatment. Year-round treatment necessitates discharge to Yellowknife Bay, which also reduces impacts on Baker Creek.

5.7.3 Underground Water Management

The proposed storage of contaminated water underground will require that the water level be kept below the bottom of the deepest pit that will remain open. This is the bottom of the A2 Pit, which is just below the 100 Level of the mine. During summer and winter each year, the minewater level will be gradually lowered to provide sufficient capacity to accommodate the additional inflows of the following freshet. Allowing for the risk of larger than normal freshet inflows will require drawing the water level down to below the 425 Level each year. The proposed underground water management system is illustrated in Figure 5.7.1.

A single pumping location will be used to control the water level throughout the mine. An entirely new water treatment plant is proposed, as described in Section 5.7.5. A final location for the plant has not been selected, but the preferred general location is the area of C-Shaft and B-Shaft, where the freeze plant will also be located. The pumping system will also be installed in this area, consisting of one or more wells, containing submersible pumping systems. A well could be created using one of the existing shafts, or new holes could be drilled to intersect the mine workings below, creating several wells clustered together.

The pumps will be controlled and accessed from surface, and removed from the well (or wells) periodically for maintenance. Such a system will not require access to the underground mine by site workers.

5.7.4 Surface Water Management

Measures to minimize flows of clean water into the mine will reduce the operating cost of the system. One measure will be to maintain the existing three runoff diversion systems that currently reduce inflow to the A1 and A2 Pits, as long as water is being pumped from the mine.

If runoff and seepage from the tailings containment areas is unacceptable for direct discharge, it will be directed underground. Runoff from the South, Central and North Ponds, would be combined with runoff from the Settling and Polishing Pond area, and directed underground by gravity flow into the B3 Pit and the 1-38 Portal. Runoff within the catchment of the Northwest Pond would be collected in a small pool on the west side of the basin, and pumped to the Akaitcho Shaft for discharge into the underground mine.

5.7.5 Water Treatment and Sludge Disposal

The new treatment plant will be located on ground with the required geotechnical stability as close as possible to the freezing plant, as noted in Section 5.1. The water will be pumped directly from the mine to the plant. The mine dewatering systems will have to be reliable and carefully controlled to avoid interruptions or short-term fluctuations that would affect the performance of the plant.

Details of the treatment process and reagent needs are provided in Supporting Document L1. The oxidation state of arsenic in the minewater pumped to surface will be monitored and, if necessary, hydrogen peroxide would be added to convert the dissolved arsenic to the oxidized form needed for efficient precipitation with iron. Ferric sulphate solution will then be added to the water, co-precipitating arsenic with a ferric oxyhyroxide phase. The pH of the water will be adjusted with lime to optimize the arsenic precipitation process. A flocculant will be added to aid in the subsequent sludge separation process. Figure 5.7.2 illustrates the water treatment process as a simplified flowsheet.

Treated water will be separated from the precipitates in a thickener, and discharged to a holding pond. The thickened sludge will be dewatered in a pressure filter, and treated water from the filter will be discharged to the holding pond. The filtered sludge will be discharged to a storage silo, and then transported in batches to a sludge disposal facility.

Treated water will be stored in a holding pond, allowing the water quality to be monitored before discharge. The pond will have sufficient capacity to store the treated water for five days (average) at the maximum treatment rate. Any treated water that fails to meet the discharge quality criteria, due to occasional plant upsets for example, will be recycled through the treatment plant, or returned to underground storage. Treated water that meets the discharge criteria will be pumped through a pipeline into Yellowknife Bay. The pipeline will run underwater for some distance out into the bay, and a diffuser system on the end of the pipe will be designed to ensure rapid dilution of the treated water. An assessment of alternative discharge locations, diffuser designs, and resulting dilution efficiencies is provided in Supporting Document L2.

The quantity of water treatment sludge requiring disposal will decrease over time, as the concentration of arsenic in the minewater decreases. In the short term (at least until the ground around each of the arsenic chambers and stopes is frozen), the quantity of sludge is expected to be great enough to warrant on site disposal. This may be achieved by backfilling the sludge into mine voids that will subsequently be frozen, such as the voids above the arsenic dust, or Chamber 15. The potential for underground disposal will be further assessed as the final remediation designs are prepared. If frozen underground disposal for the sludge is not possible, a small surface disposal facility would be required. This would be an engineered landfill lined with synthetic and natural materials to prevent discharge of leachate from the sludge, and incorporating leachate monitoring and collection systems. The landfill would be completed as a series of separate cells, each of which would be covered upon closure, with synthetic or natural materials, to minimize the infiltration of water.

5.7.6 Contingencies

The water treatment plant will be capable of handling a range of influent flow rates and arsenic concentrations. The conceptual design described in Supporting Document L1 includes capacity for extremely wet climatic conditions, and sludge separation equipment capable of handling arsenic loads several times the estimated average load.

The mine water management system will be operated with a large contingency storage capacity in the mine, to manage extremely wet climatic conditions or pumping system malfunctions. Even if this underground contingency storage were to be consumed, the minewater would simply begin to fill the open pits temporarily, but would not discharge to the environment.

In the event of a malfunction in the water treatment plant resulting in the production of water that does not meet the discharge criteria, the water would be contained in the holding pond. The water could be recycled through the plant, or returned to underground storage.

At some point in the future, the quality of the minewater could improve sufficiently to allow flooding of the pits with minewater and, eventually, direct discharge to the environment through a natural or engineered spill point. Small modifications to the pumping system would be required to control the mine water level and allow partial flooding of the pits, until direct discharge to the environment is acceptable. At that point, pumping and treatment could stop entirely.

Figure 5.7.1: Long-term Mine Dewatering System

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Figure 5.7.2: Water Treatment Flowsheet

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5.8 Baker Creek

5.8.1 Key Concerns

Water and sediment quality in Baker Creek are impacted by both historical spills and current discharges of treated effluent, and the current alignment of the creek includes many alterations and diversions that limit habitat development. The remediation of Baker Creek will also need to facilitate implementation of ground freezing around Stop C212, where the creek currently runs directly above the stope. Long-term stability at the channel is also a concern, especially where it passes alongside the C1 Pit.

5.8.2 Method Selection

Several options for the long-term configuration of Baker Creek were examined in earlier studies (Dillon Consulting Limited, 1998). Additional investigations on the capacity of the creek to support habitat are reviewed and a revised set of options is presented in Supporting Document G2.

The above studies focus primarily on the long-term future, when the site water quality is adequate to allow formation of pit lakes. However, as discussed in Section 5.7, water levels in the mine will be kept below the bottom of the deepest pit for many years, probably decades. Therefore, the Baker Creek remediation activities for this plan were selected to address the above short-term concerns, but also to keep long-term options open.

The option of rerouting Baker Creek around the mine site was examined as part of the method selection analysis. However, this option was discounted due to the fact that the mine site catchments will continue to drain to the current creek channel and so a creek will still exist through the site, albeit of significantly reduced flow.

5.8.3 Proposed Remedial Activities

The proposed Baker Creek remediation activities are shown in Figure 5.8.1.

- The diversion around the west side of the C1 Pit will either be upgraded to a permanent channel by blasting back the slope or it will be abandoned and a new channel constructed to the east of the pit along the current highway alignment. As the new eastern alignment would be built on overburden next to the C1 Pit, it may be necessary to build a rock abutment to ensure long term stability of the new channel.
- Contaminated sediments in the pond immediately below the mill area will be by-passed with a new channel that will incorporate habitat features and a flood plain. The pond will be backfilled and graded to promote surface runoff.
- After construction of the new water treatment plant, treated water will no longer be discharged into Baker Creek, as discussed in Section 5.7.5.

- The partially breached concrete weir at B-Shaft will be completely removed, allowing the upstream water to return to its natural level.
- Studies of Baker Pond sediments are ongoing. Options under consideration include diverting Baker Creek around the west side of the pond, routing Trapper Creek to tie into the modified channel, complete or partial removal of contaminated sediments, and backfilling to create a wetland area.

5.8.4 Future Improvements and Contingencies

Additional sampling and testing of Baker Creek sediments was initiated in mid-2005. The results will be used to finalize the remediation design for Baker Pond and to determine whether other sections of the creek will be targeted for remediation.

Additional changes to Baker Creek, including allowing the development of lakes in the pits, may be possible at some time in the future if water quality allows. This possibility is discussed in Section 5.7 and is many years, probably decades, in the future.

