



Former Gunnar Mining Limited Site Rehabilitation Project Proposal

By
Saskatchewan Research Council

In collaboration with
(KHS) Environmental Management Group

SRC Publication No. 12194-3E07

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TABLE OF CONTENTS

1. PROJECT DESCRIPTION

- 1.1. The Project
- 1.2. The Site

2. BACKGROUND

- 2.1. The Gunnar Mining Limited Site
 - 2.1.1. Operating History
 - 2.1.2. Open Pit Mine
 - 2.1.3. Underground Mine Development & Operations
 - 2.1.4. Mill
 - 2.1.5. Production
 - 2.1.6. Support Facilities
 - 2.1.7. Closure
- 2.2. Current Disposition of Property
- 2.3. Current Land Tenure

3. THE PROPONENT

4. PROPONENT MANAGEMENT STRUCTURE

5. PROPOSED PROJECT ACTIVITY

6. THE SITE

- 6.1. Location(s)
- 6.2. Regional Socio-Economic Environment
- 6.3. Local Socio-Economic Environment

7. EXISTING/SUPPORTING DOCUMENTATION

- 7.1. The Gunnar Site
 - 7.1.1. *The Gunnar Story*, Canadian Mining Journal, July 1963
 - 7.1.2. National Uranium Tailings Program (NUTP), 1986
 - 7.1.3. *Gunnar Site Characterization and Remedial Options Review*, Saskatchewan Research Council, January 2005
 - 7.1.4. *Gunnar Site Characterization – 2004 & 2005 Aquatic Investigations*, CanNorth, March 2006
 - 7.1.5. *Screening Level Human Health & Ecological Risk Assessment of the Gunnar Site*, SENES, March 2006

8. CURRENT SITE DESCRIPTION

- 8.1. The Gunnar Site
 - 8.1.1. Existing Facilities & Infrastructure
 - 8.1.2. Waste Rock

- 8.1.3. Tailings
- 8.1.4. Flooded Pit
- 8.1.5. Site Investigations
- 8.1.6. Gamma Radiation
- 8.1.7. Ambient Radon
- 8.1.8. Ecological and Human Health Risk Assessment

9. INVENTORY OF RESIDENT NUCLEAR SUBSTANCES

- 9.1. Waste Rock
- 9.2. Tailings

10. SITE SECURITY

11. SITE HEALTH AND SAFETY CONSIDERATIONS

- 11.1. Risk Assessment
- 11.2. Safety

12. PUBLIC CONSULTATIONS TO DATE

13. PUBLIC INVOLVEMENT PLAN

- 13.1. Introduction
- 13.2. Guiding Principles
- 13.3. Identification of Stakeholders
- 13.4. Advisory Forum Consultation Objectives
- 13.5. Public Consultations

14. MONITORING

- 14.1. Radiological
 - 14.1.1. Current
 - 14.1.2. Proposed On-Going
- 14.2. Environmental
 - 14.2.1. Current
 - 14.2.2. On-Going Monitoring

15. FINANCIAL CONSIDERATIONS

- 15.1. Project Funding
- 15.2. Financial Assurance

16. REFERENCES

Appendix A

Gunnar Site Characterization and Remedial Options Review, Saskatchewan
Research Council, January 2005

Appendix B

Gunnar Site Characterization – 2004 & 2005 Aquatic Investigations, CanNorth,
March 2006

Appendix C

Screening Level Human Health & Ecological Risk Assessment of the Gunnar Site,
SENES, March 2006

Appendix D

Saskatchewan Environment “Miscellaneous Use Permit” #602984(R), dated 23
March 2007

Appendix E

Saskatchewan Industry and Resources Letter, dated 03 April 2007

1. PROJECT PROPOSAL

1.1. The Project

This document has been prepared by the Saskatchewan Research Council (on behalf of Saskatchewan Industry and Resources, Government of Saskatchewan), as a project proposal for the rehabilitation of the former Gunnar Mines Limited site located at approximately at 59° 23' N, 108° 53' W, midway along the north shore of Lake Athabasca in the northwest corner of Saskatchewan, approximately 725 kilometres north of Prince Albert.

Generally, subject to regulatory approvals, it is anticipated that the physical project will consist of:

- Demolition of existing building, facilities and structures;
- Appropriate disposal of materials resulting from demolition;
- Installation of an appropriate cover on all or a portion of the exposed mill tailings;
- Rehabilitation of the existing waste rock piles;
- Rehabilitation of additional risk(s) as warranted;
- General site clean-up;
- Re-vegetation of areas of the rehabilitated site as required; and
- Appropriate monitoring during and after rehabilitation.

The Government of Saskatchewan and the Government of Canada have signed a Memorandum of Agreement (MOA) to effect timely and effective action be taken to address the current environmental conditions of the Cold War Legacy Uranium Mine and Mill Sites in Northern Saskatchewan, which includes the rehabilitation of the former Gunnar site. Under the MOA, Saskatchewan Industry and Resources (SIR) has been assigned the responsibility to ensure that the project is carried out on behalf of the two governments. SIR has signed a formal contract with the Saskatchewan Research Council (SRC), a wholly owned Crown Corporation under the responsibility of the Minister of SIR, to retain the SRC as project manager and designated agent to manage and perform the required environmental assessment requirements and rehabilitation activities.

1.2. The Site

Gunnar Mining Limited was incorporated as Gunnar Gold Mines Limited in October 1933 with an Ontario Charter. As such, it operated a gold mine at Beresford Lake, Manitoba from 1933 until 1942.

The Gunnar uranium deposit in northern Saskatchewan was discovered in July 1952 when two prospectors identified frost-heaved boulders in a muskeg area close to the shores of St. Mary's Channel, Lake Athabasca. After staking and initial prospecting, 11

inclined drill holes were put down and indicated a widespread pitchblende-bearing zone in the bedrock immediately beneath the muskeg. The deposit was subsequently delineated by an additional 179 vertical holes drilled on a 75-foot grid pattern for a total of approximately 70,000 feet. This drill program outlined an ore body of approximately 450 ft in diameter, plunging from surface to a depth of approximately 1,000 ft below the surface elevation of nearby Lake Athabasca. The ore body was originally estimated to contain 4 million tons of ore grading 0.19 – 0.20 % U₃O₈.

With the discovery of the Beaverlodge area uranium deposit and with the company's activities extending to uranium and chromium, in addition to gold, the name of the company was thought to be misleading and was changed to Gunnar Mines Limited (Botsford, 1963). On December 1st, 1960, Gunnar Mines Limited and Nesbitt Labine Uranium Mines Limited were amalgamated to become Gunnar Mining Limited.

During operations the Gunnar Mining Limited site consisted of:

- An open pit mine;
- An underground mine;
- A uranium milling facility;
- An acid plant;
- Tailings disposal facilities; and,
- Various additional support facilities including mine dry, geology building, maintenance shops, housing, school, recreation centre, curling rink, etc.

The open pit was 1000 feet (304 m) long, north to south and 800 feet (244 m) wide. The final depth was 380 feet (116 m), which was 360 feet (110 m) below Lake Athabasca surface levels.

Mining of the open pit ceased in 1961, at which time ore feed to the mill was entirely replaced by ore generated from the underground mine.

Preparation of the underground mine began in 1955, although ore from the open pit was the main mill feed until 1959. The first ore was produced from underground in 1957 and between then and 1961 the mill was supplied with a combination of ore from both the open pit and the underground. Underground production was increased, as necessary, until 1961 when the open pit was exhausted and the underground began to supply the entire mill ore feed.

Underground mining of the Gunnar ore body ceased in October 1963 as the ore body was considered depleted.

Mill tailings were originally discharged from the mill at 32% solids through a 1,500 ft. long, 10 in. diameter wooden stave pipe. In total, it has been estimated that the Gunnar Mining Limited mill discharged a total of 4.4 million tonnes of tailings during operations (BBT, 1986).

The tailings and other aqueous wastes were initially discharged into a small lake located 500 m to the north of the mill (Ruggles et al., 1978) that is referred to in historical documentation as either Blair Lake or Mudford Lake. This area is currently referred to as the Gunnar Main Tailings. In 1958, the mill installed a cyclone plant with four sand storage tanks for the production of sand backfill in the underground mine.

The Gunnar Main Tailings basin eventually filled with tailings solids and a small rock outcrop was blasted to allow the tailings to flow from the Main area to a small depression referred to as Gunnar Central Tailings. Once this relatively small basin was filled, the tailings continued to flow downhill, eventually entering Langley Bay, Lake Athabasca. During operations, a sufficient volume of tailings was discharged and allowed to flow into Langley Bay so as to eventually cut Langley Bay into two separate portions: one which is still connected by a narrow channel to Lake Athabasca proper and a smaller 'back bay' which has intermittent connection to Langley Bay itself.

Because of the remote location, the Gunnar site was self-contained and provided housing for all single and married employees. During operations, the site also had its own school (Grade 1-10 with approximately 100 students) a seven bed hospital with a doctor, matron and three registered nurses, a large community centre that included a Hudson's Bay Store, a Post Office, a branch of the Canadian Imperial Bank of Commerce, a coffee shop, dining room, bakery, butcher shop, beauty salon, large auditorium, bowling alley, pool room, games room, lounge, library, club rooms and radio broadcasting room.

The Gunnar site officially closed in 1964 with little or no decommissioning of the facilities.

Shortly thereafter, the blasting of a narrow, relatively shallow trench between the pit and the lake itself breached the narrow bedrock ridge that separated the open pit from Lake Athabasca. As a result, water from Lake Athabasca was allowed to flow directly into the open pit, eventually flooding the underground workings as well as the pit itself. The channel between the lake allowed the free movement of water (and presumably aquatic organisms) between the lake and the flooded pit until 1966 when the channel was blocked by filling it with waste rock.

2. BACKGROUND

2.1. The Gunnar Mining Limited Site

The former Gunnar Mining Limited site is located at approximately 59° 23' N, 108° 53' W midway along the north shore of Lake Athabasca in the northwest corner of Saskatchewan, approximately 725 kilometres north of Prince Albert (see Figure 2.1.1).

Lake Athabasca is the 22nd largest lake in the world (by area) and the eighth largest lake in Canada. It has an estimated surface area of 8,080 km² and a maximum depth of approximately 124 m (Gleick, 1993). Lake Athabasca drains north to the Arctic Ocean via the Slave and MacKenzie Rivers.

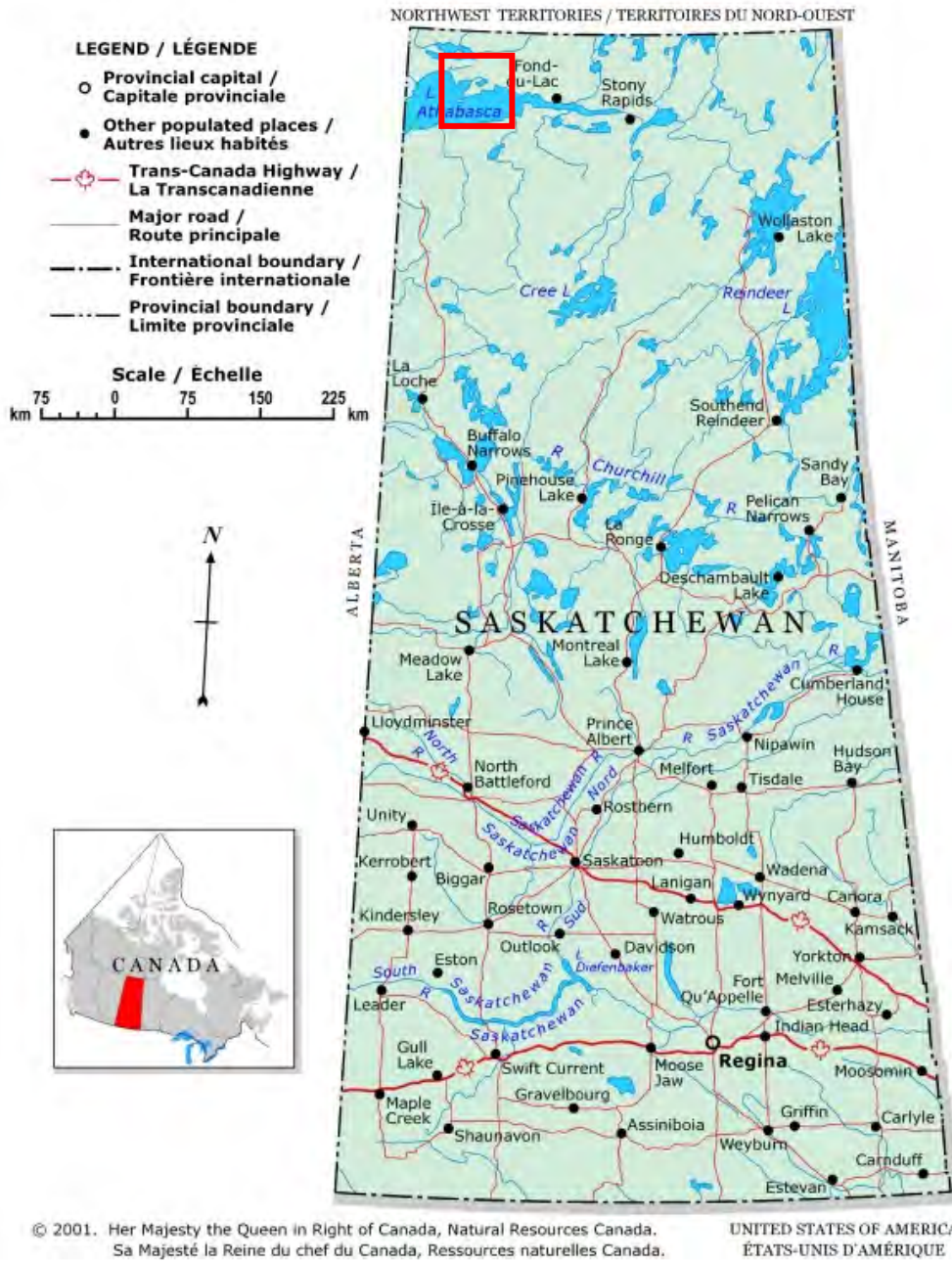
The site is located on the southern tip of the Crackingstone Peninsula approximately 25 kilometres southwest of Uranium City (see Figure 2.1.2). During operations, the site was only accessible by boat/barge in the summer and over the ice in the winter. As well, during operations, Gunnar Mining Limited maintained a small gravel airstrip approximately 3 kilometres north of the mine site. It was used to transport personnel and light freight to and from the site. Most heavy freight was delivered by barge from the railhead at Waterways, Alberta during the summer or open water season. The airstrip now provides air access to a tourist lodge located on an island south of the St. Mary's Channel and south of the mine site itself (see Figure 2.1.3).

2.1.1. Operating History

Gunnar Mining Limited was incorporated as Gunnar Gold Mines Limited in October 1933 with an Ontario Charter. As such, it operated a gold mine at Beresford Lake, Manitoba from 1933 until 1942.

The Gunnar uranium deposit in northern Saskatchewan was discovered in July 1952 when two prospectors identified frost-heaved boulders in a muskeg area close to the shores of St. Mary's Channel, Lake Athabasca. After staking and initial prospecting, 11 inclined drill holes were put down and indicated a widespread pitchblende-bearing zone in the bedrock immediately beneath the muskeg. The deposit was subsequently delineated by an additional 179 vertical holes drilled on a 75-foot grid pattern for a total of approximately 70,000 feet. This drill program outlined an ore body of approximately 450 ft in diameter, plunging from surface to a depth of approximately 1,000 ft below the surface elevation of nearby Lake Athabasca. The ore body was originally estimated to contain 4 million tons of ore grading 0.19 – 0.20 % U₃O₈.

With the discovery of the Beaverlodge area uranium deposit and with the company's activities extending to uranium and chromium, in addition to gold, the name of the company was thought to be misleading and was changed to Gunnar Mines Limited



 *Study Area*

Figure 2.1.1
Gunnar Mining Limited Location



Figure 2.1.2
Gunnar Mining Limited Location



Figure 2.1.3
Gunnar Mining Limited Site

(Botsford, 1963). On December 1st, 1960, Gunnar Mines Limited and Nesbitt Labine Uranium Mines Limited were amalgamated to become Gunnar Mining Limited.

The Gunnar uranium deposit property was comprised of two Development Areas, as defined by the *Saskatchewan Mineral Disposition Regulations*, 1961. The first area contained 35 claims covering 1423 acres, and the second contained 19 claims covering an area of 827 acres.

The Gunnar ore body was a saucer-like ore body that could, at least initially, be mined by open pit without going underground. In addition the deposit was 25 kilometres from Uranium City and, therefore, geographically isolated enough to justify construction of its own milling facility. On March 11, 1954, a contract was signed which obligated Gunnar to supply 8,100,000 pounds of U₃O₈ to Eldorado Mining and Refining Ltd. between 1955 and 1960 at a specified price. As required by the Atomic Energy Control Board, all sales were to be made to Eldorado Mining and Refining Ltd. and only Eldorado, which then signed an identical contract with the US Atomic Energy Commission for sale of product (Bothwell, 1984).

Mining Permits, MP2/54 (issued September 16, 1954 by the Atomic Energy Control Board) and MP 2/57, (issued February 1, 1957 by the Atomic Energy Control Board) specified that Gunnar Mines Limited was authorized:

“to carry on development, mining, milling and concentrating operations on the property hereunder mentioned and to ship ore and/or concentrates there from to Eldorado Mining and Refining Limited (hereinafter called “Eldorado”) in accordance with such arrangements as may from time to time be in effect between you and Eldorado.” (MP2/54, 1954, MP2/57, 1957)

Early drilling results suggested that the ore body was pinching out at approximately 450 ft and the production plan completed in 1953 assumed that an open pit mine would provide enough feed to supply a 750-ton per day mill. However, additional drilling proved that the ore body extended deeper than anticipated warranting expansion of the production facility. A revised plan was developed that increased the milling capacity from 750 to 1250 tons per day. To meet the targeted production date, it became evident that overburden removal from the open pit and rock removal required for construction of the mill, acids plant and powerhouse sites would have to commence in early 1954, prior to the date that the required heavy equipment could be brought in by barge.

2.1.2. Open Pit Mine

The open pit was 1000 feet (304 m) long, north to south, and 800 feet (244 m) wide. The final depth was 380 feet (116 m), which was 360 feet (110 m) below Lake Athabasca surface levels (see Figure 2.1.4). The upper walls of the pit were generally mined in granite gneiss.



Figure 2.1.4
Gunnar Mining Ltd. Open Pit (Circa 1962)

The north wall of the pit followed closely the footwall of the ore body resulting in the bulk of waste rock being produced from a large crescent-shaped mass in the south end of the pit decreasing in size with depth. The rock was mined in 30-foot vertical benches with a 21-foot berm on each bench. As a result, the wall angle was approximately 55° except where modified by haulage roads.

This pit design required that a substantial tonnage of ore in the south wall of the pit be lost to pit mining and left for recovery from underground. When experience proved the walls to be very competent, particularly on the south side of the pit, the design was modified to permit removal of the berms on this side on the lowest five benches of the pit. As a consequence, the south wall of the pit was left as a vertical face for a height of

approximately 150 feet. This modification, plus the removal of a bottom bench below original design specifications, improved the overall waste:ore ratio from 2.48:1 to 1.83:1.

The open pit was located very close to the shores of Lake Athabasca. The rim of the pit was separated from Lake Athabasca by a bedrock ridge approximately 2m wide and 6 m long. In spite of this close proximity to the lake and the fact that the pit extended to a depth of approximately 116 m, there was little subsurface flow from the lake to the pit or to the underground workings of the mine. During 1963, when underground development below the pit bottom essentially reached the maximum depth, pumping from underground averaged only 75 gallons per minute, which included the ingress of water from backfilling with tailings (Botsford, 1963).

Mining of the open pit ceased in 1961, at which time ore feed to the mill was entirely replaced by ore generated from the underground mine.

2.1.3. Underground Mine Development & Operations

Preparation of the underground mine began in 1955, although ore from the open pit was the main mill feed until 1959. Between 1959 and 1961 the mill was supplied with a combination of ore from both the open pit and the underground.

Surface rock excavation for the head frame, bin house, shaft collar and temporary hoist room was completed in the summer of 1955. The shaft was then sunk by Gunnar mine crews to open eight underground levels. It was allowed to fill with water while the permanent surface facilities were completed. Lateral underground development was not started until June 1957.

The first ore was produced from underground in 1957 and production increased, as necessary, until 1961 when the open pit was exhausted and the underground began to supply the entire mill ore feed.

Some historical documentation indicates the existence of a raise in addition to the main shaft while other documentation shows a raise only into the bottom of the now flooded pit. Additional investigations are required to confirm the exact location of the raise if it exists and where it came to surface.

Underground mining of the Gunnar ore body ceased in October 1963 as the ore body was considered depleted.

2.1.4. Mill

Design of Gunnar's 1250-ton a day mill began in October 1953 and the ordering of structural steel and major equipment was essentially completed by August 1954. Excavation, concrete work, steel erection, building siding and roofing, and equipment installation were completed by August 23rd 1955 and the mill commenced production on that date. The first drum of precipitate was produced on September 9, 1955.

The design of the mill building and the acid plant site provided for the possibility of expansion and the installation of additional equipment was completed in March 1957. Major items of this expansion included installation of a 42-inch gyratory crusher, two leach agitators, three string discharge drum filters, an Eimco precoat drum filter and the construction of an additional acid plant at a 65 ton per day capacity. These additions increased the mill's initial rated capacity of 1250 tons per day to 1650 tons per day. This capacity itself was exceeded with the mill achieving 2000 tons of ore processed per day in July 1958 and continued at that rate until at least July 1963.

The mill treatment plant circuit was divided into two separate production lines of the same capacity from the evenly split rod-mill discharge to the packing of the precipitate. This allowed metallurgical information to be obtained on a plant-scale basis and also provided enough flexibility to maintain a high percentage of production in the event of a serious breakdown, lack of material or other unforeseen causes. The following provides a brief discussion of one of the two separate circuits. Figure 2.1.5 provides a schematic of the milling circuit at the Gunnar Mining Limited site.

The ball-mill discharge from crushing was maintained at 69% solids, classifier overflow at 39% solids and 45% minus 200 mesh, which was then discharged to a splitter box feeding the thickeners.