Figure 5.8.1: Baker Creek Habitat Restoration

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5.9 Quarries, Borrow Pits and Overburden Piles

The existing overburden stockpiles will be used for either tailings covers or pit backfilling. In order to obtain the volume needed for covering the tailings, additional borrow pits will be opened. These borrow pits will require remediation.

Borrow pits will be remediated by resloping the pit walls and regrading the pit bottom to allow free drainage where possible. Where the pit is below grade, ponds will be allowed to form. Exposed surfaces will be revegetated. Final wall slopes will provide for long-term stability and minimize potential rock fall hazards.

5.10 Contaminated Surficial Materials

The areas identified in Section 3.10 as having arsenic concentrations exceeding the industrial land use criterion will be excavated or covered with clean material. An exception is the spilled tailings that are currently already covered by the highway, which will be left in place. The proposed excavation limit for all areas will be set at 2m. Any materials found below this depth will be covered in place using clean fill and regraded to promote surface runoff. These areas will be delineated and identified on site maps to prevent accidental excavation of the contaminated material in the future.

As discussed in Section 5.3.3, contaminated soils will be backfilled into the B1 Pit within the frozen zone that will be created by freezing the underlying stopes. The soil will be placed in lifts and compacted to minimize volume requirements, permeability and future settlement. It is currently estimated that about 60,000 cubic metres of the contaminated soil will fit into the frozen zone. The remaining 115,000 cubic metres will be disposed in the tailings and/or sludge ponds.

Waste rock that contains total arsenic above the industrial land use criterion (GNWT 2003) will be backfilled into the unfrozen section of the B1 Pit, with the remainder of the pit filled with clean fill from other sources. The B1 Pit will then be capped with a soil cover, similar to that proposed for the tailings, to provide a clean surface for re-vegetation.

Spilled tailings below the Polishing Pond will be excavated and placed in an existing tailings impoundment and covered along with the existing tailings. Any high arsenic material that is encountered will be placed either in the frozen section of the B1 Pit as compacted fill, or in Chamber 15 as a slurry.

As most of the areas with significant hydrocarbon contamination also have industrial level arsenic contamination, deposition of these soils within the frozen zone will remediate both types of contamination. However, soils in the tank farm located just northeast of the A-Shaft are contaminated only with hydrocarbons. These soils could also be bio-remediated in place.

All areas that have been stripped of contaminated surface materials will be covered with at least 0.5 m of clean fine-grained fill to provide a physical barrier and a revegetation medium.

5.11 Buildings and Infrastructure

5.11.1 Key Concerns

As discussed in Section 3.11, many of the buildings on the site contain hazardous materials that could pose risks to site workers and the environment during building demolition. The demolition of buildings and collection of waste materials will also generate a large volume of non-hazardous waste requiring safe disposal. The current route of Highway 4 through the site presents an additional concern. The highway will need to be partially re-located to allow other remediation activities to proceed as proposed.

5.11.2 Method Selection

The methods for the demolition of buildings and handling of waste will be chosen based on current best industry practises that meet local requirements for ensuring the safety of site workers and the public, and protection of the environment. Specific methods will be selected at the time of contracting.

5.11.3 Building Demolition and Waste Handling

All of the site buildings without a continuing function will be demolished. Hazardous materials and potential contaminants will be removed from the buildings prior to demolition, when this is safe and practical. Some hazardous materials may need to be left in the buildings while they are partially or completely demolished. For example, some of the arsenic contaminated process residues and process equipment would have to be handled using large equipment, and it may not be possible to gain safe access to these materials with the building standing. Measures will be taken to control dust generated during the demolition, when it is likely to be contaminated with arsenic or asbestos.

Hazardous materials removed from the buildings before demolition, or recovered from the demolition debris, will be handled and disposed of according to industry best practices and GNWT regulations. The preferred disposal location for materials with high soluble arsenic is the empty chamber 15, which would then subsequently be frozen.

Some of the friable asbestos materials in the Roaster complex may be expected to contain arsenic contaminated dust, and could also require secure disposal within the areas described above. Waste asbestos materials that are not contaminated with arsenic would be buried in tailings at the Northwest Pond.

The demolition of all of the buildings on the site is expected to generate a total of approximately 90,000 cubic metres of waste. The majority of the waste volume is expected to consist of non-hazardous construction materials and equipment, or materials that can be cleaned to remove contaminants. As discussed in Section 5.3.3, stable non-hazardous demolition waste will be deposited in the B1 Pit, outside the frozen zone. The remaining non-hazardous demolition waste would be placed in a new facility constructed on the Northwest Pond.

5.11.4 Relocation of the Public Highway

A small section of Highway 4 would be relocated to allow site remediation to proceed as proposed. A new highway alignment would avoid interference with surface facilities required for the ground freezing.

5.12 Waste Storage and Disposal Areas

As discussed in Section 3.12, eight areas of miscellaneous waste are present on the site. These wastes will require safe permanent disposal.

The selection of specific methods for waste disposal will generally be based on industry best practices and GNWT regulations. Recyclable materials such as scrap steel will be removed. Non-hazardous materials will be moved to permanent disposal in a new on site facility, described below. During this process, the presence of hazardous materials in these areas would be assessed. Some hazardous materials, such as asbestos products, would be buried in tailings at the Northwest Pond. Other hazardous materials would be transported off-site, for disposal in an approved facility. Materials contaminated with soluble arsenic would be disposed of underground, along with some of the process residues from the Roaster and Mill complexes.

A new disposal facility for non-hazardous waste will be created on the east side of the Northwest Pond, to accommodate waste from the demolition of buildings and infrastructure, and other waste gathered from storage areas around the site that can not be accommodated in the B1 Pit. The landfill will occupy an existing quarry and be constructed to blend with the local topography to the extent possible. The waste will be placed on the tailings in small lifts and compacted to minimize subsidence, and covered with broken rock to ensure that none of the waste remains exposed.

5.13 Summary of Remediation Plan

Table 5.4 summarizes the key remediation commitments proposed in the preceding sections.

Table 5.4: Summary of Proposed Remediation Activities

Component	Proposed Remediation Method	Reference(s)
Arsenic trioxide dust storage areas	Freeze in place using "frozen block" method.	Section 5.1 Supporting Documents J1, D1 and D2
Other underground mine components	Clean up and dispose of waste materials.	Section 5.2
Open pits	Backfill B1 Pit and Brock Pit. Place signs, fences and berms around remaining pits.	Section 5.3 Supporting Documents E1 & E2
Waste rock	Use as backfill in B1 Pit.	Section 5.4 Supporting Document B1
Tailings and sludge containment areas	Recontour and cover.	Section 5.5 Supporting Documents K1 and H1, H2, and H3
Historic foreshore tailings	Cover in place.	Section 5.6 Supporting Documents F1 to F3
Site water management	Direct all contaminated runoff to mine for collection and treatment.	Section 5.7 Supporting Documents B1 to B6, C1 to C6, and L1 and L2.
Baker Creek	Construct new channel around C1 Pit. Consider options for Baker Pond once sediment studies are complete.	Section 5.8 Supporting Documents G1, G2, and G3
Quarries, borrow pits, and overburden piles	Reslope and regrade for drainage, vegetate.	Section 5.9
Contaminated soils	Excavate and backfill into frozen zone in B1 Pit or use as fill for tailings and/or sludge ponds.	Section 5.10 Supporting Documents I1 and I2
Buildings and infrastructure	Remove all hazardous materials and demolish buildings.	Section 5.11
Waste disposal and storage areas	Dispose on-site in approved areas.	Section 5.12

Prepared by: mdr
Checked by: srs

6 Assessment of Post-Remediation Conditions

6.1 Post-Remediation Site Conditions

Upon completion of the remediation measures described in Section 5, the arsenic storage areas will be fully frozen, and the freezing system converted to passive thermosyphons. A fence will be constructed around each of the arsenic trioxide storage areas and the central operations area, and the fenced areas will remain under the control of DIAND and the GNWT.

The water level in the mine will be maintained below the bottom of the open pits, which will also prevent any release of contaminated groundwater to the surroundings. All surface water that does not meet discharge criteria will be collected and directed into the minewater system.

The minewater treatment plant will be constructed within the fenced area, and will be operated year-round. The treated minewater will be discharged to a diffuser constructed in Yellowknife Bay. Operation of the plant will require a small staff of treatment plant operators, maintenance specialists and security staff. The staff may also carry out long-term environment monitoring described below in Chapter 7.

Access to the open pits will be restricted by fencing or berms to ensure public safety. The pits will remain dry as long as the water level in the underground mine is kept below their base. All access openings to the underground will have been closed and permanently sealed.

In the remainder of the central core of the site, all buildings, hazardous materials and soils exceeding industrial soil contamination criteria will have been removed. The area will therefore be suitable for industrial development. Examples of possible uses included staging areas for winter roads, fuel storage, warehousing or light industry.

The tailings and sludge impoundments will have been regraded and surfaced with free draining covers. All quarries, borrow pits, and waste disposal areas will also have been regraded and covered to promote drainage and revegetation in areas not consisting of exposed bedrock. Once vegetation becomes well established, these areas will be open to use by the general public. Examples of possible uses include the development of walking, skiing or interpretive trails. Sports fields could also be constructed on portions of the covered tailings.

The Baker Creek corridor will have been remediated and is expected to see a gradual increase in the numbers and diversity of fish, animals, wildfowl and native vegetation. At the discretion of DFO, catch and release fishing may be possible, although food fisheries may need to be discouraged, depending on the level of residual arsenic contamination.

Figure 6.1.1 presents a conceptual view of the remediated site.

6.2 Predicted Water and Arsenic Balance

The water and arsenic balance described in Section 4.4 and Supporting Document M1 was used to evaluate the arsenic release to surface and groundwater after implementation of the Remediation Plan proposed in Chapter 5.

Estimates of long-term arsenic release after remediation were made for seepage and runoff from residual surface sources (tailings areas, polishing and settling pond area, open pits, and contaminated soils), any surface sources that would result from water treatment activities (*i.e*. treatment plant sludges), and from underground sources (arsenic chambers, tailings backfill, waste rock backfill, and bedrock and mine workings).

The estimates reflect long-term conditions, after the remediation activities have been completed and arsenic concentrations in the surface runoff reach levels that are acceptable for direct discharge. Therefore, the long-term arsenic releases from surface facilities are assumed to be discharged directly to the receiving environment. Since arsenic concentration in water from the underground mine will depend on the exact flow path through the various underground sources, the minewater may not be acceptable for direct discharge for many years. For the purpose of this assessment, it was assumed that partial dewatering of the mine is maintained at either the 425 Level or immediately below the base of the open pits at the 100 Level, and flows from the underground workings would continue to be treated.

A comparison of current and future flows and arsenic loading from the mine is provided in Table 6.1 and illustrated in Figure 6.2.1. The remediation activities are expected to reduce contributions from the water treatment plant to approximately 140 kg/year, contributions from the other sources to Baker Creek to approximately 190 kg/year, and contributions in direct runoff to Yellowknife Bay to approximately 69 kg/year. In addition, the water treatment plant will discharge directly to Yellowknife Bay. These changes result in a total reduction in loading to Baker Creek from approximately 800 kg/year to 480 kg/year, and a reduction in loading to Yellowknife Bay from approximately 910 kg/year to 690 kg/year. Concentrations in surface runoff from all sources are expected to decrease gradually over time as readily soluble contaminants are flushed from the system. Therefore, further reductions in loading are likely to occur in the longer-term.

Contributions to Baker Creek from upstream of the mine and from tributaries to the west of Baker Creek are expected to remain at current levels of 220 kg/year and 67 kg/year respectively, and will comprise the most significant source of loading to Baker Creek. While these sources are also expected to diminish over time, it may take several decades and possibly hundreds of years before this arsenic is flushed from the system, and there are no feasible means of accelerating this process.

Figure 6.1.1: Post Remediation Site Conditions

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Figure 6.2.1: Estimated Post Remediation Arsenic Loadings

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Table 6.1: Comparison of Current and Post-Remediation Arsenic Loadings to Baker Creek and Yellowknife Bay

Sources to Baker Creek	Average Annual Flow (m^3/yr)		Estimated Arsenic Release (kg/yr)	
	Current	Future	Current	Future
Baker Creek Upstream of Giant Mine	7,100,000	7,100,000	220	220
Tributaries from West of Giant Mine	850,000	850,000	67	67
Current Effluent Treatment Plant	750,000	na	290	0
Runoff from Giant Mine Surface Facilities to Baker Creek	230,000	390,000	220	190
Total Inputs to Baker Creek	8,900,000	8,300,000	800	480
Direct Runoff to Yellowknife Bay	300,000	290,000	110	69
New Water Treatment Plant	na	370,000	na	140
Total Inputs to Yellowknife Bay	9,200,000	9,000,000	910	690

Notes: Numbers may not add up due to rounding *Prepared by: qjk*
Checked by: kss

Remediation of the Northwest Pond and partial flooding of the workings will result in a significant reduction in inflows to the mine. As a result, the amount of water that will need to be pumped from the mine water management system and treated will be reduced to approximately 310,000 to 350,000 m^3/year (840 to 970 m^3/day, depending on the flood level). These flows were conservatively rounded up to 370,000 m^3/year or 1000 m^3/day to estimate the rate of discharge from the water treatment plant.

Isolation of the arsenic chambers by ground freezing and removal of the Northwest Pond seepage will result in a substantial reduction in arsenic loadings. Residual loadings in the underground workings would be on the order of 890 to 1050 kg/year. The average arsenic concentration in the minewater would be approximately 3 mg/L, reflecting inputs from the various backfill materials. It is assumed that this water would require treatment prior to release into the environment. However, the estimated arsenic concentration is strongly dependent on how much water flows through the backfill materials. It is possible that preferential flow through cleaner areas of the mine will result in concentrations that may eventually allow direct discharge.

6.3 Assessment of Ecological and Human Health Risks

6.3.1 Overview

Ecological and human health risk assessments were carried out to provide insight as to the level of risk that would be presented by the site after implementation of the remediation measures described in Chapter 5. The risk assessment included a complete review of available data on arsenic levels in the Yellowknife area, prediction of future arsenic intakes by ecological and human “receptors”, and a comparison of the predicted intakes to toxicological reference values (TRVs).

Figure 6.3.1 provides an overview of the calculation steps involved. In general terms, the calculations allow a risk assessor to estimate the intake of arsenic by selected ecological and human “receptors”, *i.e.* by animals and people with particular dietary habits living in the study area. Although the calculations follow a relatively straightforward logic, the assessment of ecological and human health risks by this method is never an exact science. In fact, the method requires a number of inputs and assumptions, some of which are well established and some of which are less well understood. In each of the remaining sections, a brief description is provided of each step in the risk assessment process and of those factors that are well known and those that are not known as well (*i.e.*: those with uncertainty). The last section of this chapter brings together the risk assessment results and uncertainties, and provides a summary of the key conclusions.

6.3.2 Arsenic Sources

The remediation measures proposed in Section 5 are expected to decrease the arsenic discharges from surface sources within the mine area. As discussed in Section 6.1, the post-remediation arsenic loadings are expected to be:

- 290 kg/yr from background sources (220 kg/yr upstream of the mine and 70 kg/yr from tributaries);
- 190 kg/yr in surface runoff that would flow into Baker Creek from the Giant Mine site; and
- 140 kg/yr of arsenic from the treatment plant and 70 kg/yr from surface run-off that would enter directly into north Yellowknife Bay.

Based on these estimates, the total post-remediation arsenic loading to Baker Creek would be 480 kg/yr, and the total loading to north Yellowknife Bay would be 690 kg/yr.

The arsenic loading assessment is based on only partial removal of arsenic contaminated sediments in Baker Creek. It was assumed that some portions of Baker Creek will still have sediments with arsenic concentrations of up to 2,200 mg/kg (dry weight basis). In addition, it was assumed that sediments in Back Bay and Yellowknife Bay would be left as is.

Arsenic in Other Environmental Media

In order to assess the total intake of arsenic by ecological and human receptors in the Yellowknife area, it was necessary that the risk assessment consider sources other than direct releases from the Giant Mine. Section 4 summarizes previous studies of arsenic concentrations in water, sediment, benthic organisms, aquatic plants, fish, air, soil, and terrestrial vegetation in the Yellowknife area. Complete data summaries are provided in Appendix A of Supporting Document N1. In brief, there is a substantial data set available to characterize the arsenic concentrations in environmental media in the Yellowknife area.

The data were used in several different ways in the risk assessment calculations:

- Water and sediment quality data were used to calibrate a model of arsenic transport and fate in Baker Creek, Back Bay, and Yellowknife Bay (see Section 6.3.3 below);
- Data on arsenic concentrations in soils, garden vegetables, and berries were used to calculate summary statistics that were then used directly in probabilistic calculations of arsenic intakes from those sources;
- Data on arsenic concentrations in fish, benthic organisms, and aquatic plants were used to estimate site-specific “transfer factors”. Transfer factors are used to determine concentrations of arsenic in these media into the future;

- Recent studies of the speciation of arsenic in fish from Yellowknife Bay were used to infer the effects of fish derived arsenic in humans; and
- Recent investigations of muskrat on Baker Creek were used to infer the effects of arsenic on the reproductive success of this species.