Thickening: There were two 50 ft. diameter by 23 ft. high, three-compartment, steel tank thickeners. The thickener overflow from both production lines was collected in a 20 ft. diameter, 30 ft. high steel tank and returned to the grinding circuit. Backwash solution from the ion exchange circuit was added as required. Thickener underflow, at 60% solids, was discharged by means of suction pumps and no flocculants were used in the thickener feed.

Leaching: Moved by gravity, the thickened pulp flowed to a six-inch airlift and was elevated to the No. 1 leaching agitator. This leaching feed was automatically sampled and the pulp flowed in a series through seven wood stave leaching tanks with stainless steel agitators. Six of the leach tanks were 20 ft. in diameter by 25 ft. high and one was 20 ft. in diameter by 20 ft. high. Approximately 70 cubic feet per minute of air was consumed in each leach tank with agitation being provided by a central airlift and two air jets on the agitator rakes. The addition of sulphuric acid to the No. 1 leach agitator was automatically controlled to maintain a pH of 1.7 and in all other leach tanks, pH was recorded on a strip chart with additional acid added manually when required to maintain pH 1.7.

The 93% sulphuric acid was delivered to each leach tank by gravity flow from a header system in which manual valves made of alloy were used. An oxidizing agent in the form of a 25% solution of sodium chlorate was added manually to the No. 1 leach tank in amounts sufficient to maintain a slight excess of oxidant. Retention time in the leaching circuit totalled 24 hours.

Filtration: The leached pulp was drawn from the bottom of the seventh leach tank, which served as a surge tank, and was pumped to a four-way splitter box above the primary acid filters. Two-stage filtration was completed using four string-discharge drum filters, each equipped with a wooden deck and 316 stainless steel ends, and four string discharge filters with a steel drum covered with Linatex. A filter aid in the form of ¼ % solution of ‘jaguar’ gum was added to the feed supplied to both filtration stages.

The primary filter cake was washed with water and then re-pulped to 57% solids (with water) and then pumped to a four-way splitter box over the secondary filters. The secondary cake discharge was again re-pulped with water to 57% solids and flowed to the tailings disposal tank. The combined primary and secondary filtrate was then pumped to the clarification thickener.

Clarification: In the first stage of filtrate clarification, a 30 ft. diameter by 20 ft. high wood stave thickener with stainless steel mechanisms was used. A ½ % solution of glue was added as a flocculant to the thickener feed and the settled solution was drawn from the thickener once per day and returned to the leach circuit. The overflow from one production line was passed through a 5 by 7 ft. leaf clarifier with 50 leaves and employing ‘supercel’ as a precoat material. The other production line employed an 8 ft. diameter by 14 ft. long, 60% submergence precoat drum filter as a clarifier and supercel was used as the precoat material. The clarified pregnant solution from each clarifier was pumped to a 30 ft. diameter by 20 ft. high wooden stave storage tank where the pH was automatically adjusted to 1.7 before entering the ion-exchange circuit.

Ion-exchange: Each ion-exchange production line consisted of four 7 ft. by 14 ft. columns containing 285 ft.³ of ‘IRA 400’ resin. The pregnant solution passed down flow through two of the columns in series where the uranium was selectively absorbed by the resin and exchanged with chloride ions already adsorbed to the resin. The common impurities, with the exception of ferric iron, were not adsorbed and passed through the resin bed. The discharge or effluent from the second column contained all the impurities as well as chloride ions that were replaced by uranium and this barren material was discharged to the tailings tank. When the first column had adsorbed as much uranium as possible, the adsorption phase was stopped and the column was taken from the circuit for removal of the uranium by elution. The second column in the series became the first column and a fresh column was brought on stream (as the second column) and the new adsorption phase started.

The fully adsorbed column was then placed in a two-stage elution process. In the first stage, a recycle solution composed of 1 Normal sodium chloride and 0.1 Normal sulphuric acid, was passed through the resin. In the passage, the chloride ions in the recycle solution were adsorbed on the resin and replaced the uranium. The effluent carried five times the uranium concentration of the pregnant solution and was sent to precipitation.

In the second stage of the elution process, the small amount of uranium remaining on the resin was removed by a fresh brine solution consisting of a 1 Normal sodium chloride

and 0.1 Normal sulphuric acid mixture. The effluent from this stage was then sent to a 16 ft. diameter by 20 ft. high wood stave storage tank to be used as recycle solution.

Precipitation: Precipitation was carried out in two 16 ft. diameter by 20 ft. high wood stave tanks equipped with double paddle agitators. Magnesia ground to 90% minus 200 mesh was slurried with water to 25% solids and then circulated to the precipitation tanks on an hourly basis. The batch stage was completed at a neutral pH and was completed in eight hours after which the precipitated uranium was delivered to the precipitation filters.

Product Filtration: Filtration of the precipitate was accomplished on both production lines by the use of three 36-inch wash type, plate and frame filter presses. The yellowcake was washed with water to bring impurities below contracted specifications. After a 60-minute treatment with warm, low-pressure air blown through, the yellowcake, which still contained 50 to 60% moisture, was discharged to a receiving hopper. A batch filtration cycle was completed in seven to nine hours.

The barren filtrate was returned to a pump box where salt was added manually to obtain a 1 Normal sodium chloride solution that was then pumped to a make-up tank identical to the precipitation tank. In this tank, 93% sulphuric acid was added manually to produce a 0.1 Normal acid solution. This salt-sulphuric acid solution, referred to as fresh brine, was then discharged to a 20 x 20 ft. wood stave storage tank for further use in the ion-exchange elution.

Drying and Packaging: From the receiving hopper, the yellowcake was deposited through a stainless steel chute to a dryer beneath the filter. The moisture content was reduced to 6% in a steam-jacketed, 10 ft. diameter, revolving sweep dryer for eight hours. The dried precipitate was then elevated pneumatically with a fan to a 6 ft. tall, 125 ft³ bag filter storage hopper. From storage, a drum load of precipitate was delivered by a vibrating feeder to the weigh hopper with attached scale and placed in drums with the dust created in the packing cabinet being removed and recovered.

The steel drums used to ship the product to Edmonton had a capacity of 25 gallons. Packed drums were flown out to Edmonton by either Eldorado Aviation Limited or Gunnar Nesbitt Aviation Limited.

Chemical Mixing: A chemical mixing area inside the mill building housed the equipment necessary for the preparation and storing of the jaguar and glue solutions used in the milling process. The dissolution and storage tanks for these chemicals were wooden stave type equipped with mixers. The chemicals were delivered to various areas of the mill by pumping them through a header system.

Sodium chlorate solutions were prepared in a separate building with the use of a concrete dissolving pit, aluminum storage tanks and pumps to deliver the solution through the header system to the leach tanks.

Tailings Disposal: Tailings were collected in a 20 ft. diameter, 7.5 ft. high wooden stave tank equipped with a single paddle mixer and were disposed of as 32% solids through a 1,500 ft. long, 10 in. diameter wooden stave pipe. In 1958, the mill installed a cyclone plant in order to use a portion of the tailings as sand backfill for the underground mine.

Acid Plant: Sulphuric acid was manufactured on site by the conventional contact process by means of a vanadium mass catalyst. Two plants rated at 100 tons and 64 tons per day of 100% sulphuric acid were built. The plants were similar in design but had one common section located in the 100-ton plant for the melting and filtering of sulphur and supplied both plants with molten elemental sulphur. The elemental sulphur used in the plants was transported by barge to the site from southern Alberta.

The acid produced by the plants was stored in two 32 ft. high 40 ft. diameter insulated steel tanks located behind the mill. Each tank had a capacity of 1,500 tons and acid flowed to the mill header system by gravity.

Laboratories: The analytical laboratories consisted of a floor area of approximately 3,000 ft.² and were located in the front of the mill, and included room for mill test work as well as an instrument repair shop.

Freshwater Intake: The freshwater supply was taken directly from Lake Athabasca and pumped to a 200,000 gal. tank located on the hill immediately behind the mill. During 1963, the daily requirement for water was approximately 3,200,000 gallons.

Fuel: Approximately 11,000 tons of bulk petroleum per year were delivered during the open water season to the Gunnar Mining Limited site in order to fulfill the annual requirements for heavy diesel fuel, light diesel oil and gasoline. In total, the site had storage capacity for 1,890,000 gallons of fuel.

Power Generation: All the required power generation for the Gunnar facilities was produced in the power house which measured 104 by 202 ft. and contained seven 1200 hp diesel engines direct-coupled to 2300 volt, 60 cycle, 3-phase generators, and all high and low pressure compressor and vacuum pumps required to operate the mill.

2.1.5. Production

The following table provides a summary of available data for production at the Gunnar Mining Limited facility. During its peak year milling capacity was increased to 2,000 tons of ore per day in order to handle the ore from both the open pit and the underground mine. The average ore recovery during 1961 was 95.5% producing a uranium precipitate which consisted of 76% U₃O₈.

Production Data – Gunnar Mining Limited

(Source: Company Annual Reports)

<i>Year</i>	<i>Daily Production (Tons of Ore Treated)</i>	<i>Mill-Head Grade (% U₃O₈)</i>	<i>Annual Production (Tons of Ore)</i>
1956	-	0.191	451,632
1957	1.647	0.178	601,262
1958	1.95	0.188	711,298
1959	1.975 (approx.)	0.184	719,785 (approx.)
1960	1.942	0.185	710,785
1961	2.039	-	744,227
1962	2.155	-	786,481
1963	1.848	-	769,000

2.1.6. Support Facilities

As a result of the remote location, the Gunnar site was self-contained and provided housing for all single and married employees. During operations, the site also had its own school (Grade 1-10 with approximately 100 students) a seven bed hospital with a doctor, matron and three registered nurses, a large community centre that included a Hudson’s Bay Store, a Post Office, a branch of the Canadian Imperial Bank of Commerce, a coffee shop, dining room, bakery, butcher shop, beauty salon, large auditorium, bowling alley, pool room, games room, lounge, library, club rooms and radio broadcasting room.

2.1.7. Closure

The Gunnar site officially closed in 1964 with little or no decommissioning of the facilities.

Shortly thereafter, the blasting of a narrow, relatively shallow trench between the pit and the lake itself breached the narrow bedrock ridge that separated the open pit from Lake Athabasca. As a result, water from Lake Athabasca was allowed to flow directly into the open pit, eventually flooding the underground workings as well as the pit itself. The channel to the lake allowed the free movement of water (and presumably aquatic organisms) between the lake and the flooded pit until 1966 when the channel was blocked by filling it with waste rock.

In 1971, the Athabasca Native Fisherman’s Co-operative established and began the operation of a fish processing facility at the former Gunnar Mining Limited primarily using the warehouse building near the main dock (Figure 8.1.1). In 1975, the facility was taken over by the Freshwater Fish Marketing Corporation, which continued to operate the plant until the end of 1980. During the following year, fish were dressed at the Gunnar site but were then flown to out to other plants for processing. During the entire time the processing plant was in operation, including 1981, wash water used in the fish processing

plant and offal from the processing and dressing operations were disposed of in the flooded pit (Tones, 1982).



Figure 2.1.6
Gunnar Site (circa 2004)

2.2. Current Disposition of Property

In 2001, the Contaminated Lands Evaluation and Assessment Network (CLEAN) Program was established by the Canadian Nuclear Safety Commission (CNSC) to deal with sites not previously licensed by the *Atomic Energy Control Act*, but which now must be licensed pursuant to the *Nuclear Safety and Control Act* (NSCA) (CNSC, 2001). One category of such sites includes tailings management sites resulting from the former operation of uranium mines. Documentation prepared by CNSC staff states:

“some of these tailings management sites were previously exempted from licensing because they are in the care and control of provincial or federal government agencies, and the Atomic Energy Control Act was not binding on the Crown. Others were not licensed because their operational lives ended before the Atomic Energy Control Board began exerting regulatory control on the uranium mining industry.” (CNSC, 2001).

CNSC staff also stated that the Gunnar site is considered abandoned and its care and control has reverted to the Province of Saskatchewan (CNSC, 2001). Based on this,

CNSC staff requested that the Province of Saskatchewan bring a license application to the Commission or a Designated Officer for decision.

2.3. Current Land Tenure

In 2006, Saskatchewan Environment (SE) took out a “Miscellaneous Use Permit” (MUP) on the Gunnar site. The intent of the MUP was to flag the area in the SE Lands Branch record system so that other parts of SE would not issue any land disposition in the area.

Appendix D includes a copy of Miscellaneous Use Permit #602984(R) for the Gunnar site. It is a yearly permit issued automatically every year.

3. THE PROPONENT

The Saskatchewan Research Council (SRC), on behalf of Natural Resources Canada and Saskatchewan Industry and Resources, is the proponent for the former Gunnar Mining Limited site rehabilitation project.

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4. PROPONENT MANAGEMENT STRUCTURE

Management of the Gunnar Mining Limited site rehabilitation project is the responsibility of the Project Manager, Environment & Forestry Division, within SRC.

5. PROPOSED PROJECT ACTIVITY

Generally, subject to regulatory approvals, it is anticipated that the physical project will consist of:

- Demolition of existing building, facilities and structures;
- Appropriate disposal of materials resulting from demolition;
- Installation of an appropriate cover on all or a portion of the exposed mill tailings;
- Rehabilitation of the existing waste rock piles;
- Rehabilitation of additional risk(s) as warranted;
- General site clean-up;
- Re-vegetation of areas of the rehabilitated site as required; and
- Appropriate monitoring during and after rehabilitation.

The proposed project will consist of the following activities:

1. Prepare *Former Gunnar Mining Limited Site Rehabilitation Project Proposal*.
2. Submit *Former Gunnar Mining Limited Site Rehabilitation Project Proposal* to Saskatchewan Environment, Environmental Assessment Branch for decision as to the applicability of the Environmental Assessment Act.
3. Submit *Former Gunnar Mining Limited Site Rehabilitation Project Proposal* to the Canadian Environmental Assessment Agency for decision as to the applicability of the Canadian Environmental Assessment Act.
4. Submit *Former Gunnar Mining Limited Site Rehabilitation Project Proposal* to the Canadian Nuclear Safety Commission for decision as to the applicability of the Nuclear Safety and Control Act.
5. Complete site characterization investigations as required to prepare a final rehabilitation plan for the former Gunnar Mining Limited site.
6. Complete a detailed analysis of the ecological and/or public safety risks posed by the former Gunnar Mining Limited site.
7. Identify and assess reasonable options to reduce the risks identified.
8. Conduct public and stakeholder consultations regarding potential options for the rehabilitation of the former Gunnar Mining Ltd. site.
9. Prepare *Former Gunnar Mining Limited Site Final Rehabilitation Plan*.

10. Submit *Former Gunnar Mining Limited Site Final Rehabilitation Plan* to appropriate federal and provincial government regulatory agencies for review and approvals.
11. Acquire all required federal and provincial permits, licenses and/or approvals required to conduct the rehabilitation activities identified in the *Former Gunnar Mining Limited Site Final Rehabilitation Plan*.
12. Conduct rehabilitation activities identified in the *Former Gunnar Mining Limited Site Final Rehabilitation Plan* in a manner that meets or exceeds the requirements identified in the various federal and provincial permits, licenses and/or approvals received.
13. Conduct post rehabilitation monitoring as required to demonstrate success in all identified aspects of the final rehabilitation of the former Gunnar Mining Limited site.

The following discussion has been prepared to provide an explanation of how the proponent intends to proceed with the analysis of existing ecological and/or public safety risks posed by the former Gunnar Mining Limited site, describe methods that will be employed to identify, and assess reasonable options to reduce those risks.

The key elements in the analysis of the significance of existing risk(s) and, if required, to plan and implement a risk management strategy (including a detailed review of potential options to reduce the identified risk[s]) is as follows:

1. Definition of the Entity to be Assessed
2. Familiarization
3. Risk/Hazard Identification
4. Definition of the Scope of Studies Required
5. Significance Analysis
6. Risk Reduction Options Analysis
7. Assessment of Preferred Option Against End-point Criteria/Objectives
8. Risk Treatment
9. Risk Communication

A number of the identified elements are currently underway as part of the initial site characterization work undertaken in 2004, 2005, 2006 and the screening level ecological and human health risk assessment undertaken by SENES Consultants Ltd. (SENES 2005).

The following discussion provides more detail on the various activities anticipated.

1. *Definition of the Entity to be Assessed*

Generally, this element was implemented when the Saskatchewan Research Council completed the initial site characterization and received the SENES Consultants Ltd. report entitled *Screening Level Human Health & Ecological Risk Assessment of the Gunnar Site*, in December 2005. That report identified areas of potential ecological and human health risk and quantified those risks. The identified risks to human health arose when those concentrations were modeled for a theoretical receptor temporarily residing on the site and consuming a significant portion of their diet from fish and water obtained from Langley Bay and/or the Gunnar site itself.

2. *Familiarization/Description*

Familiarity with the system, its environmental and operational context is critically important in the type of investigations being undertaken and rehabilitation options review being undertaken. The required familiarity must be based on a thorough description and understanding of the system under investigation in order to ensure that all individuals (including regulators and members of the public that are unfamiliar with the site) are all on the “same page”.

While a number of individuals from the regulatory agencies may be very familiar with the site and its environment, others involved in the review of past and future investigations may not be as familiar with the area.

3. *Risk/Hazard Identification*

The risk/hazard identification is a structured process that systematically works through the elements of the system or site under investigation in order to identify potential areas of risk and/or potential contaminants of concern and their source within the identified system.

Essentially, the preliminary steps in this activity were undertaken during the initial sampling, inspections and risk assessment modeling conducted by SENES Consultants Ltd..

4. *Define the Scope of Any Additional Study(s) Required (Purpose, objective and entities covered)*

The information assembled to date (site characterization and screening level human health and ecological risk assessment) will be reviewed in detail to identify any additional information that may be required to further enhance the information base and to more accurately assess the extent of the risks identified or to more accurately identify and define the source of those risks. The 2007 and 2008 open water season will afford the opportunity to collect additional information if it is deemed necessary.

In addition, the anticipated *Project Specific Guidelines for the Preparation of an Environmental Impact Statement* that will jointly be issued by Saskatchewan Environment, the Canadian Environmental Assessment Agency and the Canadian Nuclear Safety Commission will be reviewed in a timely manner in order to use the 2007 and potentially the 2008 open water season to collect any additional information that may be specified by those agencies.

5. *Significance Analysis*

Once the various studies are completed, the next step will be a correlation of the results of each in order to complete a site (or system) wide identification and characterization of the identified risks. This activity will include:

- The identification of risk(s) contributor(s);
- The identification of end-point criteria/objectives at various points within the system or site; and,
- The identification of potential opportunities (if any) for risk management (reduction) within the system (or site) in order to achieve end-point objectives.

This significance analysis is necessary in order to:

1. Assess the significance of the risk(s) identified within the system based on the study results;
2. To assess trends within the system;
3. Assess the significance of the trends in relation to the risk(s) to the ecosystem and to human health;
4. Assess the need to extend the ecological and human health risk assessment beyond the site (i.e. to Lake Athabasca proper).
5. Assess the need to examine potential options for additional remediation to further reduce any identified risk;
6. Assemble a detailed list of reasonable remediation options to reduce identified risk(s);
7. Provide recommendations on a formalized method to review and screen potential options; and,
8. Provide recommendations on which of the identified options will be subjected to a more detailed and rigorous engineering and feasibility investigation (options short list).

The successful implementation of the listed activities requires correlation of as much relevant and timely information as possible about the entire system under study. For this reason, the activities listed cannot be initiated until the results from all of the various studies described above are received.

Formally discussing the results with the appropriate regulatory agencies, stakeholders and the public of Uranium City will be undertaken at this point.

6. Risk Reduction Options Analysis

Based on the results of the above discussions and a technical assessment of the issues within the significance analysis report, the screening of potential options short list will be conducted under the broad principles discussed below. The process will:

- a) Involve a detailed knowledge of the relevant factors.
- b) Involve multidisciplinary input.
- c) Address the full life cycle of all interacting components.
- d) Identify work and costs versus time for each option.
- e) Include an assessment of the probability of success.

The most significant aspect of the options analysis will be to ensure that the process fully reveals and considers all risk/hazards and provides a basis for judging whether a proposed option addresses the identified risk/hazards appropriately; does not result in unacceptable secondary impacts; and, can be successfully concluded within a reasonable timeframe and budget.

The screening of potential options will employ a “Risk Based Decision Making Process”. This method of screening options has been adopted by various jurisdictions as it utilizes a “Geotechnical, Hydrological, Environmental and Economic Rating Matrix” to help focus the complex evaluation of technical and economical options for remediation.

The primary consideration related to rehabilitation of the Gunnar site is to ensure, to the maximum extent possible, that the social, health and environmental impacts of the site are limited where and when reasonable. In particular the following guidelines must be considered:

- Contaminant releases to the environment from the rehabilitated site should be as low as reasonably achievable; and,
- Reliance on active corporate or institutional control measures in the medium and long-term should be minimized.

That is to say, options that rely on passive maintenance features, either natural or engineered, should be encouraged and options that require frequent future human interventions should be minimized.

All of this must be achieved in a manner that is cost effective and consistent with the existing environment at the site.

In order to assist in a comparison of the options, an *Options Scoring Matrix* will be created for each option considered (example provided at the end of this section) based on the results of the studies currently underway in order to accommodate site-specific technical and environmental information. Each option will be ‘scored’ against a standardized set of important technical and economical risk factors.

For each option considered, a ‘ranking’ or a ‘weighted score’ between 0 and 4 is assigned to each critical factor. Application of ranking score is based on technical assessment of each option and how it affects the various risk factors. The score for each factor is generated by applying professional judgment regarding the “Rank “ of each factor against the “Balance of Probabilities” for each potential response of the option under consideration. Consequently, this simple quantifiable assessment provides not only a generic comparison of each option under consideration by way of their total score, but it also allows a comparison of the individual risk factor scores. This is helpful when comparing the sensitivity of the various options to their particular risk factors and circumstances.

To a large extent, assigning of the ranking score is subjective, however the system is transparent and allows reviewers to follow the decision making process utilized during the assessment.

After each option is assessed, they are ranked in order of the most desirable to least desirable. Ranking is a simple ordered list based on the individual scores of each option assessed and indicates the relative desirability of the option.

Each option must be technically, economically and socially feasible, with a regular and critical review to reflect changing circumstances. In addition, financial cost estimates should be reviewed regularly to reflect changing circumstances.

The preferred option must be amenable to a reasonable level of monitoring in order to verify performance.

The methods, procedures and criteria employed in arriving at the recommended ‘preferred option’ must be clearly and concisely documented in order to provide a ‘transparent’ view of the process to the regulatory agencies, other stakeholders and potentially to concerned members of the public.