Some weaknesses in the available data became apparent. Arsenic levels in terrestrial wildlife were typically below detection limits, this necessitated the use of cautious assumptions, supported by information from studies undertaken elsewhere, as to how much arsenic would accumulate in wildlife. The analytical method used to assess arsenic speciation in fish obtained from Yellowknife Bay was not able to clearly distinguish between the toxic and non-toxic forms of arsenic. To be conservative, it was assumed that all arsenic in terrestrial species and any “uncertain” arsenic present in fish would be in a toxic form.

6.3.3 Transport and Fate of Arsenic in the Aquatic Environment

Processes

For the risk assessment calculations, the arsenic released from the Giant Mine site was assumed to enter directly into Baker Creek or north Yellowknife Bay and from there into the other portions of Great Slave Lake shown in Figure 6.3.2. The interactions between waterborne and sediment-bound arsenic are very important in determining the exposure of aquatic organisms. Therefore it was necessary that the risk assessment calculations take those interactions into account.

The behaviour of arsenic in natural waters is reasonably well understood. Studies of other lake systems and the Yellowknife area studies cited in Appendices A and B of Supporting Document N1 show that arsenic exists primarily as the soluble inorganic form in lake water, and is therefore transported along with the water. The same studies also show that arsenic is removed from natural waters by reactions with sediments. Settling solids scavenge arsenic from the water column and carry it to the lake bottom, where it can be buried by subsequent sediment deposition. Contaminated sediments can also release arsenic back into the water column. In cases where the concentrations of arsenic in the water were historically higher than they are today, the sediments can become a significant long-term source of arsenic.

Modeling

The arsenic transport and sediment uptake processes within Back Bay, North Yellowknife Bay and South Yellowknife Bay, as delineated in Figure 6.3.2 were simulated with the help of a mathematical model known as LAKEVIEW. The model is described in detail in Supporting Document N1, Appendix B. The processes simulated by LAKEVIEW include:

- Historical inputs of arsenic and arsenic accumulation in sediments;
- Future inflows of water and dissolved arsenic from Baker Creek and the Yellowknife River;
- Distribution of the arsenic among Back Bay, North Yellowknife Bay and South Yellowknife Bay;
- Adsorption of arsenic on sediments, arsenic reactions in lake sediments, and subsequent release back into the water column;
- Burial of sediments by natural deposition of suspended solids; and

- Transport of water and arsenic into and out of the three lake segments.

All available sediment and water quality monitoring data from the areas shown in Figure 6.3.2 were reviewed and used to calibrate the LAKEVIEW model. In brief, the calibration comprised quantifying sediment porewater, surface water and sediment-solids interactions, and adjusting estimates of historical arsenic loads to match available data. Supporting Document N1, Attachment B provides details.

The calibration results provided interesting insights into how the system responds to changes in arsenic inputs. In particular, the model calibration showed that the water in Back Bay and Yellowknife Bay responded within a few years to previous reductions in arsenic inputs, but that arsenic concentrations in sediments are responding much more slowly. One implication is that the currently elevated arsenic concentrations in sediments are in large part due to the very high arsenic discharges that occurred in the 1960's and 1970's, i.e. prior to the water treatment improvements at the mine. Another implication is that future improvements in arsenic concentrations in sediments would take decades, even if the arsenic releases to the lake could be completely eliminated.

Future Concentrations of Arsenic in Water and Sediments

The calibrated LAKEVIEW model was then used to simulate dispersion and sediment uptake of the arsenic that would be released from the mine workings under the post-remediation conditions discussed above. Table 6.2 summarizes the water quality predictions, and compares them to water quality guidelines for aquatic life and drinking water.

As indicated in Table 6.2, only the predicted arsenic concentration in Baker Creek exceeds the CCME guideline for the protection of freshwater aquatic life and the proposed Canadian guideline for drinking water. The predicted arsenic concentrations in Back Bay and north and south Yellowknife Bay are within the water quality guidelines. However, the guidelines in Table 6.2 are designed to be protective of a wide range of aquatic species and water uses, some of which are not found in Baker Creek. The next two sections provide a more site-specific assessment of the significance of the predicted arsenic concentration for ecological and human health.

Table 6.2: Comparison of Post-Remediation Water Quality Predictions to Guidelines

	CCME Guideline for Protection of Freshwater Aquatic Life (5 µg/L)				Proposed Canadian Guideline for Drinking Water (5 µg/L)			
	Baker Creek	Back Bay	North YK Bay	South YK Bay	Baker Creek	Back Bay	North YK Bay	South YK Bay
Mean Arsenic Concentration (µg/L)	118	3	1.4	0.59	118	3	1.4	0.59
Meets CCME Guideline?	x	✔	✔	✔	x	✔	✔	✔

Notes: x - Both the predicted mean and 95th percentile arsenic concentrations exceed the guideline.Prepared by: xx
✔ All predicted arsenic concentrations are below the guideline.

Prepared by: bh
Checked by: hp

Figure 6.3.1: Steps in Risk Assessment Calculations

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Figure 6.3.2: Areas Considered in Risk Assessment

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6.3.4 Arsenic Intakes by Ecological Receptors

Assessment Methods

To make the connection between predicted arsenic concentrations and intakes by plants, fish and animals, it was necessary to carry out "pathways" calculations. The pathways calculations estimate the amount of arsenic taken in by species at various levels in the food chain, on the basis of assumptions as to the amount of time that each species spends in the arsenic-contaminated areas and their water and food intakes during that period. Figure 6.3.3 illustrates the main pathways considered in the ecological risk assessment.

For estimating the exposure and uptake of arsenic by aquatic species, it was assumed that they would be exposed to arsenic in Baker Creek, Back Bay and/or Yellowknife Bay. It is not known with certainty how long aquatic species remain in each location. To be cautious, it was assumed that the aquatic species were present 100% of the time in each water body.

For the terrestrial receptors, the estimates took into consideration exposure to arsenic in drinking water, soils or sediments, aquatic or terrestrial vegetation (by herbivores and omnivores) and wildlife (by omnivores and carnivores). The arsenic present in drinking water and food items was assumed to be 100% bioaccessible. For soils and sediments, however, limitations to arsenic bioaccessibility were considered. Sequential extraction tests carried out on the sediments from Baker Creek indicated that the bioaccessibility of arsenic was approximately 17%. It was assumed that the bioaccessibility in sediments was the same. Supporting Document N1 Appendix C provides details on the site-specific bioaccessibility studies.

Supporting Document N1, Appendix D, provides details of the assumed feeding habits for each species, and the calculations to estimate arsenic intake by each pathway. Probabilistic methods were used to account for uncertainty in several of the model inputs. For all of the terrestrial species, mean, 5th, 50th and 95th percentile daily intakes of arsenic were estimated.

Potential for Impacts on Aquatic Species

To assess the level of risk to aquatic species, the estimated concentrations of arsenic in the water (mean, 5th, 50th and 95th percentile values) at each location were compared to appropriate toxicity reference values. For each aquatic species considered in the assessment, the toxicity reference value was set at the lowest concentration at which 25% of the test species might show a toxic effect in a long-term test (EC25). Additional model runs were carried out using lowest concentrations at which 10% of the test species show a toxic effect (EC10) as the toxicity reference value.

Table 6.3 compares the estimated water arsenic concentrations to aquatic toxicity reference values, and shows that the predicted post-remediation arsenic levels are unlikely to have an adverse effect on aquatic species in Back Bay or Yellowknife Bay. In Baker Creek there may be a potential for adverse effects on both predatory and bottom-feeding fish. However, biological surveys in 2002 indicate the presence of both predatory and bottom-feeding fish in Baker Creek, upstream and downstream of the mine workings, which suggests that the toxicity reference values used in this assessment may over-estimate the actual risks.

Table 6.3: Comparison of Estimated Water Arsenic Concentrations to Aquatic Toxicity Reference Values

	Remediation Case			
	Baker Creek	Back Bay	North YK Bay	South YK Bay
Aquatic Plant	✔	✔	✔	✔
Benthic Invertebrates	✔	✔	✔	✔
Predatory Fish	x^2	✔	✔	✔
Bottom Feeder Fish	x^1	✔	✔	✔

Notes: x^1 - The predicted 95th percentile concentration exceeds the EC_{25} toxicity reference value, and the 5th, 50th and 95th percentile concentrations exceed the EC_{10} toxicity reference value.

Prepared by: hp
Checked by: bh

x^2 - The predicted concentration exceed the EC_{10} toxicity reference value, but is below the EC_{25} toxicity reference value

✔ - Indicates that all predicted arsenic concentrations are below the EC_{25} and EC_{10} toxicity reference value.

YK = Yellowknife

Potential for Impacts on Terrestrial Species

The estimated daily intakes of arsenic by the terrestrial species were also compared to toxicity reference values, in this case Lowest Observable Adverse Effects Levels (LOAEL) obtained from literature data. A LOAEL is the lowest concentration where an effect can be seen in laboratory testing.

There were a number of uncertain components in the terrestrial risk assessment. Cautious assumptions were adopted whenever the uncertainties could not be resolved. For example, for the terrestrial receptors, it was assumed that while in the study area, they spent time in the location of highest arsenic exposure (i.e.: Baker Creek), that they obtain 100% of their food and water from the study area, and that the arsenic present in these media is directly transferred into the species. In addition, most terrestrial species were assumed to consume either soil or sediment, but only a portion of the arsenic in these media was assumed to be biologically available.

The results of the risk assessment showed that, with two notable exceptions, the estimated arsenic intakes for terrestrial species were below toxicity benchmarks. Estimated arsenic intakes from all sources for bear, caribou, grouse, mallard, merganser, scaup and wolf were predicted to be well below toxicity reference values for these species. Likewise, the arsenic intakes predicted for three duck species were well below the applicable toxicity reference values.

The first exception was that of hare in the vicinity of Baker Creek, where the mean and 95th percentile estimates of intakes were predicted to exceed the toxicity reference value. The major source of arsenic for hare is terrestrial vegetation. Measured arsenic levels, representative of current conditions, were used in the assessment. While the Remediation Plan provides for removal of contaminated soils with arsenic content of greater than 340 mg/kg, the cautious assumption was made that arsenic levels in terrestrial vegetation would not change.

The second exception is that of the terrestrial species, mink and muskrat, living in the aquatic environment on Baker Creek. LOAEL's were predicted to be exceeded for both species. The predicted arsenic intake by mink and muskrat is related to the assumed levels of arsenic in the creek water, creek sediments, and aquatic plants. Post-remediation arsenic loadings to Baker Creek from the Giant Mine site will be significantly reduced, but upstream inputs will continue. As noted above, the risk assessment also assumed that contaminated sediments would remain. These assumptions may lead to a over-estimate of the effects on mink and muskrat.

Figure 6.3.3: Pathways Considered in Ecological Risk Assessment

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Recent studies of the muskrat population on Baker Creek found twelve active burrows downstream of the mine workings, supporting an estimated population of between 66 and 197 animals (Jacques Whitford, 2003). Subsequently, a number of muskrat were trapped both upstream and downstream of the mine workings and muscle, organ, and tail samples were analyzed for arsenic. Details are provided in Supporting Document N1. Measured arsenic concentrations were higher in the muskrat sampled from downstream of the mine than in muskrat sampled upstream. However, the number of active dens supporting a substantial muskrat population under current conditions indicates that the species is unlikely to be adversely effected under the post-remediation conditions.

6.3.5 Arsenic Intakes by Human Receptors

Assessment Methods

Pathways calculations were also used to estimate the amount of arsenic that could be taken in by people living in the region. The pathways considered in this case are shown in Figure 6.3.4 and include:

- Direct intake of arsenic in air and drinking water;
- Intake of arsenic-contaminated soil, as dust or from hands;
- Intake of arsenic via locally obtained fish and game;
- Intake of arsenic via locally grown garden produce and wild berries;
- Intake of arsenic via traditional teas made from local plants; and
- Intake of arsenic in store-bought foods imported from other areas.

Several hypothetical “receptors” were defined to represent different ages, diets, and residence locations. The intake of arsenic via each pathway was calculated for each receptor. The top half of Table 6.4 summarizes the arsenic intake pathways associated with each hypothetical receptor.

Additional calculations were then completed to assess the effects of possible changes in eating habits. For example, one set of calculations checked the case where Receptor 1 in Table 6.6 was assumed to eat fish from Baker Creek and drink water directly from Back Bay. Other variants that were examined included combinations of drinking water and fish sources, eating berries from the Giant Mine site, and diets with very high fish consumption.

The estimation of arsenic intakes involved some uncertainties. Cautious assumptions were used whenever the uncertainties could not be resolved. For example, it was assumed that all receptors spend their entire lifetime in the study area and are exposed to the maximum concentration of arsenic throughout this lifetime. Individuals were also assumed to obtain a relatively large portion of their food from local sources. These assumptions mean that the calculations are likely to over-estimate the true intake of arsenic by typical residents of the area.

Table 6.4: Estimated Intake of Inorganic and Toxic Organic Arsenic by Human Receptors

Diet	Receptor 1a and c		Receptor 2a and c		Receptor 3a and c		Receptor 4a and c	
Dietary Component								
Drinking Water	Municipal Supply		Municipal Supply		Municipal Supply		Municipal Supply	
Soil	Giant Townsite		Latham Island		City of Yellowknife		Dettah Community	
Garden Produce	Giant Townsite		Latham Island		City of Yellowknife		Dettah Community	
Berries	Giant Mine Site		Latham Island		City of Yellowknife		Dettah Community	
Large Game	Baker Creek		Baker Creek		Baker Creek		Dettah Community	
Small Game	Baker Creek		Baker Creek		Baker Creek		Dettah Community	
Ducks	Baker Creek/Back Bay		Back Bay		North Yellowknife Bay		South Yellowknife Bay	
Fish	Back Bay		Back Bay		North Yellowknife Bay		South Yellowknife Bay	
Medicinal Teas	-		Giant Mine Site		-		Dettah Community	
Supermarket Foods	Imported		Imported		Imported		Imported	
Estimated Mean Toxic Arsenic Intakes (mg/(kg d))								
	Adult	Child	Adult	Child	Adult	Child	Adult	Child
Remediation Case	0.00088	0.0016	0.00077	0.0013	0.00067	0.0013	0.00056	0.0010
Total arsenic intake by typical Canadian adult from all sources – 0.0001 (mg/(kg d)) to 0.0007 (mg/(kg d)).								
Arsenic Intakes by Yellowknife adults from all sources excluding market foods – 0.00012 (mg/(kg d)) to 0.00049 (mg/(kg d))								
Arsenic intakes in by adults other communities with elevated arsenic levels in local environment excluding market foods – 0.001 (mg/(kg d)) to 0.009 mg/(kg d))								
Estimated Mean Incremental Lifetime Carcinogenic Risk (Excluding Market Foods)								
	Composite Person		**Composite Person**		**Composite Person**		**Composite Person**	
Remediation Case	4.2 in 10,000		6.1 in 10,000		1.6 in 10,000		3.7 in 10,000	

Notes: Mean arsenic intakes included contributions from toxic arsenic forms and from market foods.
Underline indicates that estimated mean intake exceeds the typical range of intakes for the general Canadian population, *i.e.* 0.0001 to 0.0007 mg/(kg d) for adults and 0.0002 to 0.0021 mg/(kg d) for children aged 5 to 11 years old.
Composite Person encompasses 11 years, as a child and 59 years as an adult.

Prepared by: hp
Checked by: bh

Arsenic concentrations in water and local fish and game were estimated using the methods discussed in the preceding two sections. Arsenic concentrations in soils from different locations and in locally grown garden produce were estimated from data collected by others, generally for the Yellowknife Soils Arsenic Remediation Committee. Arsenic concentrations in store-bought foods were estimated from a Canada-wide survey (Dabeka et al. 1993). Supporting Document N1 details the assumed arsenic concentrations and reviews the available data for each case.

It was assumed that all of the arsenic present in drinking water and other food sources, with the exception of fish, would be in the more toxic inorganic form. Two recent studies (Cohen et al., 2002; Mass et al., 2001) have suggested that some forms of organic arsenic could also be toxic. A study to measure the forms of arsenic in fish from the Giant Mine area was commissioned in 2003. The results, presented in Supporting Document A8, do not quantify all of the organic arsenic forms present, so it was cautiously assumed that 78% of the organic arsenic in fish would be toxic. Supporting Document N1 provides details of the calculations.

Estimated Daily Arsenic Intakes

The bottom of Table 6.4 summarizes the estimated daily arsenic intakes for each hypothetical receptor. Receptor 1 was predicted to have the highest arsenic intake, followed by Receptor 2.