The process described has been developed in order to establish procedures that allow for an economic evaluation of different remediation options while taking into consideration the CNSC Regulatory Policy P-242, “Considering Cost-benefit Information”.

**Example of a Scoring Matrix for Further Remediation Options
 at the Gunnar Site**

Option: _____

Risk Factors¹	Rank					Factor Score
	0 <i>Very poor</i>	1 <i>Poor</i>	2 <i>Moderate</i>	3 <i>Good</i>	4 <i>Excellent</i>	
<i>Geotechnical considerations</i>						
<i>Hydrogeological considerations</i>						
<i>Surface hydrological considerations</i>						
<i>Potential to improved aquatic environment within Langley Bay watershed</i> <ul style="list-style-type: none"> - <i>Water quality</i> - <i>Sediment quality</i> - <i>Benthic community</i> - <i>Fisheries</i> 						
<i>Potential to improve terrestrial environment within identified water shed</i>						
<i>Potential to reduce risk to specific receptor</i>						
<i>Potential to reduce risk to Gunnar site receptor</i>						
<i>Public safety (physical attributes of options)</i>						
<i>OH&S during implementation of option</i>						
<i>Implementation timelines</i>						
<i>Implementation costs</i>						
<i>Ability to monitor improvements</i>						
<i>Ease of altering if required</i>						
<i>Future burden (Passive vs. active maintenance)</i>						
<i>Risk of failure</i> <ul style="list-style-type: none"> - <i>Physical failure</i> - <i>Biological failure</i> - <i>Regulatory failure</i> - <i>Economic failure (cost)</i> - <i>Social failure (public rejection)</i> 						
<i>Public preference</i>						
<i>Others?</i>						
Total Score						

The list of Risk Factors will be developed based on available information. As a result, the final matrix used may include additional criteria.

7. Assessment of Preferred Option Against End-point Criteria/Objectives

The theoretical results of implementing the preferred option will then be estimated using established and appropriate diagnostic tools (modelling, qualified professional judgement, etc.) to ensure that implementation of the preferred option will achieve the previously established end-point criteria/objective. If the end-point criteria/objectives will not be met, the sensitivity of the results to changes in conservative assumptions will be tested, the identification of potential additional risk management measures will be reviewed and the risk/hazard identification and analysis will be repeated.

If the assessment indicates that the end-point criteria/objectives will be met by implementing the preferred option, a recommendation for implementation of that option or options will be made and the *Former Gunnar Mining Limited Site Final Rehabilitation Plan* will be finalized.

The deliverable from this activity will be a *Former Gunnar Mining Limited Site Final Rehabilitation Plan (the Plan)*. The *Plan* may include a recommendation on the implementation of a ‘preferred option’ that entails further active remediation of a particular aspect of the site (i.e building demolition and appropriate disposal). On the other hand, the ‘preferred option’ for a different aspect of the site risk may be to allow the natural attenuation of contaminants of concern to continue as is, if the analysis shows that to be the most viable option.

An additional component of the *Former Gunnar Mining Limited Site Final Rehabilitation Plan* will be the development of an ongoing risk auditing/monitoring program. That program will be designed with sufficient rigour so as to identify statistically significant changes in the risk profile at the site. The *Former Gunnar Mining Limited Site Final Rehabilitation Plan* will also propose a schedule for the regular review of the plan itself and a framework under which changes in the Plan will be made. This may include revisiting earlier analytical steps and adjusting activities at the site as changes occur and new information and understanding becomes available.

It is anticipated that the *Former Gunnar Mining Limited Site Final Rehabilitation Plan* will be completed and submitted to appropriate regulatory agencies in order to acquire any necessary permits, licenses and/or approvals. As it is anticipated that the plan will include recommendations for the physical remediation of one or more aspects of the former Gunnar Mining Limited site, it is anticipated that an application to the Canadian Nuclear Safety Commission and Saskatchewan Environment will be required to undertake the required work.

8. Risk Treatment

Once approval of the *Former Gunnar Mining Limited Site Final Rehabilitation Plan* and any associated remediation activities is received from both the Canadian Nuclear Safety Commission and Saskatchewan Environment, the required activities will be undertaken

as soon as practically possible. The proponent will also implement the associated monitoring program at that time.

9. Risk Communication

Since 2005, the Saskatchewan Research Council has made significant effort to ensure that all of the activities undertaken at the former Gunnar Mining Limited site have been communicated to the public in a forum that encourages public feedback.

This has included annual public meetings held in Uranium City. Each of these meetings has included discussion of the current activities being undertaken at the site and, in all instances; the meetings have included representatives of the Environmental Quality Committee (EQC), the Canadian Nuclear Safety Commission and Saskatchewan Environment.

The SRC intends to continue an appropriate level of engaging the public of Uranium City and the Athabasca Sub-Committee of the Northern Saskatchewan Environmental Quality Committee (NSEQC) throughout the activities identified above. This consultation has and will continue to be undertaken in a manner that ensures that the community and NSEQC members are fully informed about activities at the site and in a manner that maximizes the opportunity for feedback on those activities.

Planned 2007 consultation activities include inviting members of the NSEQC to the next public meeting held in Uranium City. In addition, the SRC will invite members of the EQC to a regular Gunnar site inspection tentatively scheduled for September 2007.

6. THE SITE

6.1. Location

The former Gunnar Mining Limited site is located on the southern tip of the Crackingstone Peninsula approximately 25 kilometres southwest of Uranium City (see Figure 2.1.2). As during operations, the site is only accessible by light aircraft or boat/barge in the summer and over the ice in the winter. During operations, Gunnar Mining Limited maintained a small gravel airstrip approximately 3 kilometres north of the mine site. It was used to transport personnel and light freight to and from the site. Most heavy freight was delivered by barge from the railhead at Waterways, Alberta during the summer or open water season. The airstrip now provides air access to a tourist lodge located on an island south of the St. Mary's Channel and south of the mine site itself.

6.2. Regional Socio-Economic Environment

A total of approximately 121 people live within 80 kilometres of the Gunnar Mining Limited site. According to Saskatchewan Northern Municipal Services, as of November 2005, Uranium City, which is located approximately 25 kilometres north of the mine site had a total population of 84 permanent and part-time residents and Camsell Portage, located approximately 37 kilometres northwest of the mine site, had a total population of 37 (Figure 2.1.2). The only access either community has to the Gunnar Mining Limited site is by boat during the open water season or over the ice during the winter as there is no road access from either community.

6.3. Local Socio-Economic Environment

Figure 2.1.2 shows three additional communities: Lorado, Bushell and Eldorado. These three communities no longer exist. As of 2006, there were no permanent residents in the first two and one permanent resident at an outfitting camp at the former Eldorado town site.

7. EXISTING/SUPPORTING DOCUMENTATION

7.1. The Gunnar Site

A number of significant documents have been located or prepared which relate directly to the project and are briefly discussed below.

7.1.1. *The Gunnar Story, Canadian Mining Journal, July 1963*

This article provides an extensive discussion of the Gunnar operation and was written near the end of the operational life of the facility.

7.1.2. *National Uranium Tailings Program (NUTP), 1986*

In 1982, the National Uranium Tailings Program, funded by the Federal Government was formed and given a 5-year mandate with which to investigate the long-term significance of various methods of management of uranium mine tailings in Canada. One part of the program was to carry out a series of laboratory and field investigations that would collect data on fundamental environmental processes to determine the rate at which the processes occur at field sites.

Two field sites were chosen for detailed investigation. The second site was a neutral tailings site called ‘Gunnar’. In October 1984, a contract was awarded to BBT Geotechnical Consultants Ltd. to investigate the Gunnar site. Field activities began in late November 1984, following a period of program design and mobilization. Field investigations were carried out during the winter of 1984 – 85 and into August 1985, at which time the equipment was removed from the site. The objective of the field program was to collect integrated environmental data on the meteorology, tailings solids, tailings groundwater, surface water runoff and biology of the tailings area. As well, several special studies investigated the waste rock area, the presence of discontinuous permafrost in the tailings, and quality control and quality assurance associated with the data collected. These data were compiled, with very little interpretation, into a series of data appendices. A summary report was also produced which provides an overview of the program and data collected.

7.1.3. *Gunnar Site Characterization and Remedial Options Review, Saskatchewan Research Council, January 2005*

The Saskatchewan Research Council (SRC) was retained by the Government of Saskatchewan, as represented by the Ministry of Industry and Resources (SIR), to commence work addressing the environmental and engineering aspects of the Gunnar mine site cleanup.

The initial step in this process was to conduct a current conditions assessment at the former Gunnar site. The initial assessment relied heavily on previously collected data but also collected new data that were targeted at updating the existing database.

The current assessment at the former Gunnar facility involved the following activities:

- Literature review of previous studies;
- Completion of a current building inventory;
- Preparation of options for building demolition;
- Gunnar Pit wall stability assessment and propose long-term alternatives;
- Assessment of tailings chemistry and volumes;
- Identification of remedial alternatives for tailing areas;
- Completion of Radon analyses with Track Etch cups on tailings and waste rock areas;
- Gamma surveying of entire facility including tailings and waste rock areas;
- Water sampling and analyses (Langley Bay and in Lake Athabasca adjacent to site);
- Monitoring levels and sampling of groundwater in tailings area;
- Sediment sampling in both Langley Bay and Lake Athabasca;
- Benthos sampling in both Langley Bay and Lake Athabasca;
- Sampling and analyses of waste rock seeps;
- Identification and assessment of shaft/raise cap; and,
- Identification and inventory of appropriate potential cover material.

The entire SRC report is included as Appendix A

7.1.4. *Gunnar Site Characterization – 2004 & 2005 Aquatic Investigations, CanNorth, March 2006*

As part of the initial characterization of the Gunnar site, the Saskatchewan Research Council (SRC) retained Canada North Environmental Services (CanNorth) to conduct aquatic investigations in areas of Lake Athabasca in September 2004, and follow-up studies in September 2005.

The objective of the aquatic investigations was to gather site-specific information to use in assessing remedial activities in these areas and in the risk assessment. The studies collected information on limnology; water, sediment, plant, and fish chemistry; plankton, benthic macroinvertebrate, and fish communities; and fish habitat from the following study areas in Lake Athabasca: St. Mary's Channel, Zeemel Bay, Langley Bay, Back Bay, and Dixon Bay. In addition, a bathymetric survey was completed in Back Bay, and fish chemistry data was obtained from Gunnar pit.

The entire CanNorth report is included as Appendix B.

7.1.5. *Screening Level Human Health & Ecological Risk Assessment of the Gunnar Site, SENES, March 2006*

Physical, chemical and radiological hazards are known to exist at the Gunnar site. These hazards present ecological and human health risks, but these risks had never been quantified and assessed.

In 2005, the Saskatchewan Research Council commissioned SENES Consultants Ltd. to conduct a screening level ecological and human health risk assessment the results of which were reported upon in *Screening Level Human Health and Ecological Risk Assessment for Gunnar Mine Site*, (SENES 2006).

The results of this assessment are further discussed in section 8 of the SENES report included as Appendix C.

8. CURRENT SITE DESCRIPTION

8.1. The Gunnar Site

8.1.1. Existing Facilities & Infrastructure

The following provides a brief discussion of the facilities that still exist on the former Gunnar Mining Limited site. Figure 8.1.1 is a reproduction of a site map originally produced in 1961 by Gunnar Mining Limited and it identifies buildings still present on the site.

Utilidors

Throughout the site, remnants can be found of above-ground utilidors which appear to have connected all of the buildings on the site. During operations, these would have carried the water, sewage and steam used for heating. A typical utilidor contains 2 - 1" steel piping, 1 - 2" steel piping, 1 - 4" steel piping - all enclosed in a wooden frame insulated with fibreglass insulation and located atop a trestle when required. There is very little underground piping on the site. However, there is an area on the west side of the pit between the mill mechanical shop and the head frame where there is evidence of buried piping, the total extent of which is unknown.

Head Frame

The head frame covers an area 120 ft. by 76 ft. and is on a reinforced-concrete foundation wall pinned to bedrock. It has a total height of 157 ft. and is sheeted with asbestos siding. The entire interior was insulated with spray on asbestos fibre.

The original mine shaft consisted of an 11 ft. 8 in. by 6 ft. cage compartment, a 5 ft. 6 in. by 6 ft. skip compartment and a 5 ft. 6 in. by 6 ft. man way and was sunk to a depth of 1,905 ft. (580 m). Currently, the shaft has a concrete cap of undetermined thickness. Three, 4-inch vents are visible in the cap.

The floor of the head frame and shaft house is covered with old wooden crates and various steel objects, including engine parts. There were no chemicals located in the head frame.

The stairwell, which ascends to the top of the head frame, appeared to be in a relatively safe condition. However, the top level of the head frame is a safety hazard, because the siding has been damaged and there are no railings of any sort. As a result, 2003 site safetying activities cut the stairway to prevent any access to the upper levels of the head frame, and the head frame and shaft house itself were wrapped with 8 ft. high chain link fence to prevent unauthorized entry.

A 76 ft. by 48 ft bin house is incorporated in the head frame and contains two 1,000-ton storage bins. There is no residual ore in either of the bins and very little scrap material scattered on the floor in this area. No chemicals were found.

The shaft house is 76 ft. by 67 ft. and was built within the structural "A" of the head frame.

A short distance to the west is a concrete foundation and various pieces scrap steel. This would appear to have been the location of the hoist.

Mill

The mill is of structural steel construction and is 550 ft. long by 160 ft. wide. The roof ranges between 40 and 80 ft. in height. The mill building was sheeted with asbestos. The main building was not insulated. The laboratory areas, which are on the south side of the main building, were insulated with spray-on asbestos that was then painted.

At some time in the past, perhaps to facilitate previous salvage operations, portions of the mill roof were removed to allow light to enter.

In total, the mill building houses ore bins, the crushing plant, milling circuits and laboratories.

There are two annex buildings that house a 1,000-ton and a 200-ton ore bin and which were fed by and discharged to the mill building proper by conveyers. Both of these buildings are asbestos sheeted. In the 1,000-ton Bin Annex there is a man-way connected to the mill along the conveyor.

Working from west to east through the mill:

Crushing Grinding Area – the crushers have been removed from the crushing plant as have the Marc ball mills. In both areas, large volumes of reinforced concrete remain.

Five, 1,000-ton ore bins are in place, as is the supporting steel for the conveyers under the ore bins. Some salvage has taken place in all of these areas and the stairways are in various stages of disrepair.

Milling Circuit - Four, 50 ft. diameter by 23 ft. deep thickener tanks are supported on steel "I" beam legs approximately 7 ft. off the floor. All the tanks have been previously emptied and hatchways have been left open.

The roof to the northeast of the thickeners has collapsed to some extent; however, the reason is not obvious. In one area, there is a block of concrete approximately 1 cubic yard in size that has fallen to the floor. There is also evidence of other material dropping on the stairwells in the same area.

The majority of the leaching circuit has been salvaged at some point in the past and all that remains are three of the original 14 leach tanks. The three remaining tanks (20 ft. diameter by 20 ft. high) are complete; all that remains of the others are the steel "I" beams which were used as supports.

Fifteen string filter units are located on the upper level at the eastern end of the mill building. There are also four wood-stave clarithickeners, two Whitco Leaf clarifiers and an Eimco precoat filter.

The floor level below the string filters consists of a single wood-stave tank contained within a concrete berm approximately 7 feet deep. There is evidence that water has accumulated within this berm.

There are two 16 ft. by 16 ft. wood-stave surge tanks intact and empty.

The milling circuit then flowed to the south side of the mill building where the ion exchange and precipitation circuits are located. There are 2 brine tanks (20 ft. by 20 ft.), two recycle tanks (16 ft. by 20 ft.) and six ion-exchange columns 7 ft. in diameter and 24 ft. high.

In addition, there are three 3 ft. by 3 ft. filter presses, two 6 ft. diameter 125-cubic-foot hoppers, two 10 ft. diameter dryers and a drum packer.

In the product packaging area, there appeared to be a small amount of residue fines.

A general schematic of the milling circuits is provided in Figure 2.2.1.

Laboratory Areas – In the laboratory area, the concrete floor and the main structural walls appear to have shifted 9 or 10 inches.

The mill also has a cold storage annex on the south east side. A substantial number of salvaged doors and windows are being stored in this area. Within the building, there are also 15 pallets of magnesium oxide in 25 kg bags and 5 pallets of calcium hydroxide also in bags. Both stacks are well under roof, within the confines of the walls and well protected from weather and the environment. They are stacked in a stable manner. In addition, there is a small amount of scrap steel in this cold storage building.

The generating plant (power house), which was a separate building in front of the mill, has been dismantled, and the generating units and building steel have been transported off-site. However, the area remains littered with all of the siding and other material discarded during the salvage operation. As well, the building's concrete floor, with 3 ft. deep by 2 ft. wide concrete trenches in which piping and wiring was run, remains. As a result, the building has a substantial amount of concrete remaining.

Acid Plant

The acid plant is composed of two separate buildings with piping, associated with cooling, occupying the area between the two buildings.

Within the acid plant buildings, there is an accumulation of more than 90 barrels that were used to store the spent vanadium pentoxide pellets used as a catalyst in the process. Many of the barrels have corroded over time and the pellets have spilled onto the floor.

The buildings are constructed of steel with asbestos siding. All of the metal work in the acid plant has corroded to a large extent.

There is a substantial volume of elemental sulphur remaining in an uncovered outdoor storage area to the east of the acid plant. There is evidence that, at some time in the past, the pile started on fire.

There are two 40 ft. diameter by 30 ft. high insulated acid storage tanks located behind and slightly to the west of the acid plant on an adjacent elevated rock outcropping. The tanks are empty and most of the conduit piping has rusted away.

Freshwater Pump House

The freshwater pump house is located west of the head frame on a bedrock outcrop. On one side, it is constructed on the bedrock with log supports on other side (the lakeside). The pump house is of cinderblock construction and has concrete flooring. While the pumps have been removed, there is a quantity of scrap steel, including intake lines that still extend into Lake Athabasca.

In the same area, there is evidence of a propane storage tank building, which, at some point in the past, was entirely dismantled. One propane tank remains and was found to be empty.

North of, and slightly elevated above, the propane tank is a 1,000 gal. (estimated) steel storage tank. The tank is of bolted plate construction and is empty, but appears to have been used for bulk oil storage.

Geology\Mine Dry

The geology/mine dry building is a 150 ft. by 40 ft., two-storey building of structural steel and block construction with fibrous filler used to increase the insulation. The walls are, however, further insulated with what appears to be asbestos that was then painted over. The roof appears to have a spray-on asbestos insulation with no covering. The entire building is sheeted with asbestos siding.

All rooms were checked and no chemicals were found.

There are floor drains and sumps in the concrete ground floor.

There is a large (approx. 300 gal.) asbestos-wrapped hot water heater located in the mine dry area.

Mine Engineering

This building is attached to the maintenance shop with access between the two. It is roughly the same size as the Geology/Mine Dry and is also constructed of structural steel and fibrous blocks, insulation and siding. Partitions for offices were constructed of 2" by 4" lumber and gyproc, in most cases.

All rooms were investigated and no chemicals were found.

The building has concrete floors.

Maintenance Shops

This is a very large building constructed of steel with exterior sheeting of asbestos siding and 14 equipment access doors. The central area of the building houses a large overhead crane that has been removed and sits on the ground between the building and the flooded pit. There are 15 pallets of Portland Cement in the central area and eleven 10- gallon barrels of what appears to be caustic soda in crystal form. Inside the various bays, the area is littered with a wide array of scrap materials.

There is a 45-gallon drum containing an unidentified liquid in this area. At some point in the past, it appears the barrel had been moved to its present location in an area well-protected from the elements and where, in the unlikely event of spillage, all volumes would be contained within the building.

Cold Storage Building - Dock Area

Approximately 200 ft by 30 ft. in size, this steel frame building has corrugated tin sheet siding. During the 1970s, a fish processing plant was located in this building. The east end of the building was used for processing while the west end housed the compressors of which a number are still in place. The floor of most of this building is covered with unused cardboard boxes that were originally used to pack fish.

At the west end, there is a storage yard with a large refrigeration plant, which is intact and, in all likelihood, contains freon. It appears this area was also used as an oil storage area as there are a number of used oil drums scattered about and evidence of spillage. This spillage is approximately 25 m in-shore and appears to have happened a number of years ago.

Between this building and the shore of Lake Athabasca, there is a loading area and a large dock which is showing evidence of rot and decay.

Bunkhouses (Staffhousing)

These are two-storey, asbestos tile clad housing units approximately 90 ft. by 36 ft. in dimension. One is located immediately west of the mill; the rest are grouped further to the west. These buildings contained a number of single-room apartments with a common bathroom on each floor. There is an asbestos-wrapped hot water heater (approximately 100 gals.) located in each bathroom. The buildings are primarily of 2 x 4 construction with gyproced interior walls. It appears the roofs are constructed of plywood sheeting with 1 ft. X 1 ft. tin tiles for roofing. All hot water pipes are asbestos-wrapped

There were approximately 28 apartments per unit. Entrance and exit ways and exterior stairwells are decayed.

One building appears to be constructed on a concrete basement. The other buildings are constructed on concrete piles that result in 2-foot high crawl spaces under the lower floors.

Cold Storage

Located slightly west and south of the apartment buildings, all that remains of this facility is its original concrete piles and various scrap materials.

Community Centre

This is the largest of the non-production buildings on site. It contained a full-sized auditorium, a four-lane bowling alley, a Hudson's Bay Store, bakery and commissary, numerous walk-in coolers, a bank, post office, billiards room and numerous other club rooms. Built of structural steel and cinder block construction, all ceilings are open and show spray-on asbestos insulation. In many areas, the asbestos is falling from the ceiling and accumulating on the floor.

The building is relatively clear of any type of scrap wood or steel.

In what were the former 'photography club' rooms, there are five, partially-used, 1-gallon bottles of ethyl acetate and ammonia hydroxide.

Within the area of the walk-in coolers, there is a large refrigeration unit, possibly containing freon.

Curling Rink

Most of the curling rink has been dismantled and salvaged. What remains is a 20 ft. section of quonset which was not part of the ice surface. This is of wood construction and nothing was identified of environmental concern.

School

The school is a one-storey building of cinderblock construction with interior walls also of cinder blocks. A central corridor divides the building, with 4 or 5 regular-sized classrooms on either side. The building has a flat roof and its own furnace for steam heat.

Sewage Treatment

This cinderblock building is approximately 30 ft. by 10 ft. in dimension and consists of a pump room in the front and what appears to be a holding tank in the rear. The building is located on the road leading to the 'Married Quarters' housing at the far west end of the site.

Married Quarters

These are two-storey family accommodations built of fibrous blocks forming some of the main structural walls. The buildings are covered with asbestos siding and sit on concrete piles that support the floor. Each contains an asbestos-wrapped hot water heater and piping. There is evidence that the roofs are leaking which has caused a partial collapse of the ceilings in some rooms.

Pump Shed

This a small shed, typical of those used in the utilidor works. A number of these types of sheds exist around the property. It appears some may have been used to house fire fighting equipment. As well, they also contain valve assemblies for the various piping systems in the utilidors.

Concrete Basement

Salvage of this building took place previously and all that remains are the basement walls and a relatively small amount of scrap material.

Group of Cabins West of Marina

A group of four or five cabins are clustered in the trees near the Environment Canada Water Level Station on the shore of the lake, west of the marina, but it does not appear they have been used during the past number of years. They appear to have been

constructed of various types of wood salvaged from other facilities on site. While nothing was identified which would be of environmental concern, the area is however littered with debris.

Group of Cabins East of Headframe

This is a group of approximately 19 wood frame cabins likely constructed as support housing when the fish processing plant was operational. Some have been sheeted with salvaged aluminum siding. All are constructed with materials that appear to have been salvaged from the site.

Barge

An old wooden barge has been beached in the channel blasted between the pit and Lake Athabasca. No longer seaworthy, the abandoned barge is situated well above the water line. The interior appears to have been used, at one time in the past, as a cafeteria, perhaps for the people working at the fish processing plant.

Cookery Concrete Basement

Located south of the staff house near the mill, this structure was burned some time ago and only the basement remains. There is scrap steel within the confines of the basement.

Barrels

There are an estimated 8,000 empty steel barrels in various locations around the site. The majority are 25-gallon drums of which approximately 50% are stored near the acid plant on the waste rock pile or behind the acid plant on the bedrock out crop. There are also a large number in various locations at the toe of the waste rock pile.

The majority of the 45-gallon drums (less than 100) are concentrated in the areas around the fish processing plant and its support buildings (cabins, etc.). Every barrel that was investigated was empty or contained precipitation water as a result of the way in which it was stored. The empty barrels pose a minimal environmental or safety risk.

Fluorescent Light Ballasts/PCB

Many of the lighting fixtures used on the site are fluorescent and, because of their age, potentially contain some concentrations of PCB. While each ballast's concentration of PCB are expected to be low, there may be a sufficient quantity to warrant the development of a special handling strategy for their safe disposal.

Asbestos

As has been indicated in previous discussion of the facilities, asbestos insulation was used extensively in the construction and insulation of a number of the facilities still in existence at the Gunnar mine site. This was confirmed in earlier investigations conducted on site and in follow up laboratory verification of the composition of certain 'insulated' construction blocks encountered on the site.

The majority of the buildings on the site were sheeted in a "slate like" asbestos siding. Hot water pipes were wrapped with asbestos and in a number of the structures there appeared to be asbestos used as the primary insulation. The insulation is, in all cases, in very poor condition and large quantities litter the floor of the various buildings.

Initially, it was thought that the Geology/Mine Dry Building and a number of other structures had been constructed with cinder blocks with asbestos incorporated in the actual block. To positively identify the type of asbestos, samples were collected of both the spray-on insulation material and the cinder blocks used in the construction of the Geology/Mine Dry Building.

Under a polarizing microscope, the spray-on insulating material exhibited birefringence, which confirmed that it contains a very high percentage of crocidolite asbestos. A sample of the bricks used in the Geology/Mine Dry construction was also examined, but were found not to contain asbestos. This sample could not be positively identified but appeared to be a cellulose-loaded Portland cement compound which showed no indication of asbestos content. It is expected the cellulose was added in order to increase the insulating value of the bricks.

The mill, crusher house, acid plant, power house and auxiliary buildings were all sided with a composite board comprised of two sheets of 1/8 inch asbestos board filled with a pressed wood fibre insulation. The roofs of these buildings also contain corrugated asbestos board.

Other mine buildings on the site were constructed using asbestos board. When additional insulation was required, it consisted of a layer of Limpet asbestos fibre that was sprayed on to varying thickness.

In the community centre, the entire underside of the roof was sprayed with 1½ inches of Limpet asbestos and where ceilings were constructed they were composed of ¾ inch Limpet asbestos sprayed on to sheet metal and then painted. All bunkhouses, apartments and staff houses were constructed using asbestos shingles as siding and aluminum roof shingles.

The removal and appropriate disposal of the large volumes of asbestos must be a consideration in any planned activity at the site.

8.1.2. Waste Rock

The total volume of waste rock present on the Gunnar Mining Limited site has been estimated at 2,710,700 m³ (BBT Consultants, 1986) and includes both mine waste rock and overburden generated from surface stripping of the open pit. The majority of the waste rock is located in two piles immediately to the east of the now-flooded open pit and cover a total of approximately 10 hectares (BBT Consultants, 1986). The waste rock is located on the shore of Lake Athabasca with the toe of one of the waste rock piles protruding into the water of the lake proper and into a shallow area immediately east of the waste rock pile itself.

A gamma survey of the entire waste rock pile was conducted in June 1985 by BBT Consultants using a hand held, multiple range Berthold “Ratio/F” gamma dose-rate metre. Readings were taken at heights of 0.1 and 0.2 m above the surface at 73 locations. Survey control for the readings was achieved by a transit and stadia method.

The average readings on the waste rock pile were approximately 150 µR/hr regardless of height. Only ten percent of the readings from the 73 locations were greater than 1 mR/hr. (BBT Consultants, 1986). During a recent (July 2003) inspection of the site, Canadian Nuclear Safety Commission staff reported average gamma measurement on the waste rock pile of 1.49 µSv/h (maximum 6.13 µSv/h) (Stenson to Danielson, 2003).

To attempt to quantify the extent of impact of the waste rock piles on the surrounding air, radon measurements were made, in 1985, at areas of high gamma activity using the “mat” technique by Concord Scientific Corporation (BBT, 1986). One large mat (approximately 3m X 3m) was deployed on the northern edge of the waste rock pile in April 1985 and five cups were placed under the mat to measure radon. Detailed results are reported in BBT, 1986. Generally, the radon levels from the waste rock piles were found to be significantly lower than those on the Main Tailings area and were measured at between 199 and 361 pCi/L with a mean of 250 pCi/L.

During a 1981 investigation of the Gunnar flooded pit, Tones identified two small streams coming from the waste rock piles and estimated the flows at 3-5 L/sec and 1-2 L/sec. ²¹⁰Pb and uranium concentrations in the water seeping from the waste rock piles were found to be higher than the levels in the flooded pit. Concentrations as high as 26.8 mg/L uranium were present in the waste rock seep water, which flowed directly into Lake Athabasca (Tones, 1982).

The National Uranium Tailings Program Gunnar Field study investigated the identified seeps in 1985 and reported that the seepage flows in June and again in August 1985 were significantly less than previously reported by Tones. Samples were collected in both June and August 1985. The results of the analysis indicated that the chemistry of the seepage water was not constant, but rather showed both marked local and seasonal variation (BBT, 1986).

BBT (1986) reports that the smaller seepage noted by Tones in 1981 did not exist in 1985 and the more significant seepage stream had a flow of approximately 30% in 1985 when compared to that reported by Tones in 1981, however the general water chemistry of the flows was similar in both studies with wide variations in the uranium and ²²⁶Radium concentrations. BBT concluded that the waste rock seepages source shows a very real and marked seasonal and yearly variation that depended on yearly and seasonal precipitation patterns.

Although the ²²⁶Radium and uranium concentrations in the 1985 waste rock seep were measured at approximately 1 Bq/L and 2.0 mg/L, the fact that seepage flows of between 1 and 5 L/sec were low in comparison to the dilution in the receiving environment of Lake Athabasca suggest that any ecological effects would be very localized if they exist at all (BBT, 1986).

These seeps were investigated and re-sampled by Canada North during its 2002 investigation and reported that the uranium concentration in Zeemel Bay (220 µg/L) was much higher than all other study areas. The Zeemel Bay sample was collected near the seep from the waste rock and this may be a localized effect. The results of this sampling program were included in the SENES Risk Assessment which concluded that the uranium concentration in the waste rock seep from the toe of the waste rock pile may cause potential adverse effects on aquatic species in the wetland area into which the seep flows as well as a portion of Zeemel Bay directly outside the wet land seep.

Samples of the waste rock piles were previously recovered/analyzed as part of the 1985 investigation (BBT, 1986) and a summary of the results is presented in Appendix C of *Gunnar Site Characterization and Remedial Options Review*, Saskatchewan Research Council, January 2005.

The following table provides a summary of the 1986 results for select parameters.

	WR2	WR3	WR4	WR5	Average
Uranium (µg/g)	78.1	4.6	14.1	4.1	25.2
Thorium-230 (Bq/g)	0.09	0.08	0.18	0.11	0.12
Radium-226 (Bq/g)	0.90	0.07	0.16	0.13	0.32

As part of the 2004 SRC investigation, the waste rock piles were sampled to determine the potential for acid rock drainage (ARD) and metals leaching potential. Appendix E2 of *Gunnar Site Characterization and Remedial Options Review*, Saskatchewan Research Council, January 2005 provides a discussion of the preliminary examination of the Gunnar waste rock.

A set of only five samples were taken from shallow shovel pits across the waste rock piles. The were located in a widely-spaced pattern on the waste rock piles (Appendix E2, Figure D1). The individual samples consisted of approximately 10-12 kg of material composed of broken rock with a wide range of fragment sizes from silty material (<64 µm) to cobble size (up to ~10 cm in length).

The geochemical data for the reference rock samples indicate that the granite samples are generally similar in chemistry while the mafic hornblende gneiss is more siliceous and contains significantly higher amounts of iron and magnesium at the expense of alumina and the alkali and alkaline earth elements (CaO, K₂O, Na₂O). The pink/red-orange hornblende granite (WR#5 ref. piece) is relatively aluminous, calcic, and sodic, at the expense of silica, and also contains minor amounts of carbonate. A comparison of the waste rock data with the reference piece data shows an overall agreement indicating that the waste rock materials are composed of these rock types in varying fragment sizes.

The trace element data from these waste rock samples show moderately elevated values for only a few elements, primarily U and Pb in waste rock samples WR#4 and WR#5. In these samples, the U contents are between 106 and 253 ppm. The -0.5" size-fraction materials (253 and 184 ppm) contain nearly double the amount present in the +0.5" size-fraction materials (120 and 106 ppm). U is also elevated to a lesser extent (50-60 ppm) in waste rock sample WR#2 and, again, in the -0.5" size-fractions of waste rock samples WR#1 and WR#3. All of these values are significantly higher than the amounts of U present in the reference piece samples (5 to 23 ppm).

The sulphur contents of all of these waste rock samples are low, all being < 0.10 wt% and most being <0.06 wt%. Thus there does not appear to be much of an acid generation potential for these materials. The carbonate contents of these samples are variable from 0.4 to 2.2 wt% CO₂ (C expressed as CO₂). Thus the potential for base neutralization by these materials appears to exceed their acid generation potential.

8.1.3. Tailings

Mill tailings were originally discharged from the mill at 32% solids through a 1,500 ft. long, 10 in. diameter wooden stave pipe. In total, it has been estimated that the Gunnar Mining Limited mill discharged a total of 4.4 million tonnes of tailings during operations (BBT, 1986).

The tailings and other aqueous wastes were initially discharged into a small lake located 500 m to the north of the mill (Ruggles et al., 1978) that is referred to in historical documentation as either Blair Lake or Mudford Lake. This area is currently referred to as the Gunnar Main Tailings. In 1958, the mill installed a cyclone plant with four sand storage tanks for the production of sand backfill in the underground mine.

The Gunnar Main Tailings basin eventually filled with tailings solids and a small rock outcrop was blasted to allow the tailings to flow from the Main area to a small depression referred to as Gunnar Central Tailings. Once this relatively small basin was filled, the tailings continued to flow downhill, eventually entering Langley Bay, Lake Athabasca. During operations, a sufficient volume of tailings was discharged and allowed to flow into Langley Bay so as to eventually cut Langley Bay into two separate portions: one

which is still connected by a narrow channel to Lake Athabasca proper and a smaller ‘back bay’ which has intermittent connection to Langley Bay itself.

Historical investigations of the three Gunnar tailings areas during 1984 and 1985 indicate that the depth of tailings in Gunnar Main is approximately 14 m, in Gunnar Central 3-4 m and in Langley Bay, 2-4 m. In each case, the tailings are underlain by a peat or organic clay layer which is 0.5-9.4 m in thickness under Gunnar Main, 3-6 m under Gunnar Central and 8-16 m under the Langley Bay tailings (BBT Consultants, 1986). This layer of clay, which had an *in situ* permeability of approximately 10^{-7} cm/s, forms a reasonably tight physical and geochemical seal under all the tailings and as a result, all of the water transported from the tailings occurs as either very shallow groundwater flow or as surface flows.

As part of the National Uranium Tailings Program (NUTP) investigation of the Gunnar Site, boreholes and wells were completed into tailings areas (BBT, 1986). Samples of the soils and tailings materials encountered during the drilling of these boreholes and wells were submitted for chemical analyses; results of these analyses are included in Appendix C of *Gunnar Site Characterization and Remedial Options Review*, Saskatchewan Research Council, January 2005 which is appended.

BBT (1986) analyzed these soils and tailings samples for up to three components; water soluble component, acid soluble component and fusion component, which were combined to make up the total concentrations. The water soluble component is interpreted to provide an indication of the readily mobilized material. The acid soluble component which was interpreted to represent the fraction that was mobilized during the acid leach in the mill and subject to re-precipitation in the tailings areas in the form of hydroxides (BBT, 1986). The fusion component was the residue after water and acid soluble material had been removed; this component is thought to be relatively immobile. These three components were also combined into a total concentration of the tested parameters.

The 1986 study showed that there was general variability of all three components due to changes in the material and amount of leaching these materials were exposed to. It is reasonable to expect that, in the intervening years, in general the water soluble concentrations and, to a lesser degree, the acid soluble concentration had been reduced. The following table summarizes the variation in the uranium, thorium-230 and radium-226 concentrations.

<i>Location</i>	<i>Total Concentrations (BBT, 1986)</i>		
	<i>Uranium (µg/g)</i>	<i>Thorium-230 (Bq/L)</i>	<i>Radium-226 (Bq/L)</i>
<i>Gunnar Main</i>			
<i>Average</i>	43.5	3.9	6.9
<i>Minimum</i>	4	0.13	0.2
<i>Maximum</i>	77	12.5	30
<i>Gunnar Central</i>			
<i>Average</i>	32.5	10.0	14.9
<i>Minimum</i>	4	0.11	0.2
<i>Maximum</i>	77	25	50
<i>Langley Bay</i>			
<i>Average</i>	36.9	10.2	14
<i>Minimum</i>	4.4	7	0.6
<i>Maximum</i>	82	15	45

Addition tailings samples are being collected to verify this historical information.

There are presently, several beaver dams between Gunnar Main and Gunnar Central. The beaver dams have backed up ponded water onto the low lying areas of Gunnar Main as they have been constructed in the channel that was blasted to form the outlet from Gunnar Main tailings area.

The flooded area is separated into two ponds; a northern pond, which is held back by the beaver dams and the southern pond that drains into the northern pond. The northern pond is approximately 51,000 m² in size, while the southern pond is smaller at about 35,500 m². These two ponds are separated by a marshy area. The amount of water in the ponds on Gunnar Main tailings area is not known but conservatively assuming an average depth of 1.5 metres and calculating a surface area of 86,500 square metres (m²) the volume of water is approximately 130,000 m³.

Surface water samples were collected from the northern pond on Gunnar Main (Gunnar Tailings Pond) and the creek on Gunnar Central (GC Creek) during the 2004 SRC investigation. The sampling locations are shown on Figure 3.4 of SRC 2004 and that document presents the results of the analysis in Appendix C.

Generally, the surface water samples from the ponded water on the Gunnar main tailing and from the creek between Gunnar Main and Gunnar Central tailings area met the Saskatchewan Surface Water Quality Objectives (SSWQO) except for ²²⁶Ra. The reported ²²⁶Ra concentration from the Gunnar Tailings Pond sample was 0.15 Bq/L and the SSWQO for this parameter is 0.11 Bq/L.

The creek between Gunnar Main and Gunnar Central tailings area is thought to be the discharge route for most of the porewater in contact with the Gunnar Main tailings and the surface water from this area.

Porewater and surface water from Gunnar Main flow to Gunnar Central and when the surface and porewater holding capacity of Gunnar Central is exceeded the water continues to flow on to Langley Bay. Presently, the impact of the Gunnar Main water on Langley Bay is likely mitigated or controlled by the beaver dams controlling the flow out of Gunnar Main and improvement in the water quality as it flows from Gunnar Main to Langley Bay.

If all of the beaver dams at the outlet of Gunnar main were to fail there would be a sudden release of most of the surface water on Gunnar Main onto Gunnar Central. This release of water would result in erosion and transport of Gunnar Main and Gunnar Central tailings. This water would quickly fill up the holding capacity of Gunnar Central and flow onto Langley Bay. The water quality in Gunnar Main, although of fair quality, is still of lower quality than that in Langley Bay so there may be a temporary impact to aquatic environment in this area. It is unlikely that all of the beaver dams would fail at the same time but even if the upper-most dam failed then there would likely be a release of a smaller volume of water until a new equilibrium was established. The release of this smaller volume could possibly result in the erosion of some material in Gunnar Central and a volume of Gunnar Main water reaching Langley Bay. This potential failure of these beaver dams at some point in time is a concern.

8.1.4. Flooded Pit

The open pit mine at Gunnar was depleted in 1961 and ore from underground was used solely to supply the mill until October 1963. The mine was officially closed early in 1964.

Shortly thereafter, the blasting of a narrow, relatively shallow trench between the pit and the lake itself breached the narrow bedrock ridge that separated the open pit from Lake Athabasca. As a result, water from Lake Athabasca was allowed to flow directly into the open pit, eventually flooding the underground workings as well as the pit itself. The channel between the lake allowed the free movement of water (and presumably aquatic organisms) between the lake and the flooded pit until 1966 when the channel was blocked by filling it with waste rock.

In 1971, the Athabasca Native Fisherman's Co-operative established and began the operation of a fish processing facility at the former Gunnar Mining Limited primarily using the warehouse building near the main dock (Figure 3.3.1). In 1975, the facility was taken over by the Freshwater Fish Marketing Corporation, which continued to operate the plant until the end of 1980. During the following year, fish were dressed at the Gunnar site but were then flown to out to other plants for processing. During the entire time the processing plant was in operation, including 1981, wash water used in the fish processing plant and offal from the processing and dressing operations were disposed of in the flooded pit (Tones, 1982).

The flooded pit at the Gunnar site is approximately 300 m long and 250 m wide with a total estimated surface area of approximately 7 hectares. The flooded pit has a maximum depth of 110 m and a shoreline perimeter of 1700 m (Tones, 1982).

In 1981, a study was completed by the Saskatchewan Research Council on the physical, chemical and biological characteristics of the flooded Gunnar pit (Tones, 1982). In 2002, Canada North Environmental Services was retained by COGEMA Resources Inc. (now AREVA) to conduct a reconnaissance survey to repeat selected monitoring components of the original SRC study. This study was completed in September 2002 and the resulting report in its entirety is included as Appendix F of *Gunnar Site Characterization and Remedial Options Review*, Saskatchewan Research Council, January 2005 (SRC, 2005). That report is included in this document as Appendix A.

The primary objectives of the 2002 study were to collect limnological, water chemistry, sediment chemistry, plankton, benthic macroinvertebrate, fish community and habitat assessment data in order to obtain recent information on the state of the aquatic environment in the flooded Gunnar pit. Where appropriate, the 2002 data was compared to the 1981 SRC study to assess the ecological status of the flooded pit after 21 years.

Both the 1981 and 2002 data indicate that the flooded Gunnar pit is meromictic, meaning that the dense lower water layer is essentially isolated and does not mix with the upper layer. The dense layer, referred to as the monimolimnion, has increased in thickness from 20 m in 1981 to 35 m in 2002. Temperature, dissolved oxygen and specific conductance levels measured in the monimolimnion were generally comparable between the years.

The largest difference in the limnology of the pit between sampling years was that the water column in the pit was well oxygenated down to 50 m in September 2002, while in 1981, the pit was nearly anoxic below 8 m in August and September before the autumnal overturn. In addition, dissolved oxygen levels in the metalimnion were high in 2002, measuring 13.7 mg/L in August and 12.5 mg/L in September. Lower levels were reported in the 1981 data. It is postulated that breakdown of fish waste, which were dumped into the pit from 1971 to 1981, was the major cause of the reduced dissolved oxygen levels measured in 1981.

In general, pH levels were slightly above neutral. In August 2002, values ranged from 7.6 at 45 m to 8.6 at 8 m. In September 2002, a pH value of 8.0 was measured near surface. The 1981 pH values ranged from 6.7 (November; 108.5 m) to 9.5 (August; 1m) although most values were slightly above neutral (7.0).

Flooded Pit Water Chemistry

Discrete water samples were collected at depths of 0, 50, 85 and 108 m from a station located near the center of the flooded pit (Station S-1). In addition, surface samples were collected from the pit tow locations which correspond to stations sampled in 1981.

Analyte levels measured in the surface water samples differed little between the three sampling locations. The exception was total carbon levels which were lower in station S-3 (6 mg/L) than at S-1 and S-2 (20 mg/L)

At station SL-1, concentrations of arsenic, boron, iron, manganese, soluble silicon, strontium, ammonia as nitrogen, total Kjeldahl nitrogen, phosphorus, total carbon, ²¹⁰Pb, ²¹⁰Polonium, ²²⁶Radium, and all organic ions (except carbonate) were notably higher in the water samples collected from depths of 85 m and 108 m than in the water samples collected from depths of 0 m and 50 m. Conversely, uranium concentrations decreased with depth from 863 µg/L at surface to 348 µg/L at 108 m.

In samples from all stations and depths, the majority of metals and trace elements were measured below analytical test detection limits and were lower than applicable Saskatchewan Surface Water Quality Objectives (SSWQO). However, ammonia as nitrogen levels in the water samples from Station S-1 at depths of 85 m (5.9 mg/L) and 108 m (5.5 mg/L) were approximately three-fold higher than the SSWQO.