Figure 6.3.5 shows the significance of each source of arsenic for each hypothetical receptor. Interestingly, store-bought foods are estimated to be the largest source of arsenic in all cases. The importance of the other sources varies. Receptor 1 is estimated to receive a significant proportion of the arsenic intake from produce, which is assumed to be grown in a garden at the Giant Mine Townsite, and berries is assumed to be gathered from the Giant Mine site. Receptor 2 is estimated to receive a significant proportion of arsenic intake from fish that are assumed to be obtained only from Back Bay. Receptors 2 and 4 are estimated to receive significant proportions of their arsenic intake from locally harvested game. Those results reflect both the greater proportion of country foods in the Receptor 2 and 4 diets, and the conservative assumptions used to estimate arsenic concentrations in local wildlife. For example, the caribou consumed by Receptors 2 and 4 were assumed to have spent 10% of their lifetimes in the Giant Mine area.

For simplicity, results of the additional calculations to assess dietary variants are not shown in Figure 6.3.6. In brief, the additional calculations showed that obtaining the entire fish portion of one’s diet from Baker Creek could increase the estimated arsenic intakes by a factor of 5 to11. Other changes in the assumed dietary characteristics had much less effect on estimated arsenic intakes.

The bottom of Table 6.4 compares the estimated arsenic intakes to values typical of the Canadian population as a whole, and to estimated arsenic intake rates in other Canadian cities that also have elevated levels of arsenic. Only the estimated intake rates for Receptors 1 and 2 are above the range typical of the Canadian population as a whole. Even those estimates are at the low end of the range associated with other Canadian cities such as Deloro, Ontario, and Wawa, Ontario that have elevated levels of arsenic and where studies have not shown elevated levels of skin cancer or other health effects.

Potential for Human Health Effects

Perhaps the greatest source of uncertainty in the risk assessment process is in the relationship between arsenic intakes and potential health effects. Evidence from many studies shows that long-term intake of arsenic at sufficiently high rates results in skin cancers. The skin cancers predominantly occur as squamous cell and basal cell carcinomas, which are highly treatable if detected in time. Ingestion of inorganic arsenic has also been reported to increase the risk of cancer in the bladder, lung, liver, kidneys and prostate, and other health related effects of a less serious nature (ATDSR, 2000 and references therein).

The most difficult question surrounds whether health effects such as those described above can be expected to result from long-term exposure to low levels of arsenic. The U.S. EPA reviewed studies (U.S. EPA 2004 IRIS) with information on the linkage between arsenic intake and skin cancer, and determined that the most useful basis for quantitative risk assessment was an epidemiology study conducted in an area of Taiwan where the well water content was high in arsenic (Tseng *et al.* 1968 and Tseng, 1977).

Several documents and authors point to the difficulty in using the Taiwanese data to estimate cancer risks in North American populations. Furthermore, the quantitative relationships between arsenic intake and cancer risk in the Taiwanese study apply directly only to relatively high arsenic intakes. There is no agreed basis for extrapolating the data to the lower intakes typical of other cases. The assumption that a linear relationship exists and that any exposure to arsenic, even at very low intakes, will result in a proportionate increase in cancer risks is adopted in most risk assessments. This approach is recognized as being cautious and, therefore, most likely over-estimates cancer risks.

In a recent analysis by Health Canada (2004), the cancer risk models based on Taiwanese data have been updated (Morales *et al.* 2000). Health Canada also assumed the linear dose–response relationship and used the Taiwanese data to develop a slope factor of 1.2 $(mg/(kg\ d))^{-1}$ for use in the drinking water guideline, based on kidney cancers in men and lung cancer in women. That value implies that Receptor 1, with an average lifetime total arsenic intake rate of 0.001 mg/(kgd), would increase the receptor's lifetime risk of getting cancer by 1.2 x 0.001 = 0.0012, or roughly 12 in 10,000.

Figure 6.3.7 provides a comparison of the predicted incremental lifetime risks from exposure to arsenic for Receptor 2 (receptor with the highest risk) to other Canadian cancer statistics (Canadian Cancer Statistics 2003). In addition, the bottom portion of Table 6.4 provides the incremental lifetime risks for the other receptors considered in the assessment. It should be noted that the incremental lifetime risks include exposure to arsenic in various media such as soils, water and traditional foods but do not include exposure to arsenic present in market foods. As seen in the figure, the predicted cancer risks are well below the lifetime incidence cancer rate of 3 in 10 for the Northwest Territories population (Canadian Cancer Statistics, 2003) as well as the incidence of lung cancer (5 in 100) or skin cancer (2 in 100) in the Canadian population. These results suggest that the development of cancer from total arsenic exposure would be 20 to 300 times lower than the overall cancer risk.

Figure 6.3.4: Pathways Considered in Human Health Risk Assessment

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Figure 6.3.5: Breakdown of Total Arsenic Intake by Pathway

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Figure 6.3.6: Comparison of Arsenic Intakes

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Figure 6.3.7: Comparison of Cancer Risk

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6.3.6 Uncertainties

As with any risk assessment, there are a number of uncertainties involved in the calculations. Table 6.5 summarizes the major assumptions adopted for the ecological and human health risk assessments. Each assumption was reviewed to determine whether it was likely to lead to under-estimation or over-estimation of risks. The resulting table allows the overall effect of these assumptions to be examined. It is clear that the majority of assumptions lead to “over-estimation” of risks.

6.3.7 Risk Assessment Conclusions

For the purposes of developing a Remediation Plan for the Giant Mine, the conclusions of the ecological and human health risk assessments can be most clearly stated as follows:

- Aquatic plants and fish in Back Bay and Yellowknife Bay are not at risk of adverse effects from post-remediation arsenic releases. The predicted post-remediation arsenic release of 190 kg/year from the site to Baker Creek, in addition to arsenic from upstream is expected to result in arsenic concentrations above the CCME guideline of 5 µg/L for protection of aquatic life, and may result in potential adverse effects on fish in Baker Creek. Additional clean-up of Baker Creek sediments would reduce these risks.
- Further studies of Baker Creek sediments are underway and should provide stronger evidence as to whether historical arsenic contamination in Baker Creek sediment has caused a reduction in benthic community diversity. Recovery of this system is expected to take a long time. The diversity of benthic communities in parts of Back Bay and North Yellowknife Bay may also be affected by existing levels of arsenic but this situation will gradually improve as sediments with elevated arsenic levels are buried over time and covered with cleaner material.
- The assessment indicates that some small terrestrial animals (*e.g*. mink and muskrat) in the Baker Creek watershed are potentially at risk under the proposed remediation scenario. The primary sources of arsenic intake by these species are related to the elevated arsenic levels in Baker Creek sediments, aquatic plants and surface drainage, all of which are linked to historical contamination in the watershed. Field investigations carried out in 2003 and 2004 however, show that there is a good population of muskrat in the downstream reach of the creek. While the muskrat at downstream locations were found to contain higher levels of arsenic in muscle and body organs than muskrat from upstream locations, the tissue arsenic levels were below those found to have toxic effects in other animals. Taken as a whole, these results suggest that the arsenic present in Baker Creek does not appear to have an adverse effect on the muskrat population.
- People living in the study area are unlikely to be at risk of adverse effects from arsenic exposure, even though arsenic levels in the area are higher than found in most communities. The estimated total arsenic intakes for Yellowknife area residents generally fall within the range of typical arsenic intakes estimated for other Canadians. Estimated cancer risks arising from Giant Mine arsenic are well below the risks associated with other causes of cancer.

Table 6.5: Summary of Uncertainties in Assessment of Ecological and Human Health Risks

Assumption	Effect of Assumption			
	Possibly Leads to Under-estimation of Risks	Leads to Neither Over- nor Under-estimation	Likely Leads to Over-Estimation of Risks	Could Lead to Over or Under-Estimation
Arsenic Sources				
Estimates of Arsenic Releases from Giant Mine			x	
Estimates of Arsenic in Water, Soils, Sediments		x		
Estimates of Arsenic in Market Foods		x		
Arsenic Transport and Fate				
Mass Transfer Coefficients - Exchange between water column and sediment calibrated against measured levels		x		
Historic Loads to Area - Not known with certainty but estimated in part through model calibration		x		
Arsenic Intake by Ecological Receptors				
Residence Time of Aquatic Species - assumed to be in each water body 100% of time - Fish - Benthos and Aquatic Plants		 x	 x	
Aquatic Toxicity Reference Values - Based on Laboratory Toxicity Testing			x	
Dietary and Feeding Characteristics of Terrestrial Species -Based on Literature Information		x		
Exposure of Terrestrial Species - Assumed while in the study area to obtain all food and water from Baker Creek - Ducks assumed to spend 100% of whole time in study area on each waterbody			x x	
Bioaccessibility - Assumed arsenic bioaccessibility measured in sediments is the same as for soils[1]				x
Terrestrial Toxicity Reference Values - Based on Laboratory Toxicity Testing[2]				x
Arsenic Intake by Human Receptors				
Residency Time - Assumed to be present for a full 70-year lifetime at each location and to be exposed at maximum conditions			x	
Soil Ingestion for Humans - Assumed soil ingestion constant for whole year			x	
Backyard Garden Produce - Assumed to occur every day for whole year. Amount of produce grown based on literature studies			x	
Drinking Water Intakes - Assumed all receptors obtain drinking water from the municipal supply		x		
Dietary Intake Rates of Food			x	
Local Meat Sources - Assumed that all arsenic is in toxic inorganic form			x	
Local Fish Sources - Assumed 3% of total arsenic is in inorganic form - Assumed 78% of organic arsenic is in toxic form[3]		 x	 x	
Arsenic Toxicity Reference Values - Oral cancer slope factor based on Taiwanese Data[4]			x	

Prepared by: bh
Checked by: hp

Notes:

1. From a human health perspective, the soil pathway is relatively minor and as such it is unlikely that the estimated risk estimates would change. For the terrestrial animals, soil represents a larger fraction of exposure; however, given that the estimated intakes are well below the TRV for all animals that consume soil with the exception of the hare, the findings would not be different.
2. It is unknown whether the toxicity reference values derived from laboratory studies on mice are directly applicable to the wildlife in question.
3. Additional research carried out on fish in Yellowknife Bay indicated that 3% of the total arsenic is in the inorganic form. However, the analytical method used was unable to specify non-toxic organic forms. The results of the test indicate that as much as 78% of the organic arsenic could potentially be toxic.
4. The derivation of risks using the 2004 Health Canada slope factor is cautious since it is based on upper bound estimates of exposure. However, there are other slope factors provided by the U.S. EPA and older Health Canada documents that are more restrictive.

7 Monitoring

7.1 Surface Water Monitoring

Water quality monitoring at the site currently follows the Surveillance Network Program or SNP requirements set out in previous water licenses. During and after remediation, the SNP will need to be modified to take into account the changes in surface water flow patterns. Figure 7.1.1 shows the proposed monitoring stations:

- Monitoring stations 43-05 (Baker Creek), 43-11 (Baker Creek), 43-16 (Trapper Creek) from the current SNP will continue to be sampled;
- The locations of stations 43-01 (treated water discharge point) and 43-04 (raw water intake) will be modified; and
- New monitoring stations will be established to sample seepage from Dams 3 and 11, and surface runoff from the North Pond, Settling Pond, and Northwest Pond.

Monitoring of the new stations will start during the remediation in each area, and will be continued until the water quality is shown to be consistently acceptable for direct release to the environment.

All stations will be sampled at least monthly during open water season, and more frequently when remediation activities are occurring in the respective catchments. The proposed analyte list is provided in Table 7.1.

Additional temporary stations will be established to monitor any water discharged from areas of active remediation or construction, including demolition areas, areas of contaminated soil removal, tailings areas during regrading and cover construction, spillway construction sites, borrow pits and quarries. The sampling schedules will be established as part of final design. Analyte lists will focus on suspended sediments and other contaminants specific to each activity.

In the case of the tailings covers, monitoring of suspended sediments will continue until erosion rates are shown to be similar to those in natural areas.

Table 7.1: Proposed Analyte List for Surface and Groundwater Samples

Parameter Name (Units)	Parameter Type	Detection Limit		Preparation Method		Test Method
Alkalinity (mg$CaCO_3$ eq/L)	physical	0.1		none		SM2320:B
Conductivity, Specific (S/cm)	physical	0.4		none		SM2510:B
pH	physical	0.05		none		SM4500-H:B
Solids, Total Dissolved (mg/L)	physical	10		GF/C Filt.		SM2540:C
Solids, Total Suspended (mg/L)	physical	3		GF/C Filt.		SM2540:D
Calcium (mg/L)	major ion	0.1		none		SM4110:B
Cation/Anion Balance (mg/L)	major ion	na		Major Ion Detection		Calculated
Chloride (mg/L)	major ion	0.7		none		SM4110:B
Electroneutrality (mg/L)	major ion	na		Major Ion Detection		Calculated
Magnesium (mg/L)	major ion	0.1		none		SM4110:B
Nitrate as Nitrogen (mg/L)	major ion	0.01		none		SM4110:B
Nitrite as Nitrogen (mg/L)	major ion	0.01		none		SM4110:B
Potassium (mg/L)	major ion	0.1		none		SM4110:B
Sodium (mg/L)	major ion	0.1		none		SM4110:B
Sulphate (mg/L)	major ion	1		none		SM4110:B
Ammonia as N (mg/L)	nutrient	0.005		none		SM4500-NH3:G
Nitrate + Nitrite as Nitrogen (mg/L)	nutrient	0.01		none		SM4110:B
Arsenate (μg/L)	other	5		none		SM3113:B
Arsenite (μg/L)	other	5		none		SM3113:B
Inorganic Carbon, Dissolved (mg/L)	other	0.5		GF/C Filtration		EPA415.1
Organic Carbon, Dissolved (mg/L)	other	0.5		GF/C Filtration		SM5310:B
Metals		**Total**	**Dissolved**	**Total**	**Dissolved**	
Aluminum (mg/L)	metals	0.03	0.0006	Acid Digest	(0.45 μm filt.)	EPA200.8
Antimony (mg/L)	metals	0.0001	0.0001	Acid Digest	(0.45 μm filt.)	EPA200.8
Arsenic (mg/L)	metals	0.0002	0.0002	Acid Digest	(0.45 μm filt.)	EPA200.8
Barium (mg/L)	metals	0.0001	0.0001	Acid Digest	(0.45 μm filt.)	EPA200.8
Beryllium (mg/L)	metals	0.0001	0.0001	Acid Digest	(0.45 μm filt.)	EPA200.8
Cadmium (mg/L)	metals	0.0001	0.00005	Acid Digest	(0.45 μm filt.)	EPA200.8
Caesium (mg/L)	metals	0.0001	0.0001	Acid Digest	(0.45 μm filt.)	EPA200.8
Chromium (mg/L)	metals	0.0003	0.0001	Acid Digest	(0.45 μm filt.)	EPA200.8
Cobalt (mg/L)	metals	0.0001	0.0001	Acid Digest	(0.45 μm filt.)	EPA200.8
Copper (mg/L)	metals	0.0003	0.0003	Acid Digest	(0.45 μm filt.)	EPA200.8
Iron (mg/L)	metals	0.05	0.05	Acid Digest	(0.45 μm filt.)	EPA200.8
Lead (mg/L)	metals	0.0001	0.0001	Acid Digest	(0.45 μm filt.)	EPA200.8
Lithium (mg/L)	metals	0.0003	0.0002	Acid Digest	(0.45 μm filt.)	EPA200.8
Manganese (mg/L)	metals	0.0001	0.0001	Acid Digest	(0.45 μm filt.)	EPA200.8
Molybdenum (mg/L)	metals	0.0001	0.0001	Acid Digest	(0.45 μm filt.)	EPA200.8
Nickel (mg/L)	metals	0.0001	0.0001	Acid Digest	(0.45 μm filt.)	EPA200.8
Rubidium (mg/L)	metals	0.0001	0.0001	Acid Digest	(0.45 μm filt.)	EPA200.8
Selenium (mg/L)	metals	0.001	0.0003	Acid Digest	(0.45 μm filt.)	EPA200.8
Silver (mg/L)	metals	0.0001	0.0001	Acid Digest	(0.45 μm filt.)	EPA200.8
Strontium (mg/L)	metals	0.0001	0.0001	Acid Digest	(0.45 μm filt.)	EPA200.8
Thallium (mg/L)	metals	0.0001	0.0001	Acid Digest	(0.45 μm filt.)	EPA200.8
Titanium (mg/L)	metals	0.0001	0.0001	Acid Digest	(0.45 μm filt.)	EPA200.8
Uranium (mg/L)	metals	0.0001	0.0001	Acid Digest	(0.45 μm filt.)	EPA200.8
Vanadium (mg/L)	metals	0.0001	0.0001	Acid Digest	(0.45 μm filt.)	EPA200.8
Zinc (mg/L)	metals	0.01	0.0004	Acid Digest	(0.45 μm filt.)	EPA200.8

Prepared by: mdr
Checked by: srs

Figure 7.1.1: Location of Existing Proposed SNP Stations

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7.2 Treated Water Monitoring

Effluent from the water treatment plant will be monitored at three locations:

- In the outflow pipe to the holding pond;
- In the discharge pipe from the holding pond; and
- Near the diffuser.