The concentration of most metals, including aluminium, chromium, copper, iron, manganese, nickel, lead and zinc, were lower in the water samples from 2002 than in the samples from 1981. However, it is noted that even in 1981, metal concentrations in the flooded pit were very low. Phosphorus levels were higher in 1981 than in 2002 at all depths and inorganic ion levels were generally similar, with the exception of bicarbonate levels which were higher in 2002. Radium-226 levels were higher in 2002 than in 1981 in the water samples collected from all depths. Lead-210 levels were lower in 2002 than in 1981 in the water from the surface, but the reverse trend was observed at depths of 85 m and 108 m. Uranium levels at the surface were comparable between the years, but at depths of 50 m and 85 m, the levels were approximately two-fold higher in 2002 than in 1981. However, at a depth of 108 m, uranium concentrations decreased eight-fold from 2,900 µg/L in 1981 to 348 µg/L in 2002.

Flooded Pit Sediments

The analyte levels measured in the sediments samples from the flooded Gunnar pit were compared to the interim Sediment Quality Guidelines (ISQG) and the Probable Effects Level (PEL) recommended by the Canadian Council of Ministers of the Environment for arsenic, cadmium, chromium, copper, lead and zinc. The mean concentrations of metals measured in the sediment samples from the deep location within the pit all exceeded the ISQG, but not the PEL, with the exception of cadmium. In the sediment samples collected from the shallow site within the flooded pit, the mean concentration of metals were lower than the ISQG. Cadmium levels were below the analytical detection limit of 0.5 µg/g in all sediment samples.

The radionuclide levels measured in the sediment samples collected at the deep site were high, particularly uranium levels which averaged 19,700 µg/g. Elevated uranium levels were also measured in the sediment samples from the shallow site (806 µg/g), although these levels were markedly lower than those from the deep site. Levels of lead-210,

polonium-210, radium-226 and thorium were also higher in the sediment samples from the deep site when compared to the shallow site.

The sediment samples collected from the shallow areas of the pit contained higher levels of arsenic, polonium-210, and lead in 2002 when compared to 1981 data. However, cadmium, lead-210 and zinc levels were lower in 2002 samples and uranium levels were similar in both years. In the sediment samples collected from the deep area of the pit, levels of arsenic, chromium, copper, lead, polonium-210, radium-226 and uranium levels were substantially higher in 2002 than in 1981. Similar to the data from the shallow area, cadmium and zinc levels were lower in 2002.

Phytoplankton

In two samples collected from the flooded pit, there was a total of 33 taxa identified and an mean abundance of $3,958,100 \pm 36,030$ cells/L. The largest number of phytoplankton genera were found within the division Chlorophyta (green algae) (n=8) however, the abundance was low compared to other divisions. The numerically dominant divisions included Cyanophyta (blue-green algae) (35.3% of the sample population), Cryptophyta (30.9%) and Crysoohyta (golden-brown algae) (23.9%). In terms of biomass, the division Cryptophyta contributed 42.9% of sample biomass, followed by Chrysophyta (21.1%) and Cyanophyta (20.6%).

The Shannon-Wiener diversity index value was relatively high (3.03 ± 0.03). The ratings of the Simpson's dominance index are the inverse of the Shannon-Wiener diversity index, with 1.00 being the maximum value. The Simpson's dominance index for the phytoplankton from the flooded pit in 2002 was low measuring 0.17 ± 0.02 . The results of these indices suggests a stable and numerically even phytoplankton assemblage.

The phytoplankton samples from 1981 contained 94% Cyanophyta and small abundances of four other divisions. The 2002 phytoplankton samples contained a more numerically even community with three main divisions dominating the samples and lower numbers of four other divisions. The phytoplankton community in 2002 was less characteristic of a nutrient-rich environment that the community described in 1981. This shift is expected as nutrient levels were higher in the water samples from 1981, most likely from the deposition of fish waste into the pit.

Zooplankton

The total number of taxa identified in two composite samples collected from the flooded pit in 2002 was 16. The abundance values averaged 66.9 ± 27.2 cells/L. The majority of the zooplankton identified in the pit samples were rotifers (89.4% of the sample population) and the remainder were crustaceans (10.6%). The biotic indices for the zooplankton samples were 2.62 ± 0.12 (Shannon-Wiener diversity index) and 0.22 ± 0.02 (Simpson's dominance index). Although the values of these indices are slightly lower than the indices calculated for the phytoplankton samples, they are still favourable and reflect a diverse and numerically even zooplankton community.

The only organism identified in the 1981 samples were two genera of crustaceans, *Daphnia sp.* From the Class Cladocera and *Cyclops sp.* From the class Copepoda. The number of crustacean genera was lower than the six genera identified in the samples collected from the pit in September 2002. It is suspected that rotifers were present in 1981 samples, but taxonomic identification and enumeration were only conducted on crustaceans.

Benthic Macroinvertebrate Communities

Three samples collected from the deep site (110 m) in the flooded pit in 2002 contained no benthic macroinvertebrates. These results are consistent with the 1981 data in which no benthic macroinvertebrates were found in samples taken at depths of 82.5 m, 109 m, and 110 m. The absence of benthic macroinvertebrates from the deep areas of the flooded pit in both 1981 and 2002 is likely due to low dissolved oxygen levels.

The three composite samples collected from the shallow site in 2002 contained a mean 22 ± 7 taxa and a total of 32 taxa. Total abundance varied greatly between samples ranging from 4115 organisms/m² to 25,172 organisms/m². The most abundant taxon was the Family Tubificidae (aquatic earthworms), which comprised 52.6% of the sample population. The next most abundant taxon was the *Limnaea sp.* Of the Class Gastropoda (snails) (10.3%), followed by genera from the Family Chironomidae (midges).

The Shannon-Wiener diversity index was 2.47 ± 0.39 and the Simpson's dominance index was 0.30 ± 0.14 . In general, the samples from the shallow area of the flooded pit contained a diverse and abundant benthic macroinvertebrate community that was dominated by contaminant tolerant taxa (aquatic earthworms and chironomids), but did contain some contaminant sensitive taxa (Ephemeroptera (mayflies) and Trichoptera (caddis fly)).

In 2002, the samples from the shallow areas of the pit were collected at a mean depth of 2.32 ± 0.23 m. Therefore, these data are not directly comparable to the quantitative (Ekman dredge) samples collected in the 1981 study, since the shallowest sampling depth was 7 m. At a depth of 7 m, only large numbers of *Chironomus sp.* and a small number of *Gordius sp.* from the Order Nematophora (horsehair worms) were identified. The 1981 study also collected non-quantitative samples from the littoral fauna of the pit using a net sweep method. Most major taxa were represented in the samples from both years, but the number and type of genera, as well as the abundance of organisms within each taxon, differed.

Fish Community

A total of 29 northern pike (*Esox lucius*) were captured by standardized test netting. Additionally, one juvenile northern pike was captured by electrofishing and two northern pike were observed. Although no small bodied fish were caught in the minnow traps,

there was one ninespine stickleback (*Pungitius pungitius*) captured by electrofishing and two ninespine stickleback were identified in the stomach of one northern pike.

In the 1981 study, 33 northern pike, four white suckers (*Catostomus commersoni*), and one longnose sucker (*Catostomus catostomus*) were captured. Small-bodied fish capture methods were not employed, however, ninespine sticklebacks were identified in the stomach contents of the northern pike. Due to low densities of suckers captured in the 1981 study, it is possible that they still reside in the flooded pit and were not captured during the 2002 study, although no evidence of this was found.

The length-weight curves for the northern pike measured in the 1981 and 2002 studies demonstrate a broad size distribution in both years and a high correlation between the fork length and weight. The length-frequency distribution indicate that the sizes of the northern pike captured in 1981 were more normally distributed than those captured in 2002. The northern pike measured in the pit had similar condition factors between years averaging 0.74 ± 0.07 in 1981 and 0.73 ± 0.07 in 2002. These condition factors are high when compared to northern pike data from other waterbodies in northern Saskatchewan. The northern pike residing in the flooded pit appeared healthy externally and internally based on brief field examinations. The stomach contents were mainly empty, but a few contained invertebrates and one contained two ninespine stickleback. The subsample that were sexed indicated an even sex ratio since eleven males and ten females were caught. A wide range of northern pike size classes were captured and the abundance was relatively high. The northern pike population in the flooded pit appears to be self-sustaining since there was evidence that they were successfully reproducing in the pit (juvenile fish were located) and migration from other waterbodies is not possible.

Habitat Assessments

A total of 12 habitat units (HUs) were identified in the flooded pit representing several habitat types ranging from bedrock cliffs to densely vegetated areas. There was a good diversity of aquatic/wetland macrophytes in the pit including two genera of macro algae and 11 genera of vascular plants.

Each HU was assessed for its potential as spawning habitat for northern pike, white sucker or longnose sucker. There were no moderately or highly suitable spawning habitats for sucker identified in the pit (clean, gravel/cobble area). Three HUs contained marginal habitat for sucker spawning because of their moderate density of cobble substrate, but the substrate also contained silt/clay and organic material and was not clean.

Numerous habitats were assessed as containing northern pike spawning habitat due to the high density of vegetated areas. There were three HUs that contained a sufficient quantity of vegetations to be rated as providing marginal habitat for northern pike spawning. Three other HUs were rated as moderately to highly suitable habitat for northern pike spawning. These areas were shallow with moderate to heavy abundances of emergent vegetation.

Conclusion

The flooded Gunnar pit continues to be a challenging environment for biota with elevated radionuclide levels in the water and sediments as well as low dissolved oxygen levels in the bottom half of the pit. However, the aquatic community of the flooded pit did not show signs of deterioration after a 21 year period. On the contrary, in 2002, the pit was found to contain a good diversity of aquatic biota in a number of groups (phytoplankton, zooplankton, benthic macroinvertebrates, and macrophytes) as well as a self-sustaining population of northern pike.

8.1.5. Site Investigations

The Saskatchewan Research Council (SRC) retained Canada North Environmental Services (CanNorth) to conduct aquatic investigations in areas of Lake Athabasca related to the Gunnar site in September 2004, and follow-up studies in September 2005. The report prepared by CanNorth is included as Appendix B.

The objective of the aquatic investigations was to gather site-specific information to use in assessing remedial activities in these areas and in the risk assessment. These studies collected information on limnology; water, sediment, plant, and fish chemistry; plankton, benthic macroinvertebrate, and fish communities; and fish habitat from the following study areas in Lake Athabasca: St. Mary 's Channel, Zeemel Bay, Langley Bay, Back Bay, and Dixon Bay. In addition, a bathymetric survey was completed in Back Bay, and fish chemistry data was obtained from Gunnar pit.

St. Mary's Channel is a large strait located directly south of the Gunnar mine site. Zeemel Bay is part of the St. Mary's Channel study area and is located adjacent to the waste rock pile. Langley Bay is approximately 2 km north of the Gunnar mine site and the southeast side of the bay contains tailings deposits. Back Bay was isolated from Lake Athabasca by historical tailings deposition from the Gunnar mine site, however, it remains connected to Langley Bay through a narrow, intermittent channel. Dixon Bay was sampled as a reference area in Lake Athabasca.

Results

Bathymetry

The shore length of Back Bay is approximately 2 km long and it contains a surface area of 17.74 ha. Back Bay is relatively shallow with a mean depth of 1.8 m and a maximum depth of 4 m. The total volume of Back Bay is 0.32×10^6 m³ and approximately 25% of the water is contained in the top 0.5 m.

Limnology

Limnology measurements were taken in St. Mary's Channel and Langley Bay in 2004, and from all study areas in 2005. The water temperature in all study areas was uniform throughout the water column. Dissolved oxygen levels were relatively high in St. Mary's Channel, Langley Bay, and Dixon Bay (9.4 to 11.3 mg/L), were slightly lower in Zeemel Bay (approximately 8.7 mg/L), and were much lower in Back Bay (3.4 to 3.9 mg/L). Specific conductance levels were the same in Dixon Bay and St. Mary's Channel (57 $\mu\text{S}/\text{cm}$), slightly higher in Langley Bay (76 $\mu\text{S}/\text{cm}$ in 2005 and approximately 96 $\mu\text{S}/\text{cm}$ in 2004), and higher still in Zeemel Bay (112 $\mu\text{S}/\text{cm}$). In Back Bay, specific conductance was higher than at the other study areas, measuring approximately 435 $\mu\text{S}/\text{cm}$. The pH levels were slightly basic in all study areas (7.2 to 8.1 units).

Water Chemistry

Water samples were collected in St. Mary's Channel and Langley Bay in 2004, and from all study areas in 2005. Water chemistry in St. Mary's Channel was comparable to the reference station and metal concentrations were lower than applicable provincial and federal guidelines. In Zeemel Bay, the concentrations of numerous ions were higher than at the reference station in Dixon Bay. The radium-226 concentration of 0.02 Bq/L in Zeemel Bay was higher than in Dixon Bay (<0.005 Bq/L), however, this level remains well below the general surface water quality guideline set by the Saskatchewan Surface Water Quality Objectives (SSWQO) of 0.11 Bq/L. The uranium concentration in Zeemel Bay (220 $\mu\text{g}/\text{L}$) was much higher than all other study areas, where levels ranged between 0.4 and 11 $\mu\text{g}/\text{L}$. The Zeemel Bay sample was collected near the seep from the waste rock and this may be a localized effect.

Langley Bay contained levels of metals, trace elements, ions, and nutrients that were similar to the reference station in Dixon Bay. In Back Bay, water concentrations of ions, nutrients, and some metals, such as arsenic, iron, manganese, and strontium, were higher than at the reference station. The only metals above guidelines were iron and arsenic in Back Bay, which were above the federal guidelines, but were well below the SSWQO.

Radionuclide concentrations in the water samples from both Langley and Back bays were higher than in Dixon Bay. The radium-226 concentrations in Langley Bay (0.16 Bq/L in 2004 and 0.12 Bq/L in 2005) and Back Bay (0.79 Bq/L) exceeded the SSWQO of 0.11 Bq/L.

Sediment Chemistry

Sediment samples were collected from a 5 m depth in St. Mary's Channel and Langley Bay in 2004, and at a comparable depth from the reference area in Dixon Bay in 2005. Sediment samples were collected at a 2 m depth from Back, Zeemel, and Dixon bays in 2005. Data are only compared within each depth range.

Sediment concentrations of sulphate, numerous metals and trace elements, and all radionuclides were substantially higher in Back Bay compared to Dixon Bay. Mean concentrations of copper, lead, and arsenic in Back Bay exceeded federal sediment quality guidelines. Mean chromium concentrations were higher than the guideline in both Dixon and Zeemel bays, indicating that high chromium levels are found naturally in parts of Lake Athabasca. Radionuclide concentrations were higher in Zeemel Bay than in Dixon Bay, however, they were much lower than in Back Bay, with the exception of uranium. In Zeemel Bay, sediment uranium concentrations were elevated at the stations located near the seep, measuring 291 and 316 µg/g, while the station located closer to the mouth of the bay contained a uranium level that was similar to reference (7 µg/g).

In St. Mary's Channel, mean sediment concentrations of boron, chromium, lead, and radionuclides were higher than in the reference area. Langley Bay sediment contained mean concentrations of several metals, trace elements, and all radionuclides that were higher than reference. Federal sediment quality guidelines were exceeded by cadmium, copper, lead, and arsenic in Langley Bay, and chromium in St. Mary's Channel. Sediment radionuclide concentrations in St. Mary's Channel were higher at stations 1 and 2, located near the channel that previously connected Gunnar pit to Lake Athabasca. Although the sample size is small, these results suggest that there may be some localized sediment contamination resulting from historical mining activities.

Sedge Chemistry

Sedge (*Carex* sp.) shoot and root samples were collected and chemically analyzed from Zeemel Bay, Langley Bay, Back Bay, and Dixon Bay in 2005. In addition, sediment samples were collected for chemical analyses from beneath the plants. There were several instances where mean metal and trace element concentrations were higher in the exposure areas compared to the reference area. Of particular note were the mean concentrations of iron, lead, manganese and arsenic, which were substantially higher in sedge root and shoot samples from Langley and Back bays than in the samples from Dixon Bay.

There were large differences in radionuclide concentrations between the exposure areas and the reference area. Mean levels of lead-210, polonium-210, radium-226, and thorium-230 were higher in Zeemel Bay compared to Dixon Bay and levels in Langley and Back bays were higher than those from Zeemel Bay. However, uranium showed a different pattern in that the highest concentrations were measured in the Zeemel Bay sediment, root, and shoot samples. Radionuclide levels were generally elevated in Langley and Back bays at the stations located closest to the tailings beach, and in Zeemel Bay at the stations located closest to the seep. Concentration ratios demonstrated that radionuclide levels were higher in sedge roots than in the shoots and sediment in Langley and Zeemel bays.

Northern Pike Chemistry

Northern pike (*Esox lucius*) were retained for chemical analyses from Gunnar pit, Langley Bay, and St. Mary's Channel in 2004, and from St. Mary's Channel, Langley Bay, Back Bay, and Dixon Bay in 2005.

Northern pike sampled from Gunnar pit in 2004 contained higher mean concentrations of barium, mercury, selenium, and arsenic in the flesh, nickel and selenium in the bone, and most radionuclides in both flesh and bone, than the 2005 samples from Dixon Bay. In addition, mercury concentrations in the three Gunnar pit northern pike (0.58 to 0.73 µg/g) warrant consumption restrictions according to provincial guidelines.

In the other study areas, the metal that demonstrated the most notable difference between reference and exposure northern pike was manganese. In the northern pike bone samples from Back Bay, the mean manganese concentration was 29.4 µg/g, which is elevated compared to Dixon Bay (mean = 8.12 µg/g). In Langley Bay, the 2005 data showed higher mean manganese concentrations than the reference area, but the 2004 data did not. Mercury concentrations in the northern pike from St. Mary's Channel, Langley Bay, Back Bay, and Dixon Bay were all below provincial guidelines.

Most radionuclide concentrations in the northern pike from Langley and Back bays were higher than in Dixon Bay. Levels of polonium-210 and radium-226 in the bone samples from Back Bay were higher than in the other study areas, and averaged approximately 50 times higher than in the reference area. Northern pike from St. Mary's Channel contained radionuclide levels that were comparable to reference, with the exception of uranium concentrations in the bone samples that were approximately 10-fold higher.

Lake Whitefish Chemistry

Lake whitefish (*Coregonus clupeaformis*) were captured for chemical analyses from St. Mary's Channel, Langley Bay, and Dixon Bay in 2005. There were few notable differences in the metal and trace element concentrations between the exposure areas and the reference area. In the lake whitefish flesh samples, only selenium was notably higher in Langley Bay (mean = 0.49 µg/g) compared to Dixon Bay (mean = 0.22 µg/g). In the bone samples, mean manganese concentrations were higher in Langley Bay (mean = 8.52 µg/g) compared to Dixon Bay (mean = 4.82 µg/g). The mercury concentrations in all samples were well below provincial guidelines.

Uranium levels in the St. Mary's Channel lake whitefish flesh and bone samples were approximately four times higher than reference. Radionuclide concentrations were generally higher in Langley Bay compared to reference, particularly in the lake whitefish bone samples. In Langley Bay, mean values of lead-210, radium-226, and uranium were lower in 2005 when compared to a single composite sample tested in 1983 (Waite et al. 1988).

Phytoplankton Community

Phytoplankton samples were collected from Langley Bay and St. Mary's Channel in September 2004, and from Dixon Bay, Back Bay, and Zeemel Bay in September 2005. The phytoplankton sample from Dixon Bay was relatively evenly distributed consisting of 29% Chrysophyta (golden algae), 21% Haptophyceae (dinoflagellates), 19% Cyanophyta (blue-green algae), and 17% Chlorophyta (green algae). The samples from Langley Bay, St. Mary's Channel, and Zeemel Bay were all dominated by golden algae (approximately 40% of the sample populations). The phytoplankton sample from Back Bay was almost entirely comprised of the blue-green algae Aphanizomenon flos-aquae (94%).

Phytoplankton abundance in Back Bay was approximately twice as high as in the other study areas, however, measures of richness and diversity were much lower. The low Simpson's diversity index (0.17) and evenness (0.20) in Back Bay reflects the dominance of the community by a single species. The community metrics for the other study areas indicated diverse and numerically even phytoplankton communities.

Zooplankton Community

Zooplankton samples were collected from Langley Bay and St. Mary's Channel in September 2004, and from Dixon Bay, Back Bay, and Zeemel Bay in September 2005. The sample from Dixon Bay contained equal abundances of crustaceans and rotifers, while the samples from Langley Bay, Back Bay, and St. Mary's Channel were dominated by rotifers (>75%). The sample from Zeemel Bay different from the other areas in that it was dominated by crustaceans (70.5%).

The high abundance of organisms, low number of taxa, and high percentage of a single taxon resulted in low diversity indices for the zooplankton community in Back Bay. The zooplankton communities in Dixon Bay, Langley Bay, and St. Mary's Channel attained high diversity and evenness values: 0.79 to 0.82 (Simpson's diversity index) and 0.83 to 0.86 (evenness). Zeemel Bay contained slightly lower diversity indices, likely because of the low abundance of zooplankton in the sample.

Benthic Macroinvertebrate Community

Benthic macroinvertebrate samples were collected from a 2 m depth in Back, Zeemel, and Dixon bays in September 2005. Overall, the most dominant taxon in Dixon Bay was Corynocera sp. from the Family Chironomidae, although they were largely contained within one of the three samples. In Back Bay, the Family Chironomidae occupied 74% of the sample population, with 35% from the genus Psectrocladius sp. In Zeemel Bay, 82% of the sample population was from the Family Chironomidae, with 55% from the genus Tanytarsus sp. However, similar to Dixon Bay, the high numbers of Tanytarsus sp. were only found in one of the three samples. Back Bay contained a higher mean density of

organisms than Dixon Bay and Zeemel Bay. Although there was some variation between stations, mean values of richness, Simpson's diversity, and evenness were highest in Dixon Bay, followed by Back Bay, and were lowest in Zeemel Bay.

Benthic macroinvertebrate samples were collected at a 5 m depth in St. Mary's Channel and Langley Bay in 2004, and in Dixon Bay in 2005. The dominant taxon in Langley Bay was the genus Tanytarsus sp., which comprised 23% of the sample population. The dominant taxon from St. Mary's Channel, the species Diporeia hoyi, comprised 63% of the sample population. The community in Dixon Bay was also dominated by organisms from the Family Haustoriidae, however, it was a different species than in St. Mary's Channel. Pontoporeia hoyei comprised 30% of the Dixon Bay sample population.