The proposed monitoring schedule and analytes are shown in Table 7.2.

Table 7.2: Treated Water Monitoring

Sample Location	Schedule	Parameters
Outflow to holding pond	Daily	pH, TSS, total arsenic
Discharge from holding pond	Continuous	Flow metering
	Weekly	pH, major ions, TSS, total arsenic, antimony, metals
	Monthly in first year and quarterly thereafter	Bio-assays
Diffuser area	Annually for three years	Water, sediments and benthics in dilution zone

Prepared by: srs
Checked by: mdr

7.3 Minewater Monitoring

During the period when water levels in the mine are allowed to rise, water levels and quality will be monitored using the existing C-Shaft multilevel well system. Once the water reaches its long-term level below the frozen zones, a modified minewater pumping system will be commissioned. Water quality samples will thereafter be collected from the pump discharge as it is fed to the water treatment plant.

Samples will be taken daily during pumping, and analyzed for the parameters shown in Table 7.1.

A surface based monitoring system will also be installed to monitor minewater in specific tunnels and levels surrounding the frozen arsenic storage areas. These monitoring locations are shown in Figure 7.2.1. The wells will be sampled quarterly and analyzed for parameters listed in Table 7.1.

7.4 Groundwater Monitoring

Groundwater will be monitored in the fifteen deep multilevel monitoring well systems, comprising 129 separate monitoring zones in total, that have already been installed around the mine. Each of these discrete zones will be monitored for piezometric levels every year during re-flooding and for three years thereafter. Approximately 40 selected zones will be sampled for water quality annually during re-flooding and for five years thereafter. Existing shallow standpipes located around the mill area, the tailings impoundments, and at the historic tailings deposition area below the South Pond (as shown in Figure 7.3.1) will be sampled annually during the remediation work and for five years thereafter. A reduced number of sampling points will be identified for long-term monitoring based on the understanding of the groundwater flow at that time.

All samples will be analyzed for the dissolved parameters shown in Table 7.1.

7.5 Air Monitoring

7.5.1 Task Specific Monitoring

Fugitive dust will be monitored during tailings regrading and covering, excavation of contaminated soil, and demolition of buildings. The proposed sampling schedule and monitoring parameters are listed in Table 7.3. Monitoring locations and other details will be defined in dust control plans specific to each activity.

Table 7.3: Task Specific Monitoring Schedule and Parameters

Reclamation Activity	Sampling Schedule	Parameters
Tailings re-grading and construction of covers	Every 6 days	TSP, PM 10, and arsenic
Demolition of arsenic and asbestos contaminated facilities	Daily	TSP, PM 10, arsenic and asbestos
Excavation of contaminated soils	Daily	TSP, PM 10, and arsenic

Prepared by: deh
Checked by: mdr

7.5.2 Site Wide Monitoring

Monitoring of site wide air quality will continue using the baseline stations established in 2004 (Figure 4.7.1). The Townsite "Hi-Vol" sampler may need to be relocated to accommodate reclamation of the area and changes in the power lines. The site wide air quality monitoring will be continued until surface remediation activities are complete and for three years thereafter.

Figure 7.2.1: Location of Long-Term Mine Workings Monitoring System

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Figure 7.3.1: Location of Long-Term Peripheral Groundwater Monitoring System

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7.6 Environmental Effects Monitoring

Environmental effects monitoring at the site currently follows requirements established under the Metal Mining Effluent Regulation. Those requirements will continue to be met during remediation. After surface remediation activities are complete, environmental effects monitoring will continue at the same stations but at a decreasing frequency of bi-annually for ten years and once every five years thereafter.

7.7 Frozen Ground Monitoring

A ground temperature monitoring system will be installed along with the ground freezing system. The monitoring components will include thermistors or thermocouples mounted on the freeze pipes as well as additional thermistor or thermocouple strings installed in separate drillholes.

During the period of active freezing, the in-ground monitoring will be supplemented by monitoring of temperatures and pressures in the coolant as it enters and leaves freeze pipes or groups of freeze pipes. This method is commonly used in freezing systems of similar design to ensure that all freeze pipes are functioning correctly.

Once frozen conditions have been established and the active freezing system is converted to passive thermosyphons, the performance of each thermosyphon will be monitored by annual checks of gas pressure and monitoring of heat loss from the radiators. Ground temperatures will continue to be monitored using the thermistors or thermocouples mounted on the freeze pipes and in independent drillholes.

7.8 Physical Monitoring and Inspections

The long term plan for the site calls for a permanent staff presence to operate the water treatment systems. Site staff will also carry out daily or weekly monitoring of access roads, security fences, pit wall safety berms, power supplies, thermosyphons, tailings covers, ditches and spillways.

Spillways, ditches, and relocated sections of Baker Creek will be inspected annually by a geotechnical engineer for as long as they remain in use. The tailings and sludge covers will be inspected annually for five years or until vegetation is fully established and erosion rates reach those consistent with the local environment. Pit walls, crown pillars, and closed mine entries will be inspected annually for five years and every second year for ten years thereafter.

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8 Implementation

8.1 Implementation Framework

Under the terms of the Cooperation Agreement that was signed by Canada and the GNWT in March 2005, the Oversight Committee shall, with the agreement of both parties, develop options and recommendations for a project implementation office to implement the Approved Remediation Plan. The Oversight Committee will also provide general direction and guidance to the project implementation office if established. The full text of the Cooperation Agreement is included as Supporting Document Q1.

Implementation of the Remediation Plan will be in accordance with applicable federal and territorial legislation, policies and guidelines. The legislative framework under which the project will be implemented is described in Supporting Document Q2. Subsurface rights have been withdrawn from disposal by an Order in Council under the Territorial Lands Act (P.C. 2005-1055 May 31, 2005) "… to allow remediation of the site and to avoid potential conflicts with other users." A copy of the withdrawal order is included as Supporting Document Q3.

8.2 Schedule

Figure 8.1.1 provides an overview of the implementation schedule for the remediation measures discussed herein. DIAND is committed to the implementation of the Giant Mine remediation project and meeting the proposed schedule is a priority for the Northern Affairs Contaminated Sites Program.

Subject to approval from the Board, the majority of the surface remediation activities will be completed within five years, with additional work and verification testing continuing until 2025 or later. Underground remediation, including installation and active operation of the freeze system is expected to take place over nine years. Surface work will be scheduled taking seasonal climatic conditions into account.

8.3 Potential Impacts and Mitigation Measures

To evaluate potential environmental impacts of the undertaking, a matrix of potential environmental impacts related to the different work components of the planned remediation was developed in an attempt to identify likely effects or impacts of the each individual work component. The matrix indicates that many of the more significant impacts of the remediation project relate to the generation of dust and contaminated dust. Appropriate mitigation measures will be put in place during remediation to ensure that the potential impacts of the project can be reduced to levels that will be indistinguishable from normal background levels. Mitigation measures will be developed specifically as a component of the detailed engineering design for all work components.

The detailed environmental impact matrix is included as Supporting Document Q4. Supporting Document Q5 describes a similar assessment of the potential for cumulative impacts.

Based on the environmental impact matrix and the cumulative impact assessment it is clear that a number of mitigation measures will be required.

- Effective dust and sediment control measures will be required during most of the surface earth works.
- Surface work requiring the use of heavy equipment or blasting will generate noise. The site is not within the immediate vicinity of residential or commercial activities. Therefore it is expected that no people will be adversely affected by noise coming from the site. Impacts on wildlife are expected to be minor and temporary.
- A general contingency and emergency spill response plan is already developed and in place for the Giant Mine site.
- INAC has a health and safety plan for contaminated sites. In addition, all contractors will be required to comply with the NWT Mine Health and Safety Act and Regulations and other applicable permits and legislation.

Supporting Document Q6 provides a preliminary screening of socioeconomic implications of the proposed project. On the basis of the screening, further socioeconomic assessment may be required.

Figure 8.1.1: Giant Mine Remediation Plan Implementation Schedule

Click here to open Figure

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This report, **"Giant Mine Remediation Plan"**, has been prepared by SRK Consulting (Canada) Inc.

Prepared by

ORIGINAL SIGNED AND STAMPED

____

Michael Royle, P.Geo.
Project Manager

Reviewed by

ORIGINAL SIGNED AND STAMPED

____

Daryl Hockley, P.Eng.
Principal

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