Benthic macroinvertebrate density was much higher in the samples from Dixon Bay (18,868 organisms/m²) than in St. Mary's Channel (6,944 organisms/m²) and Langley Bay (5,156 organisms/m²). Taxon richness was similar in Dixon Bay and St. Mary's Channel, but was lower in Langley Bay. Conversely, diversity indices were almost the same in Langley Bay and Dixon Bay and were lower in St. Mary's Channel. This is attributable to the relatively high proportion of a single species in St. Mary's Channel.

Fish Community

During the 2004 fish community survey conducted in St. Mary's Channel and Zeemel Bay, a total of 25 northern pike and six lake whitefish were captured by gillnets. Additionally, two juvenile northern pike, nine lake chub (Couesius plumbeus), two slimy sculpin (Cottus cognatus), and two burbot (Lota lota) were captured by electrofishing.

Ciscoes (Coregonus artedii) were identified in the stomachs of northern pike. In 2005, one half standard gang gillnet set in St. Mary's Channel in front of the mouth of Zeemel Bay resulted in the capture of nine northern pike, three lake trout (Salvelinus namaycush), and ten lake whitefish. The stomach contents of the three northern pike contained numerous slimy sculpin and ninespine stickleback (Pungitius pungitius).

The 2004 fish community survey conducted in Langley Bay resulted in the capture of ten northern pike and four lake whitefish by gillnets, and five juvenile northern pike and one yellow perch (Perca flavescens) by electrofishing. Additionally, one juvenile northern pike was identified from the stomach of a northern pike. In September 2005, three gillnets were set in Langley Bay and these captured four northern pike and 12 lake whitefish. A lake whitefish was also found in the stomach contents of one northern pike. The higher amount of lake whitefish captured in 2005 compared to 2004 is likely a result of the nets being set at a deeper depth.

A fish community survey was conducted in Back Bay in September 2005 and the only fish species captured was northern pike. A total of ten northern pike were captured in three gillnet sets. The only fish identified in the stomach contents of the five northern pike retained for chemical analyses was also northern pike. Considering the diverse

stomach contents of the northern pike captured in the other study areas, this suggests that the species diversity is low in Back Bay and may be restricted to northern pike.

Dixon Bay contains a high abundance of fish. One gillnet set for 2.15 hours captured ten northern pike and five lake whitefish. Two burbot were captured electrofishing and one burbot was found in a northern pike stomach. In addition, one ninespine stickleback was captured electrofishing and one slimy sculpin was found in a northern pike stomach.

Fish Habitat

Fish habitat assessments were conducted in St. Mary's Channel/Zeemel Bay and Langley Bay in 2004, and in Back Bay and Dixon Bay in 2005. Each study area was assessed for its potential to provide spawning habitat for northern pike, walleye (Stizostedion vitreum), lake whitefish, arctic grayling (Thymallus arcticus), lake trout, suckers, and yellow perch. The assessments included detailing information on the density and composition of aquatic/wetland macrophyte species in the littoral zone of each study area. None of the species identified are considered rare under provincial listings.

The study area within St. Mary's Channel has an upland zone associated primarily with uranium mining activities. Some of the infrastructure has encroached into the water and has altered the shoreline and aquatic habitat. In most of the study area, the shoreline contained little or no vegetative cover, the substrate was predominantly sand/cobble/boulder, and the bottom slope was steep. High densities of aquatic/wetland macrophytes were restricted to Zeemel Bay and to the area south of the waste rock pile near Zeemel Bay. Zeemel Bay is a long, shallow, vegetated bay with organic substrate that was assessed as providing highly suitable spawning habitat for northern pike and yellow perch, and potential rearing habitat for northern pike. The remainder of the St. Mary's Channel study area provided either marginally suitable spawning habitat, or unsuitable spawning habitat, for all of the fish species assessed.

The upland area surrounding Langley Bay contained a mature, mixed forest. Near the mouth of the bay, the aquatic/wetland macrophyte cover was generally sparse to moderate and the substrate was rocky. The south and eastern portions of Langley Bay constituted the area of Gunnar tailings deposition within the bay. The substrate consisted of tailings fines and was completely void of rocks. The depth remained shallow (<0.5 m) until approximately 20-30 m into the bay perpendicular to the shore. The littoral zone was largely covered in a good diversity and density of aquatic/wetland macrophytes. Langley Bay had an abundance of moderately suitable spawning habitat for walleye, lake whitefish, northern pike, and yellow perch due to the high densities of shallow cobble areas with near shore emergent aquatic/wetland macrophytes.

Back Bay was separated from the main body of Lake Athabasca by former tailings deposition from the Gunnar mine site, however, it remains connected to Langley Bay through a narrow, intermittent channel. The amount of water in the channel varies seasonally and annually. There was a high diversity of aquatic/wetland macrophytes

consisting predominantly of sedge and cattails. The channel width ranged from 4 to 8 m and the depths ranged from 0.7 to 1 m during the 2005 survey.

The deepest part of Back Bay was near the bedrock outcropping on the south side of the bay. The remainder of the bay contained a gentle to moderately sloped lake bottom with high densities of aquatic vegetation. In the eastern part of the bay, the substrate consisted mostly of silt/clay/tailings, while in the western part of the bay, the substrate contained a high cobble/boulder content. There was an abundance of marginally to moderately suitable spawning habitat for northern pike and yellow perch, however, large densities of submergent vegetation and algae precluded the habitat from being rated as highly suitable. Suitable spawning habitat for other fish species was not identified.

Dixon Bay contains a diversity of habitat types that are typical of those found throughout Lake Athabasca. The initial part of the study area contained rocky substrate with sparse to moderate densities of vegetation. These areas provide potential spawning habitat for species that prefer to spawn on rocky substrate, including arctic grayling, lake trout, lake whitefish, suckers, and walleye. The area of Dixon Bay sheltered behind the island contained high densities of emergent aquatic/wetland macrophytes, especially sedge, which provide good spawning habitat for northern pike and yellow perch.

Discussion

The potential environmental concerns identified in the study area of St. Mary's Channel during the 2004 and 2005 aquatic investigations included: 1) elevated radionuclide levels measured in the sediment near the channel that previously connected Gunnar pit to Lake Athabasca, and 2) higher uranium levels in the fish tissues when compared to the fish from the reference area.

In Zeemel Bay, the waste rock pile seep continues to be a source of contamination and this may require addressing as part of the remediation strategy.

The tailings area in Langley Bay is being re-colonized by a diversity of aquatic vegetation which provides habitat for fish and a food source for wildlife. Even though the fish species chemically analyzed were large-bodied and potentially migratory, their tissue samples demonstrated elevated radionuclide levels compared to the reference fish.

Back Bay contains high contaminant levels, large algal blooms, and it appears that northern pike are residing there. It is of a sufficient size and depth to provide year-round fish habitat. In addition, the channel connecting Back Bay to Langley Bay permits fish migration when water levels are adequately high. At the time of the survey, Back Bay contained a high diversity and density of migratory ducks and there was beaver activity in the creek. Therefore, the habitat provided by Back Bay is used by aquatic and terrestrial wildlife who would be subject to contaminant exposure.

8.1.6. Gamma Radiation

A detailed review of previously conducted gamma surveys conducted on the Gunnar mine site and associated facilities was completed during the course of the preparation of this report. This included the results of a survey conducted by Saskatchewan Environment and Public Safety in 1993, as well as data collected by representatives of the Canadian Nuclear Safety Commission during its 2003 inspection of the site (CNSC, 2003).

In addition, during the 2004 investigation, more than 5,000 additional gamma radiation measurements were taken of relevant areas of the Gunnar site. The 2004 gamma investigation was conducted using systematic measurement of gamma levels at one metre above surface on a 2 m grid pattern in the following areas:

- The north and south waste rock piles,
- The areas of waste rock near the open pit;
- The ore haul road from the pit to the eastern end of the mill (i.e. ore dump):
- The area surrounding the acid plant,
- The area between the mill and the various conveyors and ore storage bins.

In addition, the 2004 gamma survey included each of the three separate tailings management areas by conducting a 60 – 90 minute traverse of each individual area using the automatic recording capacities of the gamma meter. In all instances, the survey was conducted using an Automess 6150 AD6 Gamma Metre manufactured by Automess GmbH. The meter was calibrated each morning and all gamma measurements were taken on a two metre grid and at a 1 m (waist) height (the same model instrument used by both the 1994 survey conducted by Saskatchewan Environment and Public Safety). The Automess AD 6 instrument reports in the units of microsievarts per hour ($\mu\text{Sv/h}$) but in fact actually measures microrem per hour ($\mu\text{R/h}$, where Rem or R stands for roentgen equivalent man) and assumes a simple conversion to μSv using a factor of 0.01. In reality, the conversion factor is smaller. While various conversions can be developed, the UNSCEAR 1993 report assumes a default conversion factor of 0.7 sieverts/gray (Sv/Gy) for converting absorbed dose in air to effective dose received by adults.

Thus, the simple conversion implicit in the Gunnar gamma survey results is a conservative overestimate of the dose to a casual visitor to the site.

The primary issue to be addressed by this survey was the identification of any areas of elevated radiation which would be of concern in terms of the health and safety of workers who theoretically would spend extended time on the site during a rehabilitation operation. Table 3.5 and 3.6 presents a summary of the results of the various gamma surveys conducted of the former Gunnar Mines Ltd. site.

A post-decommissioning gamma radiation level of 250 $\mu\text{R/h}$ ($\approx 2.5 \mu\text{Sv/h}$), the maximum dose from any individual area, provides a reasonable basis for evaluating gamma radiation surveys in support of decommissioning. At the time that the Eldorado

Beaverlodge mill and mines were decommissioned, an objective of 100 $\mu\text{R}/\text{h}$ was established as the (maximum) average dose after decommissioning and a level of 250 $\mu\text{R}/\text{h}$ established as the maximum allowable dose at any individual area (Eldorado, 1983). However, in addition to this benchmark, it is important that the public dose limit of 1 millisieverts per annum (mSv/a , where 1 $\text{mSv}/\text{a} = 1,000 \mu\text{Sv}/\text{a}$) above the dose from natural background not be exceeded under reasonable, casual access visits to the former Gunnar site ($<100 \text{ hrs}/\text{a}$).

Site Facilities

Generally, the site does not exhibit gamma radiation levels that would constitute a serious concern to casual access by members of the public or for workers involved in the rehabilitation of the site. Saskatchewan Environment and Public Safety reported gamma radiation levels in the support buildings (non-production facilities) as ranging from a background of less than 0.1 $\mu\text{Sv}/\text{h}$ to 1.5 $\mu\text{Sv}/\text{h}$ (at 1 metre), the latter of which was a measure of the levels on the haul road from the head frame to the mill (Sask, 1994).

During that study, three areas were identified on the site that would require special attention prior to the introduction of a full work force to the site: the product packaging area and string filters within the mill building and two fines piles near the conveyor annex attached to the mill.

Saskatchewan Environment reported that the string filters in the mill had gamma levels ranging from 5.0 to 12.0 $\mu\text{Sv}/\text{h}$ (at surface) which was the highest level measured anywhere on the Gunnar site (Sask, 1994). In the product packaging of the mill, gamma radiation levels of 10 $\mu\text{S}/\text{h}$ were measured in the vicinity of what appeared, and was later identified as residual U_3O_8 remaining from operations. The total volume of residual product was estimated at less than 0.25 m^3 (Sask, 1994)

That same report stated that three fines piles existed on the exterior of a conveyor annex slightly south of the mill (approximate total volume of 3 m^3) were identified as having elevated gamma radiation levels. Saskatchewan Environment reported that these piles were measured at 5.0 $\mu\text{Sv}/\text{h}$ at 1 m (6.0 - 7.0 $\mu\text{Sv}/\text{h}$ at surface).

The 2004 SRC investigation did not confirm the gamma measurements report for areas within the mill itself as the mill building was secured against entry, however, the fines piles in front of the mill and the conveyors was the subject of a more detailed survey in 2004. The entire area was surveyed on a two-metre grid with a total of 161 different measurements being taken. The 2004 investigation resulted in an average gamma level (at 1 m above surface) of 1.9 $\mu\text{Sv}/\text{h}$ with a maximum of 5.16 $\mu\text{Sv}/\text{h}$ identified. In total, 34 of the measurements exceeded the 2.5 $\mu\text{Sv}/\text{h}$ benchmark established for maximum.

Waste Rock Piles

The 2004 SRC investigation also included a survey of the two major waste rock piles at the former Gunnar Mine site. This entire waste rock area was surveyed on a two-metre grid with a total of approximately 3000 separate measurements being taken. The 2004

investigation resulted in an average gamma level (at 1 m above surface) of 0.98 $\mu\text{Sv/h}$ (with a maximum of 4.88 $\mu\text{Sv/h}$) identified. In total, 42 of the measurements exceeded a 2.50 $\mu\text{Sv/h}$ benchmark established as the maximum for post decommissioning. It must be noted that in virtually all instances, those areas measured above the 2.5 $\mu\text{Sv/h}$ criteria were areas that did not consist of waste rock but were materials that had been hauled to the waste rock pile and end dumped from the back of a truck. The materials appeared to be hauled from the mill and may have been sludges etc. from tanks that were emptied at the time the mill was shut down. Notwithstanding this observation the areas which exceeded 2.5 $\mu\text{Sv/h}$ were not contiguous or situated in close proximity to each other on the surface of the waste rock piles. In total, there were 19 separate areas, each approximately 2 m² that exceed 2.5 $\mu\text{Sv/h}$.

Based on these results, for an assumed 100 hours per annum (h/a) of casual exposure to the waste rock piles by a casual visitor to the Gunnar site, the dose to a member of the public would amount to approximately 98 microsieverts per annum ($\mu\text{Sv/a}$), which is well below the annual dose limit of 1000 $\mu\text{Sv/a}$.

Tailings Areas

The tailings pipeline from the rear of the mill to the tailings area shows evidence of tailings spills along its entire length, however measured gamma levels were generally less than 2 $\mu\text{Sv/h}$. It should be noted that the area shows aggressive natural re-vegetation including trees currently in excess of 2 m in height.

A gamma radiation survey was also conducted on the three separate tailings areas at the Gunnar site. The tailings themselves typically had an average gamma level of 4 $\mu\text{Sv/h}$ at 1 m and the rate varied very little with the height at which the measurement was taken.

8.1.7. Ambient Radon

One of the radionuclides released by exposed uranium mine waste rock and tailings such as that present at the Gunnar site is radon-222 (“radon”), a decay product of Radium-226 (²²⁶Ra). ²²²Rn is an inert gas with a radiological half-life of 3.82 days. The release to the atmosphere of ²²²Rn and its decay produces lead-210 (²¹⁰Pb, with a half life of 22 years) and polonium-210 (²¹⁰Po) can be an important environmental pathway of radiological exposure.

In 1985, in an attempt to quantify the extent of impacts from radon at the Gunnar site, Concord Scientific Corporation (BBT, 1986) established 13 monitoring stations in and around the Gunnar facilities and the associated tailings areas. At each of these stations, a Terradex TRACK-ETCH Type ‘F’ detector was deployed in a protective canister, approximately 1 metre above the ground. Two of the sites contained duplicate detectors to allow a measure of sampling precision.

As part of the 2004 site characterization campaign, nine Radtrak radon detectors supplied by Landauer Inc. (Glenwood, Illinois) were deployed at various locations throughout the

Gunnar site. Efforts were made to locate these detectors in locations that approximate those used in 1985.

As per the manufacturers direction, each detector used in 2004 was installed in a protective canister that was itself installed approximately 1.5 metres above the ground. Figure 8.1.2 provides a representation of each station location.

Radon Monitoring Results

The following table presents the results of the ambient radon monitoring conducted at the Gunnar site to date.

<i>Location</i>	<i>Average Concentration (pCi/L)</i>	<i>Radon</i>
A1	1.4	
A2	3.2	
A3	1.0	
A4	3.3	
A5	1.1	
A7	1.5	
A8	2.8	
A11	2.2	
A13	1.7	
A14	2.3	

A review of this data shows that the monitoring since 2004, the average ambient radon concentration at the Gunnar site was 2.05 pCi/L. This can be compared to the average radon concentration of 1.32 pCi/L measured at the decommissioned Beaverlodge site between 2000 and 2003 concentration and the Saskatchewan and Saskatoon radon concentration of 1.64 and 1.67 pC/L respectively reported by Health Physic (1994).

8.1.8. Ecological and Human Health Risk Assessment

Using the results of the SRC and Canada North investigations, the Saskatchewan Research Council (SRC) requested SENES Consultants Ltd. to conduct an assessment of existing ecological and human health risks at the orphaned Gunnar Mine site in Northern Saskatchewan, as well as the impact of preliminary remedial options for reducing the risks at the site. The entire report is included as Appendix C.

The Gunnar site has been subject to a number of studies and investigations over the last 40 years, the most recent being in 2004 when field investigations substantially increased the site data and knowledge base. Also, a thorough review of preliminary remedial options was completed at that time and this provides a solid base for moving forward to decision making for final closure.

Physical, chemical and radiological hazards are known to exist at the Gunnar site. These hazards present ecological and human health risks, but these risks have yet to be quantified and assessed. Without this assessment, site remedial options have been guided primarily by aesthetic and practical considerations only.

A human health risk assessment (HHRA) evaluates the probability of adverse health consequences caused by the presence of contaminants in the environment. In a HHRA, receptor characteristics (e.g., portion of time spent in the study area, source of drinking water, composition of diet) and exposure pathways (e.g., ingestion of berries) are taken into consideration to quantify the risk of adverse health effects. Unlike an ecological risk assessment (ERA), which is concerned with population effects, the HHRA focuses on effects on individuals.

Additionally, a HHRA does not follow the tiered framework of the ERA; rather, it relies mainly on measured data where possible and concentrations of contaminants of potential concern (COPC) in the flesh of animals calculated from the ERA. The HHRA uses scenarios that are considered to be realistically conservative for the site in order to ensure that potential exposures and risk are over estimated. In this assessment, the HHRA examined the potential adverse effects on individuals visiting and using the Gunnar Mine site under current conditions for various purposes and periods of time.

Ecological risk assessment (ERA) is the evaluation of the probability of adverse health consequences to ecological receptors such as fish, terrestrial vegetation, soil-dwelling organisms, mammals and birds caused by the presence of contaminants at a site.

The Canadian Council of Ministers of the Environment (CCME) (CCME 1996) has provided general guidance concerning its views on what constitutes an ecological risk assessment (ERA).

The recommended framework is similar to that proposed by Environment Canada (Environment Canada 1997) and is supported by the Ontario Ministry of the Environment (MOE 1996). The CCME recommends three levels of investigation:

- Screening Level Assessment (SLA or Tier 1): essentially a qualitative assessment of potential risks to important ecological receptors.
- Preliminary Quantitative Risk Assessment (PQRA or Tier 2): focuses on filling gaps identified at the screening level.
- Detailed Quantitative Risk Assessment (DQRA or Tier 3): includes more detailed data and modeling.

The rigour of the risk assessment adopted for a particular situation should be commensurate with the degree and extent of potential harm and may progress to a more stringent level (i.e., from Tier 1 to Tier 2 or from Tier 2 to Tier 3) depending on the findings at each level. Each level in this tiered approach has the same structure and builds upon the data, information, knowledge and decisions generated from the preceding level. Thus, each level is progressively more rigorous and complex. Each level of the assessment includes the following elements:

- Receptor Characterization: At this phase of the assessment, the potential receptors are identified and the pathways of exposure are defined.
- Exposure Assessment: The purpose of this stage is to quantify the contact between the receptor and the contaminant of concern.
- Hazard Assessment: This phase of the ERA examines the potential effects of a contaminant to a receptor.
- Risk Characterization: The risk characterization stage combines the information collected in the exposure assessment and the hazard assessment, and the potential for adverse ecological effects is estimated.

Adverse ecological effects are characterized by the value of a simple screening index (generally considered to be 1). This index is calculated by dividing the expected exposure concentration or dose by the selected toxicity reference value for each ecological receptor. An ERA is concerned with estimating effects on populations, communities and ecosystems (multi species). Estimation of population level impacts is a complex issue and involves some level of scientific judgment.

A selection process was used to identify the contaminants of potential concern (COPC) at the former Gunnar Mining Limited site as described in Appendix A of SENES 2005. To summarize, the concentrations in water and soils in the affected area were compared statistically to background/baseline concentrations.

Those contaminants that were found to be significantly different from background/baseline were then compared to CCME guidelines for water (for protection of aquatic life) and/or for soil (for residential/parkland use). If the measured levels exceeded either guideline value, or if guidelines were not available, then the contaminants were carried through the risk assessment.

Based on this screening procedure, the following contaminants were identified as COPC: antimony; arsenic; boron; cadmium; lead; manganese; molybdenum; strontium; uranium and vanadium. The uranium decay series of radionuclides (uranium-238, radium-226, thorium-230, polonium-210 and lead-210) were also considered as COPC because the site was a former uranium mine and radionuclides are known to cause cancer.

Maximum measured selenium levels in surface water and fish muscle tissue at the Gunnar Mine site are 0.005 mg/L (0.5 µg/L) and 0.51 µg/g(dw), respectively. Selenium has the ability to bioaccumulate and biomagnify through aquatic food webs and therefore, this factor was taken into account in the screening process. Lemly and Smith (1987) indicate that selenium water concentrations of 2 to 5 µg/L can result in reproductive effects due to food-chain bioconcentration. In addition, the U.S. EPA (2004) in their draft aquatic life criterion for selenium indicate that a muscle concentration of 8.8 µg/g(dw) or (2 µg/g(dw)) may result in reduced survival following water and dietary exposure. The maximum measured concentrations in water and fish muscle tissue are well below these benchmarks and thus, selenium was not considered to be a COPC. In the Gunnar Pit, maximum measured fish muscle concentrations were 1.9 µg/g(dw). This level is just below the 2 µg/g(dw) benchmark; however, fish in the Gunnar Pit have been noted to be healthy (CanNorth 2004).

Surface water samples in Back Bay, Langley Bay, Zeemel Bay and St. Mary's Channel all had mercury concentrations below detection limits. Concentrations of mercury in muscle tissue of forage fish were below detection limits whereas predatory fish in Back Bay, Langley Bay and St. Mary's Channel had maximum measured concentrations of mercury in muscle tissue ranging from 0.16 to 0.28 µg/g(ww). These levels are very similar to mercury levels measured in the Northwest Territories (SENES 2005). However, in Gunnar Pit the mercury levels in fish muscle tissue are approximately three times higher (0.73 µg/g(ww)) than those measured in Back Bay, Langley Bay and St. Mary's Channel. These measured levels are above the guideline level of 0.5 µg/g(ww) that Saskatchewan has derived for mercury consumption of fish by humans (SERM 1999). It is unlikely that humans will catch and eat fish from the Pit given that Lake Athabasca is in close proximity; however, if they consume a fish from the Pit, it is unlikely to cause any adverse effect in humans.

The Canadian Council of Ministers of the Environment (CCME 2001) have developed an ecological Tissue Residue Guideline (CTRG) of 0.03 µg/g(ww) of methyl mercury in prey. The measured levels of mercury are above this guideline value. There is a healthy population of fish in Gunnar Pit (CanNorth 2004) indicating that there are no adverse effects occurring in fish in the Gunnar Pit from these high mercury tissue concentrations. There is a likelihood that ducks and small terrestrial animal may consume some fish from the Gunnar Pit; however, there is not sufficient habitat around the Pit to support any sizeable population of these species; therefore, it is unlikely that any adverse effects would be observed in populations of ecological species that have a substantial fish diet. Therefore, mercury is not considered further in the assessment.

Summary and Conclusions

According to SENES 2005, several sampling programs have been conducted over the course of the last 20 years and two recent programs (2004 and 2005) capture the existing conditions at the site. The available data for the site were used to identify contaminants of potential concern (COPC) to be carried through the assessment. As the objective of this assessment was to determine the potential impact of current conditions, emphasis was placed on the use of data from the 2004-2005 period.

A pathways model was used to estimate exposure levels (intakes or doses) to ecological receptors and people from contaminants in the environment taking into account the dietary characteristics of the receptors and on-site locations where the receptors might spend significant amounts of time. The modeling relied on measured data but also employed transfer factors to estimate concentrations in environmental media that were not measured (e.g. berries). Exposure estimates were then compared to toxicological reference values for metals and dose limits for radioactivity to identify combinations of contaminants and receptors that may require further investigation.

The COPC identified for the risk assessment included: antimony, arsenic, boron, cadmium, lead, manganese, molybdenum, strontium, uranium (chemical toxicity), vanadium and radioactivity.

For the ecological risk assessment, a range of ecological receptors were examined from different trophic levels in the aquatic and terrestrial environments. As there are no people currently living on-site, it was assumed for the human health risk assessment that adult and child campers could spend up to 3 months per year at various locations on-site.

The results of the radionuclide assessment for aquatic receptors highlighted that, in general, releases from the Gunnar Mine site do not pose any risk of adverse effects to aquatic biota with the exception of aquatic plants. The measured radionuclide concentrations in aquatic plants in Back Bay, Langley Bay and the area close to the waste rock seep on Zeemel Bay are substantially higher than background. Aquatic screening index values were calculated for the non-radionuclide COPC. The results of this assessment indicate that uranium exposure, in particular has the potential to result in adverse effects to aquatic species in several water bodies across the site including the Gunnar Main Surface Discharge, Back Bay, Langley Bay and the Gunnar Pit. The uranium concentration in waste rock seep from the toe of the waste rock pile is high and may cause potential adverse effects on aquatic species in the wetland area into which the seep flows as well as a portion of Zeemel Bay directly outside the wetland. It should be noted that this area in Zeemel Bay is quite small and the rest of Zeemel Bay has low uranium concentrations.

The assessment of exposure to terrestrial wildlife to radionuclides indicated that there are no risks of adverse effects from radiation exposure. Exposure to non-radionuclides showed that uranium is an issue for terrestrial animals with a large aquatic diet such as beaver, ducks, mink and muskrat. Uranium concentrations in aquatic plants, benthic organisms and sediments are the main contributors. The areas of concern include the Gunnar Pit, Back Bay, Langley Bay and the small area in Zeemel Bay close to the waste rock seep.

The radiological dose estimates for the hypothetical campers (adults and children (5 to 11 yrs)) on the site were below the regulatory incremental dose limit of 1000 $\mu\text{Sv/y}$. However, the predicted doses were close to limit with gamma exposures amounting for the majority of the dose. Hence, reduction of the gamma fields on the exposed tailings may warrant considerations in the development of the remediation plan for the site. Exposures to the non-radionuclides on site are not predicted to result in adverse health effects to individuals who might spend time onsite.

The entire *Screening Level Human Health & Ecological Risk Assessment of the Gunnar Site* report prepared by SENES Consultants Ltd. in March 2006 is included as Appendix C.

9. INVENTORY OF RESIDENT NUCLEAR SUBSTANCES

9.1. Waste Rock

The total volume of waste rock present on the former Gunnar Mining Limited site has been estimated at 2,710,700 m³ (BBT Consultants, 1986) and includes both mine waste rock and overburden generated from surface stripping of the open pit. The majority of the waste rock is located in two piles immediately to the east of the now-flooded open pit and covers a total of approximately 10 hectares (BBT Consultants, 1986). The waste rock is located on the shore of Lake Athabasca with the toe of one of the waste rock piles protruding into the water of the lake proper and into a shallow area immediately east of the waste rock pile itself.

A gamma survey of the entire waste rock pile was conducted in June 1985 by BBT Consultants using a hand held, multiple range Berthold “Ratio/F” gamma dose-rate metre. Readings were taken at heights of 0.1 and 0.2 m above the surface at 73 locations. Survey control for the readings was achieved by a transit and stadia method.

The average readings on the waste rock pile were approximately 150 µR/hr regardless of height. Only ten percent of the readings from the 73 locations were greater than 1 mR/hr. (BBT Consultants, 1986). During a recent (July 2003) inspection of the site, Canadian Nuclear Safety Commission staff reported average gamma measurement on the waste rock pile of 1.49 µSv/h (maximum 6.13 µSv/h) (Stenson to Danielson, 2003).

To attempt to quantify the extent of impact of the waste rock piles on the surrounding air, radon measurements were made, in 1985, at areas of high gamma activity using the “mat” technique by Concord Scientific Corporation (BBT, 1986). One large mat (approximately 3m X 3m) was deployed on the northern edge of the waste rock pile in April 1985 and five cups were placed under the mat to measure radon. Detailed results are reported in BBT, 1986. Generally, the radon levels from the waste rock piles were found to be significantly lower than those on the Main Tailings area and were measured at between 199 and 361 pCi/L with a mean of 250 pCi/L.

The 2004 SRC investigation included a survey of the two major waste rock piles at the former Gunnar Mine site. This entire waste rock area was surveyed on a two-metre grid with a total of approximately 3000 separate measurements being taken. The 2004 investigation resulted in an average gamma level (at 1 m above surface) of 0.98 µSv/h (with a maximum of 4.88 µSv/h) identified. In total, 42 of the measurements exceeded a 2.50 µSv/h benchmark established as the maximum for post rehabilitation. It must be noted that in virtually all instances, those areas measured above the 2.5 µSv/h criteria were areas that did not consist of waste rock but were materials that had been hauled to the waste rock pile and end dumped from the back of a truck. The materials appeared to be hauled from the mill and may have been sludges etc. from tanks that were emptied at the time the mill was shut down. Notwithstanding this observation, the areas which

exceeded 2.5 µSv/h were not contiguous or situated in close proximity to each other on the surface of the waste rock piles. In total, there were 19 separate areas, each approximately 2 m², that exceed 2.5 µSv/h.

Samples of the waste rock piles were previously recovered/analyzed as part of the 1985 investigation (BBT, 1986) and a summary of the results is presented in Appendix C of *Gunnar Site Characterization and Remedial Options Review*, Saskatchewan Research Council, January 2005.

The following table provides a summary of the 1986 results of waste rock sample analysis for select parameters.

	WR2	WR3	WR4	WR5	Average
Uranium (µg/g)	78.1	4.6	14.1	4.1	25.2
Thorium-230 (Bq/g)	0.09	0.08	0.18	0.11	0.12
Radium-226 (Bq/g)	0.90	0.07	0.16	0.13	0.32

As part of the 2004 SRC investigation, the waste rock piles were also sampled to determine the potential for acid rock drainage (ARD) and metals leaching potential. Appendix E2 of *Gunnar Site Characterization and Remedial Options Review*, Saskatchewan Research Council, January 2005 provides a discussion of the preliminary examination of the Gunnar waste rock.

A set of five samples were taken from shallow shovel pits across the waste rock piles. The sample sites were located in a widely-spaced pattern on the waste rock piles (*Gunnar Site Characterization and Remedial Options Review* Appendix E2, Figure D1). The individual samples consisted of approximately 10-12 kg of material composed of broken rock with a wide range of fragment sizes from silty material (<64 µm) to cobble size (up to ~10 cm in length).

The geochemical data for the reference rock pieces indicate that the granite samples are generally similar in chemistry while the mafic hornblende gneiss is more siliceous and contains significantly higher amounts of iron and magnesium at the expense of alumina and the alkali and alkaline earth elements (CaO, K₂O, Na₂O). The pink/red-orange hornblende granite (WR#5 ref. piece) is relatively aluminous, calcic, and sodic, at the expense of silica, and also contains minor amounts of carbonate. A comparison of the waste rock data with the reference piece data shows an overall agreement indicating that the waste rock materials are composed of these rock types in varying fragment sizes.

The trace element data from these waste rock samples show moderately elevated values for only a few elements, primarily U and Pb in waste rock samples WR#4 and WR#5. In these samples, the U contents are between 106 and 253 ppm. The -0.5" size-fraction materials (253 and 184 ppm) contain nearly double the amount present in the +0.5" size-fraction materials (120 and 106 ppm). U is also elevated to a lesser extent (50-60 ppm) in waste rock sample WR#2 and, again, in the -0.5" size-fractions of waste rock samples

WR#1 and WR#3. All of these values are significantly higher than the amounts of U present in the reference piece samples (5 to 23 ppm).

The sulphur contents of all of these waste rock samples are low, all being < 0.10 wt% and most being <0.06 wt%. Thus there does not appear to be much of an acid generation potential for these materials. The carbonate contents of these samples are variable from 0.4 to 2.2 wt% CO₂ (C expressed as CO₂). Thus the potential for base neutralization by these materials appears to exceed their acid generation potential.

9.2. Tailings

Mill tailings were originally discharged from the mill, at 32% solids, through a 1,500 ft. long, 10 in. diameter wooden stave pipe. In total, it has been estimated that the Gunnar Mining Limited mill discharged a total of 4.4 million tonnes of tailings during operations (BBT, 1986).

The following table provides a summary of available data for production at the Gunnar Mining Limited facility. During its peak year, 1958, milling capacity was increased to 2,000 tons of ore per day in order to handle the ore from both the open pit and the underground mine. The average ore recovery during 1961 was 95.5% producing uranium precipitate which consisted of 76% U₃O₈.

Production Data – Gunnar Mining Limited

(Source: Company Annual Reports)

<i>Year</i>	<i>Daily Production (Tons of Ore Treated)</i>	<i>Mill-Head Grade (% U₃O₈)</i>	<i>Annual Production (Tons of Ore)</i>
1956	-	0.191	451,632
1957	1.647	0.178	601,262
1958	1.95	0.188	711,298
1959	1.975 (approx.)	0.184	719,785 (approx.)
1960	1.942	0.185	710,785
1961	2.039	-	744,227
1962	2.155	-	786,481
1963	1.848	-	769,000

As part of the National Uranium Tailings Program (NUTP) investigation of the Gunnar Site, boreholes and wells were completed into tailings areas (BBT, 1986). Samples of the soils and tailings materials encountered during the drilling of these boreholes and wells were submitted for chemical analyses; results of these analyses are included in Appendix C of *Gunnar Site Characterization and Remedial Options Review*, Saskatchewan Research Council, January 2005 which is appended..

BBT (1986) analyzed these soils and tailings samples for up to three components; water soluble component, acid soluble component and fusion component, which were combined to make up the total concentrations. The water soluble component is

interpreted to provide an indication of the readily mobilized material. The acid soluble component was interpreted to represent the fraction that was mobilized during the acid leach in the mill and subject to re-precipitation in the tailings areas in the form of hydroxides (BBT, 1986). The fusion component was the residue after water and acid soluble material had been removed; this component is thought to be relatively immobile. These three components were also combined into a total concentration of the tested parameters.

The 1986 study showed that there was general variability of all three components due to changes in the material and amount of leaching these materials were exposed to. It is reasonable to expect that, in the intervening years, in general the water soluble concentrations and, to a lesser degree, the acid soluble concentration had been reduced. The following table summarizes the variation in the uranium, thorium-230 and radium-226 concentrations.

<i>Location</i>	<i>Total Concentrations (BBT, 1986)</i>		
	<i>Uranium (µg/g)</i>	<i>Thorium-230 (Bq/L)</i>	<i>Radium-226 (Bq/L)</i>
<i>Gunnar Main</i>			
<i>Average</i>	43.5	3.9	6.9
<i>Minimum</i>	4	0.13	0.2
<i>Maximum</i>	77	12.5	30
<i>Gunnar Central</i>			
<i>Average</i>	32.5	10.0	14.9
<i>Minimum</i>	4	0.11	0.2
<i>Maximum</i>	77	25	50
<i>Langley Bay</i>			
<i>Average</i>	36.9	10.2	14
<i>Minimum</i>	4.4	7	0.6
<i>Maximum</i>	82	15	45

Addition tailings samples are being collected to verify this historical information.

10. SITE SECURITY

10.1. The Gunnar Site

Because of the remote location and limited population near the property, there is minimal security at the site. The site is located on the southern tip of the Crackingstone Peninsula, approximately 25 kilometres southwest of Uranium City. There are no roads to the site and it is only accessible by light aircraft or boat/barge in the summer and over the ice in winter.

Approximately 121 people live within 80 kilometres of the Gunnar Mining Limited site. According to Saskatchewan Northern Municipal Services, as of November 2005, Uranium City, which is located approximately 25 kilometres north of the mine site had a total population of 84 permanent and part-time residents and Camsell Portage, located approximately 37 kilometres northwest of the mine site, had a total population of 37 (see Figure 2.1.2).

11. SITE HEALTH AND SAFETY CONSIDERATIONS

11.1. Risk Assessment

A pathways model was used to estimate exposure levels (intakes or doses) to ecological receptors and people from contaminants in the environment, taking into account the dietary characteristics of the receptors and on-site locations where the receptors might spend significant amounts of time. The modeling relied on measured data but also employed transfer factors to estimate concentrations in environmental media that were not measured (e.g. berries). Exposure estimates were then compared to toxicological reference values for metals and dose limits for radioactivity to identify combinations of contaminants and receptors that may require further investigation.

The contaminants of potential concern (COPC) identified for the risk assessment included: antimony, arsenic, boron, cadmium, lead, manganese, molybdenum, strontium, uranium (chemical toxicity), vanadium and radioactivity.

For the ecological risk assessment, a range of ecological receptors were examined from different trophic levels in the aquatic and terrestrial environments. As there are no people currently living on-site, it was assumed for the human health risk assessment that adult and child campers may spend up to 3 months per year at various locations on-site.

The results of the radionuclide assessment for aquatic receptors highlighted that, in general, releases from the Gunnar Mine site do not pose any risk of adverse effects to aquatic biota with the exception of aquatic plants. The measured radionuclide concentrations in aquatic plants in Back Bay, Langley Bay and the area close to the waste rock seep on Zeemel Bay are substantially higher than background. Aquatic screening index values were calculated for the non-radionuclide COPC. The results of this assessment indicate that uranium exposure, in particular, has the potential to result in adverse effects to aquatic species in several water bodies across the site, including the Gunnar Main Surface Discharge, Back Bay, Langley Bay and the Gunnar Pit. The uranium concentration in waste rock seep from the toe of the waste rock pile is high and may cause potential adverse effects on aquatic species in the wetland area into which the seep flows as well as a portion of Zeemel Bay directly outside the wetland. It should be noted that this area in Zeemel Bay is quite small and the rest of Zeemel Bay has low uranium concentrations.

The assessment of exposure to terrestrial wildlife to radionuclides indicated that there are no risks of adverse effects from radiation exposure. Exposure to non-radionuclides showed that uranium is an issue for terrestrial animals with a large aquatic diet such as beaver, ducks, mink and muskrat. Uranium concentrations in aquatic plants, benthic organisms and sediments are the main contributors. The areas of concern include the

Gunnar Pit, Back Bay, Langley Bay and the small area in Zeemel Bay close to the waste rock seep.

The radiological dose estimates for the hypothetical campers (adults and children (5 to 11 yrs)) on the site were below the regulatory incremental dose limit of 1000 $\mu\text{Sv/y}$. However, the predicted doses were close to limit with gamma exposures amounting for the majority of the dose. Hence, reduction of the gamma fields on the exposed tailings may warrant considerations in the development of the remediation plan for the site. Exposures to the non-radionuclides on site are not predicted to result in adverse health effects to individuals who might spend time onsite.

11.2. Safety

In August/September 2003, the Government of Saskatchewan completed a number of activities at the Gunnar Mining Limited site designed to limit casual access to the mill building, the bulk ore storage building near the mill, the acid plant, head frame, community centre and bulk storage tanks. These activities included:

Mill Building, Head Frame & Acid Plant

- If entry to the building could not be adequately secured, all internal stairways were removed at a height of not less than 2.5 metres above the floor.
- All exterior stairways and ladders reaching to ground level were cut off at a height of not less than 2.5 metres from the ground.
- Chain link fencing was securely installed to limit all access to the capped mineshaft.
- All doors, if they existed, were closed and secured by permanently welding, welding a steel reinforcement to permanently close or anchored by fastening with bolts/screws (with bolts/screws left in an inoperable manner).
- If no door existed, the opening was secured with 8' chain link fencing welded or anchored to the building, using screws/washers (with screws left in an inoperable manner).
- All window openings extending to less than 2.5 metres above the ground were secured using chain link fencing welded or anchored to the building, using screws/washers (with screws left in an inoperable manner).
- All other openings (due to vandalism, deteriorated siding, etc.) less than 2.5 metres from the ground that would allow access into the buildings were secured with chain link fencing welded or anchored to the building, using screws/washers (with screws left in an inoperable manner).

Bulk Ore Storage Tank Near Mill

- Chain link fencing, securely fastened, was used to close off an approximate 30' length of sidewall missing from the lower reach of the western-most conveyor that leads to the mill from the south ore bin tower.

Community Centre

- All doors, if they existed, were closed and secured by permanently welding them or by welding steel reinforcement to permanently close the door, or by anchoring them using screws/bolts (with screws/bolts left in an inoperable manner)
- If no door existed, the opening was secured with 8' chain link fencing welded or anchored to the building, using screws/washers (with screws left in an inoperable manner).

Bulk Storage Tanks

- Any exterior access ladders on the water tower and acid storage tanks located west of the Acid Plant Building and on the bulk fuel storage tank located near the shore to the west of the maintenance building were cut off at a height of not less than 2.5 metres above the ground.

A local contractor completed the identified work between August 21 and August 31, 2003. Following completion of the work, representatives of Saskatchewan Environment and Saskatchewan Northern Affairs conducted a site inspection on September 1, 2003 and the contractor addressed all deficiencies identified during the inspection by September 2, 2003.

Posting of Warning Signs

A total of (50) 4 ft. x 8 ft. coroplast signs were installed at various locations throughout the Gunnar Mining Ltd. site to warn casual visitors to the site of the danger posed by radiation, asbestos and the unsafe structural condition of the buildings. Figure 3.5.1 shows a mock-up of the sign design, while Photo Plates 5-9 show the placement of 6 of the 50 actual *in situ* signs posted at the site during August 2003. The signs warn in both English and Dene of the potential risk posed by radiation, asbestos and the structural integrity of the buildings, and instruct the public not to enter.

The signs were anchored every 18-24 inches to the buildings and the anchoring hardware within ground reach was left inoperable. These measures were undertaken to deter vandalism or the removal of the signs. Plastic signs are anticipated to be more effective and longer lasting because, unlike plywood, they have no secondary use by local people in the area. Therefore, there is less risk of people removing the signs for their construction value.

Free-standing signs to be erected near the tailings area and at other specified locations throughout the site were glued to plywood backing boards and then mounted, with their bottom edges a minimum 5 feet from the ground, on welded steel 6-legged stands. The elevation of the signs ensures they are readily visible, even in winter. The weight of the free-standing welded stands is intended to discourage vandalism of the signs.

The warning signs were posted as follows:

Mill Building - (14 signs):

- 2 signs secured to the east end of the building;
- 6 signs secured to the front (southern face) of the building;
- 4 signs secured to the two ore bin towers (2 each) at the west end of the mill building; and
- 2 signs secured to the north (back) side of the building.

Acid Plant Building - (6 signs):

- 4 signs secured to the front (south side) of the building (2 on each half); and
- 1 sign secured to each of the east and west ends of the building.

Head Frame Main Building - (4 signs):

- 1 sign on each side of the main building.

Other Buildings on Site - (14 signs on 13 buildings):

- 1 sign secured to the south face of the old fish plant building at its east end;
- 1 sign secured to the north side of the mine dry/geology building (located immediately north of the headframe);
- 1 sign secured to the front (east end) of the engineering building (adjoins the maintenance building along its southern edge);
- 1 sign secured to the front (east end) of the centre bay of the maintenance building, above the two industrial door openings;
- 1 sign secured to the former lodge building located amongst the trees to the southeast of the engineering building towards the lake;
- 1 sign secured to the front (south side) or otherwise most prominent face of each of the four (4) residences located immediately to the west of the mill building;
- 1 sign secured to the front face (along the road) of each of the other two residences located to the west of the former rec centre/sports complex;
- 2 signs secured to the former store/rec centre/sports complex – one on the north side and one on the south side; and
- 1 sign to be secured to the north side of the former school (visible from the road side).

Tailings Area (2 Signs)

- 1 sign was erected near the edge of the tailings area at the end of the trail leading up from the west residence; and
- 1 sign was erected near the edge of the tailings area at the end of the trail leading up from the acid plant building.

Additional Locations Throughout the Site (7 signs):

- 1 sign was erected along the road leading to the store/rec centre/sports complex at the western edge of the clearing (old soccer pitch) in front of the main residences;
- 1 sign was erected along the road leading from the store/rec centre/sports complex & west residences, at the eastern edge of the clearing (old soccer pitch) in front of the main residences;
- 1 sign was erected near the shore at the docks in front of the old fish plant;
- 1 sign was erected near the shore in the centre of the clearing (old soccer pitch) in front of the main residences;
- 1 sign was erected on the road leading to the site from the airstrip;
- 1 sign was erected near the water tower on the trail leading up to the tails, behind the acid plant building; and
- 1 sign was erected at the fork in the road, near the loose sulphur deposit at the east end of the acid plant building.

In addition, the local contractor completing the work was permitted to exercise discretion, as he saw the need, in placing (3) spare signs that had been ordered as replacements for any signs that might be damaged during their placement. These additional signs were placed on the former recreation centre building, the former fish packing plant (warehouse) near the docks and on the geology/mine dry building.

Communications with Local Public

During the summer of 2001 and 2002, as part of Saskatchewan Environment's multi-year Abandoned Mines Assessment Program, an assessment was completed on all abandoned mines (uranium, gold and base metal) in the Uranium City area. The assessment consisted of inspecting each abandoned mine site to identify and rank public safety risks and potential impacts that the sites may be having on the surrounding environment.

The inspection included all aspects of the mine itself and of the surrounding area. This included such things as locating and examining the current condition of any adits, shafts or raises, inspecting any debris and/or old buildings that may still exist, and photo documenting the site. Other activities included collecting water samples (when discharges were evident) and conducting a survey of gamma radiation levels at any of the sites where uranium was mined in the past.

During both years that the assessment took place, members of the community of Uranium City were often consulted in regard to locations and access to the sites under investigation. In addition, during both years, a local Uranium City resident was hired as part of the assessment team. As Uranium City is a small community (less than 200 people at the time), this served to significantly increase the local awareness and discussion of risks and related issues posed by the sites.

The public release of the Abandoned Mines Assessment Program reports by Saskatchewan Environment also served to raise the level of local understanding of the potential safety, radiological and environmental risks posed by some of the sites.

In addition, representatives of the Government of Saskatchewan have attended a number of fora in 2002 and 2003 in order to inform people, particularly residents of the area, of the risks posed by abandoned uranium mines in the north.

Of particular note in this regard is Saskatchewan Environment's and the Medical Health Officer's (northern Regional Health Authorities) attendance at a public meeting held in Uranium City on April 22, 2003. The public meeting was sponsored by Cameco Corporation to discuss the results of an environmental and human health assessment conducted on the residual impacts associated with the decommissioned Beaverlodge uranium mine and mill facility. A portion of the agenda was given over to Saskatchewan Environment and the Medical Health Officer to discuss not only the risks associated with that site, but also those associated with the other uranium sites located in the region.

In addition, Saskatchewan Environment and the Medical Health Officer posted public notices in every Athabasca Basin Community advising residents of the area not to drink untreated water from any lake or river and not to consume raw water from a number of specific lakes, including Beaverlodge, Nero and Langley Bay on Lake Athabasca as they contained elements that would not be eliminated by boiling. The public notice also recommended appropriate consumption levels of fish from Beaverlodge Lake, Langley Bay and a number of other lakes in the area.

Representatives of the Northern Saskatchewan Environmental Quality Committee are also present during regularly held inspections of the decommissioned Beaverlodge facilities near Uranium City and often raise the issue of the 'other' former uranium mining and milling sites in the region. Representatives of Saskatchewan Environment are always in attendance at these meetings and use the opportunity to inform the participants of the risks associated with the various sites and to recommend that community members avoid the sites if at all possible.

Instruction to Local Outfitters

On February 1, 2003, Saskatchewan Environment informed all outfitters in the Athabasca region as to the risks posed by all types of abandoned mines in the Uranium City area.

A letter was sent to each outfitter in the region pointing out that there are a number of abandoned mines that may present a risk to people who visit the sites and that plans are being prepared to address the sites of highest risk to both people and the environment. However, until such work is complete, Saskatchewan Environment formally requested that the outfitters and their staff keep clients and other visitors away from all abandoned mine sites.

The letter also stated that as part of the Abandoned Mines Assessment Program conducted from 2000 to 2002, an assessment was made of the 42 abandoned uranium mines located in the Athabasca Region and identified the Gulch, Gunnar and Lorado mine sites as the most accessible. At the Gunnar site on the Crackingstone Peninsula, hazards include deteriorating buildings, radioactive tailings and an unstable steep-walled pit. The letter went on to draw the outfitters' attention to the fact that the Gunnar site has signs posted warning people not to enter the location.

Saskatchewan Environment concluded by requesting that each outfitter advise their clients to stay away from all abandoned mines and that they report any activity observed at an abandoned mine site to the department by phoning their La Ronge or Stony Rapids offices, and provided the appropriate phone number for each.

Site Inspections

Environmental site inspections have been conducted regularly at the Gunnar site, in 1993 and 1996, and annually from 1998-2006. These inspections typically include physical inspections and gamma surveys of the buildings, facilities and grounds, as well as the collection of water samples from locations on and around the sites to identify any changes that might have occurred. As previously indicated, the Gunnar site was also subject to specific environmental site assessments in 2000, as part of Saskatchewan Environment's broader assessment of abandoned mines in northern Saskatchewan.

These inspections will continue.

Representatives of the Canadian Nuclear Safety Commission also generally conduct a site visit/inspection during the summer months each year.

12. PUBLIC CONSULTATIONS TO DATE

Since 2004, Saskatchewan Northern Affairs and the Saskatchewan Research Council has made significant effort to ensure that all of the activities undertaken at the former Gunnar Mining Limited site have been communicated to the public in Uranium City in a forum that encourages public feedback.

This has included annual public meetings held in Uranium City. Each of these meetings has included a discussion of the current activities being undertaken at the site and, in all instances, the meetings have included representatives of the Environmental Quality Committee (EQC), the Canadian Nuclear Safety Commission and Saskatchewan Environment.

The Saskatchewan Research Council intends to continue an appropriate level of engaging the public of Uranium City and the Athabasca Sub-Committee of the Northern Saskatchewan Environmental Quality Committee (NSEQC) throughout the development of the rehabilitation plan. This consultation has and will continue to be undertaken in a manner that ensures that the community and NSEQC members are fully informed about activities at the site and in a manner that maximizes the opportunity for feedback on those activities.

Planned 2007 consultation activities include inviting members of the NSEQC to the next public meeting held in Uranium City. In addition, the SRC will invite members of the EQC to a regular Gunnar site inspection tentatively scheduled for September 2007.

13. PROJECT PUBLIC INVOLVEMENT PLAN

13.1. Introduction

The prospect of a project such as the rehabilitation of the former Gunnar Mining Limited site, suggest economic benefits to a community in the form of employment and business development. However, the same project may also raise concerns and uncertainty in a segment of the community, particularly with regard to the potential for negative impacts to the biophysical environment or to traditionally important activities such as hunting and fishing.

The proponent recognizes the importance of full and open discussion of the issues and options available for rehabilitation of the site and related concerns that the communities may have in relation to these activities. In light of this, the Saskatchewan Research Council, as the proponent, wants the final rehabilitation strategy and its operational practices, both now and into the future, to reflect the values, expectations and needs of the community where SRC is operating.

Stakeholders are defined as those groups, sub-groups and individuals whom the project might affect. They all have a stake in the progress of the project, whether they are regulators, supporters or critics.

Consultations relating to this framework are to include open and informed discussion of the various options that must be considered in the rehabilitation of the site. An informed discussion and decision on the preferred option must be developed with regulator and community from the onset to ensure acceptance of the final rehabilitation of the site.

At the end of the rehabilitation of the site, all parties must be satisfied that the sites pose no danger to public health and safety, is not a source of ongoing pollution or instability and allow for productive use of the land similar to its original use or for an acceptable alternative.

As a result, the proponent may establish an Advisory Forum that would become an entity lasting through the life of the rehabilitation project. This forum would facilitate general public meetings to discuss the project in impact community(s).

13.2. Guiding Principles of all Project Consultations (Advisory Forum and General Public)

The following principles have and will continue to be used by the proponent in conducting consultations with stakeholders:

- Communicate clearly and at an appropriate time.
- Provide information promptly to encourage fair and informed discussion.

- Respond to information requests fully and quickly.
- Establish clear and realistic timetables for accepting requests, suggestions and submissions. Be sensitive to the limited resources available to people and groups.
- Provide information, particularly technical information, in plain language.
- Give practical help to people and groups to participate in the remediation work, with attention to equal opportunity.
- Include people from non-English speaking backgrounds.
- Provide frequent feedback, including the results of meetings, incoming suggestions and requests, key recommendations, and information about emerging technologies.
- Ensure that people who join the consultation process at different stages will, as much as possible, be able to influence the direction of the rehabilitation activity.
- Stimulate conciliatory and constructive exchanges of views and genuinely try to address, without prejudice, the major issues.
- Frequently monitor and evaluate the effectiveness of the consultation program during and at the end of each phase of the project.
- Share with the community the responsibility for effective consultations.

13.3. Identification of Stakeholders

The following communities/groups/agencies have been identified as key stakeholders:

- Northern Community of Uranium City
- Northern Community of Camsell Portage
- Fond du Lac First Nation
- Northern Community of Stony Rapids
- Black Lake First Nation
- Athabasca Sub-Committee of the Northern Saskatchewan Environmental Quality Committee
- Athabasca Land Use Plan Panel
- Cameco Corporation/AREVA Resources Inc.
- Saskatchewan Industry and Resources

In addition, the following regulatory agencies are considered stakeholders as they will play a direct role in the oversight of various aspects of the proposed project.

- Saskatchewan Environment
 - Assessment Branch
 - Industrial, Uranium and Hard Rock Branch
 - Fisheries Branch
- Canadian Environmental Assessment Agency
- Canadian Nuclear Safety Commission
 - Environmental Assessment & Protection Division
 - Uranium Mines and Mills Division
- Fisheries And Oceans Canada
- Environment Canada

13.4. Advisory Forum Consultation Objectives

The objectives of the Advisory Forum consultations throughout the life of the project are as follows:

Objective 1

Establish post rehabilitation land use objectives for the Gunnar site.

Objective 2

Develop and agree upon project specific standards and closure criteria for the rehabilitation of the Gunnar site.

Objective 3

Establish a set of indicators that will demonstrate the successful completion of the rehabilitation process.

Objective 4

Develop and agree upon a procedure to screen potential options for the rehabilitation of the sites.

Objective 5

Establish and agree to procedures to conduct economic evaluation of different remediation options.

Objective 6

Identify and document the responsible authority to make the final decision on when the completion criteria is met.

These objectives will be reviewed on a regular basis to ensure they remain applicable. At the end of the rehabilitation of the sites, all parties must be satisfied that the sites pose no danger to public health and safety, are not a source of ongoing pollution or instability and allow for a productive use of the land similar to its original use or an acceptable alternative.

The following provides initial points for consideration for each of the stated objectives:

Objective 1 - *Establish land use objectives for the Gunnar site after rehabilitation activities are completed.*

- Must be realistic and conditioned by the surrounding regional land use.
- What potential use will the rehabilitated land have?

Objective 2 - *Develop and agree upon project specific standards and closure criteria for the rehabilitation of the Gunnar site.*

- Standards and Closure Criteria
 - Establish a set of indicators that will demonstrate the successful completion of the rehabilitation process;
 - Standards and completion criteria are the focal point of the rehabilitation activities;

- Best Practice standards and completion criteria are those that are clearly understood and agreed to by the proponent, the regulators and other stakeholders;
 - Relevant standards for site rehabilitation ideally need to be developed on a site-specific basis based on the nature of the site and the environment in which it is situated. However, this approach also needs to be based on generic regulatory standards to provide the community with a degree of confidence that minimum acceptable outcomes will be achieved.
- Standards and completion criteria must be finely balanced between flexibility and predictability. They must allow for changes in circumstances while being specific enough to provide certainty through measurable outcomes.
 - Broad objectives for site rehabilitation are often set in the context of generic outcomes such as: “to prevent or minimize adverse long-term environmental impacts, and to create a self-sustaining ecosystem based on an agreed set of land use objectives”.
 - Overly prescriptive, uniform standards may restrict options for rehabilitation that represent best rehabilitation outcomes for a particular site but may be totally inappropriate for another.
 - Effective consultation between the proponent, the community and regulatory authorities is the best way to develop standards that are both appropriate and achievable. This will also help to ensure that there is broad agreement for both the ongoing land use objectives and the basis for measuring the achievement of the objectives.
 - More specific criteria may be developed through the life of the rehabilitation activity. These may serve as environmental indicators which, upon being met, demonstrate successful rehabilitation of the site.
 - Where/when possible, the closure criteria should be benchmarked against established standards.

Objective 3 - *Establish and agree upon a set of indicators that will demonstrate the successful completion of the rehabilitation process.*

Principles for developing project specific standards for rehabilitation of the Gunnar site are defined as follows:

1. Legislation provides broad regulatory framework for the rehabilitation process;
 - a. *Nuclear Safety and Control Act* and associated regulations;
 - b. *Environmental Management and Protection Act* and associated regulations;
 - c. Others?
2. It is in the interest of all of the various stakeholders to develop site-specific standards that are acceptable, achievable and transparent;
3. Completion criteria are specific to the rehabilitation of the site and must reflect the unique set of environmental, social and economic circumstances;

4. A set of indicators is required to demonstrate successful rehabilitation of the site;
5. Targeted research will assist both government and the proponent in making better and more informed decisions.

Objective 4 - *Develop and agree upon a procedure to assess and screen potential options for the rehabilitation of the sites.*

- Draft set of activities is provided in section 5.

Objective 5 - *Establish and agree to procedures to conduct economic evaluation of different remediation options.*

- Establish procedures to conduct economic evaluation of different remediation options.
- The procedures should be shared with and vetted by key stakeholders.

Objective 6 - *Identify and document the responsible authority to make the final decision on when the completion criteria is met.*

- Establish a mechanism to make this authority accountable.

13.5. Public Consultations

The proponent intends to continue to engage the general public of Uranium City, Camsell Portage, Fond du Lac, Stony Rapids, Black Lake, the Athabasca Land Use Plan Panel and the Athabasca Sub-Committee of the Northern Saskatchewan Environmental Quality Committee (NSEQC), communication will continue throughout development of the rehabilitation plan through scheduled public meetings in relevant communities. Consultation has and will continue to be undertaken in a manner that ensures that the communities and committee members are fully informed about activities at the site in a manner that maximizes the opportunity for feedback on those activities.

The proponent will employ a number of different approaches to appropriately involve the general public. These will include:

- Provision of appropriate information through community meetings, open houses or other media so that the public can be informed and participate effectively;
- Creation of activities designed to promote a broader understanding of: both potential impacts of the rehabilitation, and proposed mitigation measures to reduce potential negative impacts associated with the rehabilitation activities;
- Involvement of the local public in issues [e.g. contribution of traditional knowledge to the determination of Valued Ecosystem Components (VECS)]and rehabilitation options;
- Provide a forum for meaningful discussion of enhanced regional business, training and employment opportunities;

- Receive information from and respond in a timely manner to issues raised by the public; and
- Inform participants of results and decision in a timely and meaningful manner.

14. MONITORING

14.1. Ambient Radon

14.1.1. Current

As part of the 2004 site characterization campaign, (9) Radtrak radon detectors supplied by Landauer Inc. (Glenwood, Illinois) were deployed at various locations throughout the Gunnar site. Efforts were made to locate these detectors in locations that approximate those used in 1985.

As per the manufacturers direction, each detector used in 2004 was installed in a protective canister that was itself installed approximately 1.5 metres above the ground. Figure 14.1.1 provides a representation of each station location. In 2005, a tenth station was added near the airstrip located north of the site itself.

14.1.2. Proposed On-Going

This monitoring regime will be continued with the replacement of the Radtrak radon detectors on a six month rotation with the spent cups being shipped to Landauer Inc. (Glenwood, Illinois) for analysis.

14.2. Water Quality

14.2.1. Proposed On-Going Monitoring

Significant initial investigations have been conducted of the water quality in and around the former Gunnar Mining Limited site. In order to enhance the data base of the site the following water quality monitoring regime will be implemented in June 2007.

It is anticipated that additional special investigations initiated to support the development of the final rehabilitation plan (such as the investigation of the waste rock pile seep in Zeemel Bay) will also entail some level water quality monitoring. Such monitoring will be conducted in addition to that specified in Table 14.1.

Table 14.1
Propose Water Quality Monitoring Regime

<i>Station</i>	<i>Location</i>	<i>Frequency</i>	<i>Parameters</i>
AB-1	St. Mary's channel oposite pit discharge	June, September, December	General chemistry package, ICP-MS metals plus bismuth, mercury, phosphorous, ammonia (NH ₃), nitrate + nitrite, total kjeldahl nitrogen, total nitrogen, organic carbon, total suspended solids, lead-210, and radium-226
AB-2	St. Mary's channel central channel		
AB-3	Langley Bay Discharge		
GP-1	Gunnar flooded pit		
ZC-1	Zeemel Creek upstream of site		
ZC-2	Zeemel Bay at Zeemel Creek discharge		
ZC-3	Zeemel Bay outlet to St. Mary's channel		
TA-1	Gunnar main poded water		
TA-2	Tailings Creek		
TA-3	Between Gunnar central and Langley		
TA-4	Back Bay		
TA-5	Langley Bay		

Figure 14.1.1 provides a summary of water quality stations from which water samples will be collected in order to enhance the data base of the former Gunnar Mining Ltd. site.

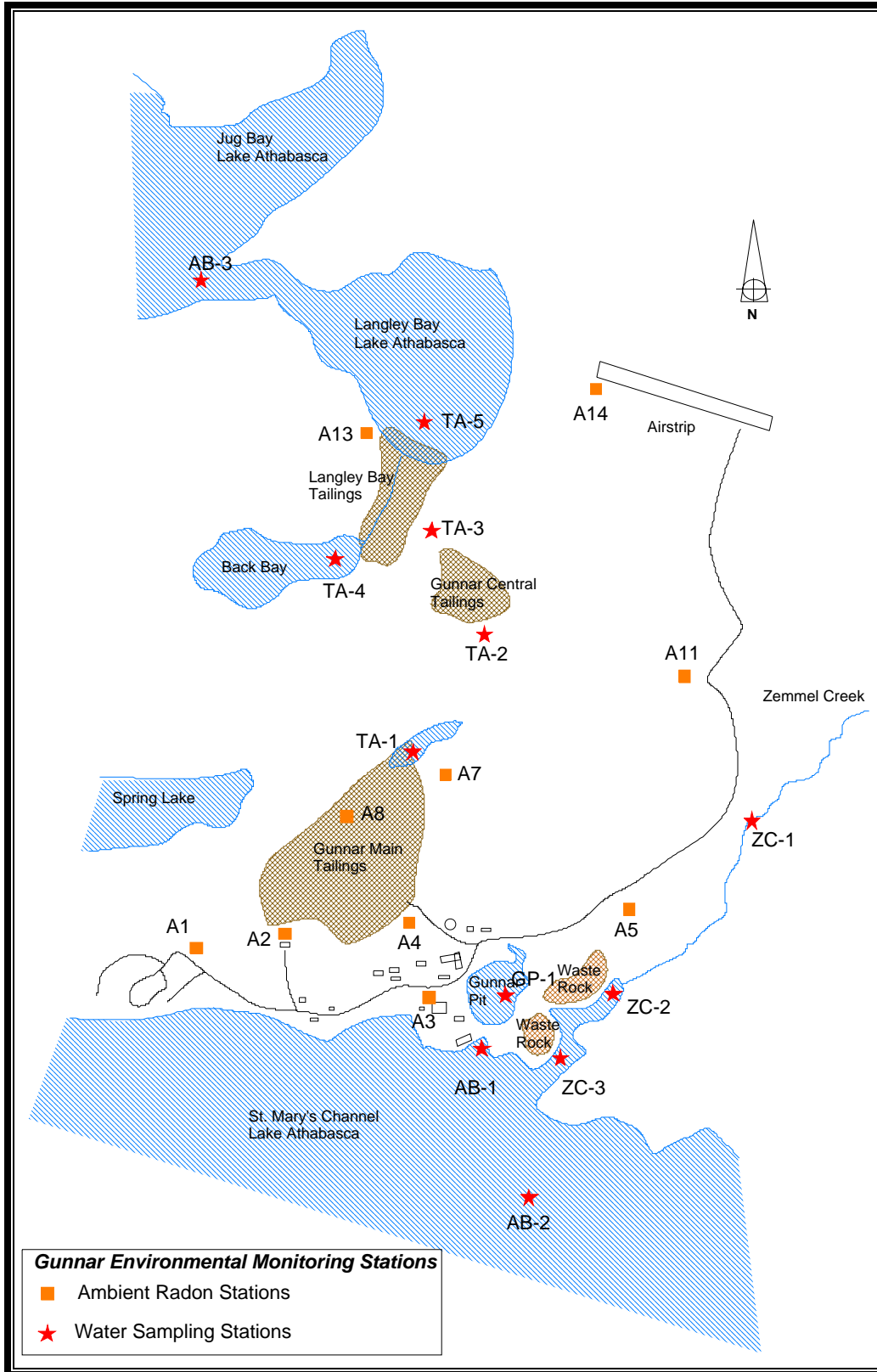


Figure 14.1.1

15. FINANCIAL CONSIDERATIONS

15.1. Project Funding

The Government of Saskatchewan and the Government of Canada have signed a Memorandum of Agreement (MOA) to effect timely and effective action be taken to address the current environmental conditions of the Cold War Legacy Uranium Mine and Mill Sites in Northern Saskatchewan, which includes the rehabilitation of the former Gunnar site. Under the MOA, Saskatchewan Industry and Resources (SIR) has been assigned the responsibility to ensure that the project is carried out on behalf of the two governments. SIR has signed a formal contract with the Saskatchewan Research Council (SRC), a wholly owned Crown Corporation under the responsibility of the Minister of SIR, to retain the SRC as project manager and designated agent to manage and perform the required environmental assessment requirements and rehabilitation activities.

Appendix E includes a copy of a letter from Saskatchewan Industry and Resources (SIR) stating the above, dated 03 April 2007.

15.2. Financial Assurance

The Saskatchewan Research Council will manage the rehabilitation of the former Gunnar Mines Ltd. site and hold all required approvals, permits or licenses on behalf of Saskatchewan Industry and Resources. All costs associated with the management of the site and to conduct approved activities at the site will be reimbursed to the Saskatchewan Research Council from Saskatchewan Industry and Resources.

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