APPENDIX 1

GUNNAR AND LORADO DETAILED INFORMATION

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1.0 Gunnar Mine Site

1.1 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% U_3O_8.

With the discovery of the adjacent 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 1, 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.

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.

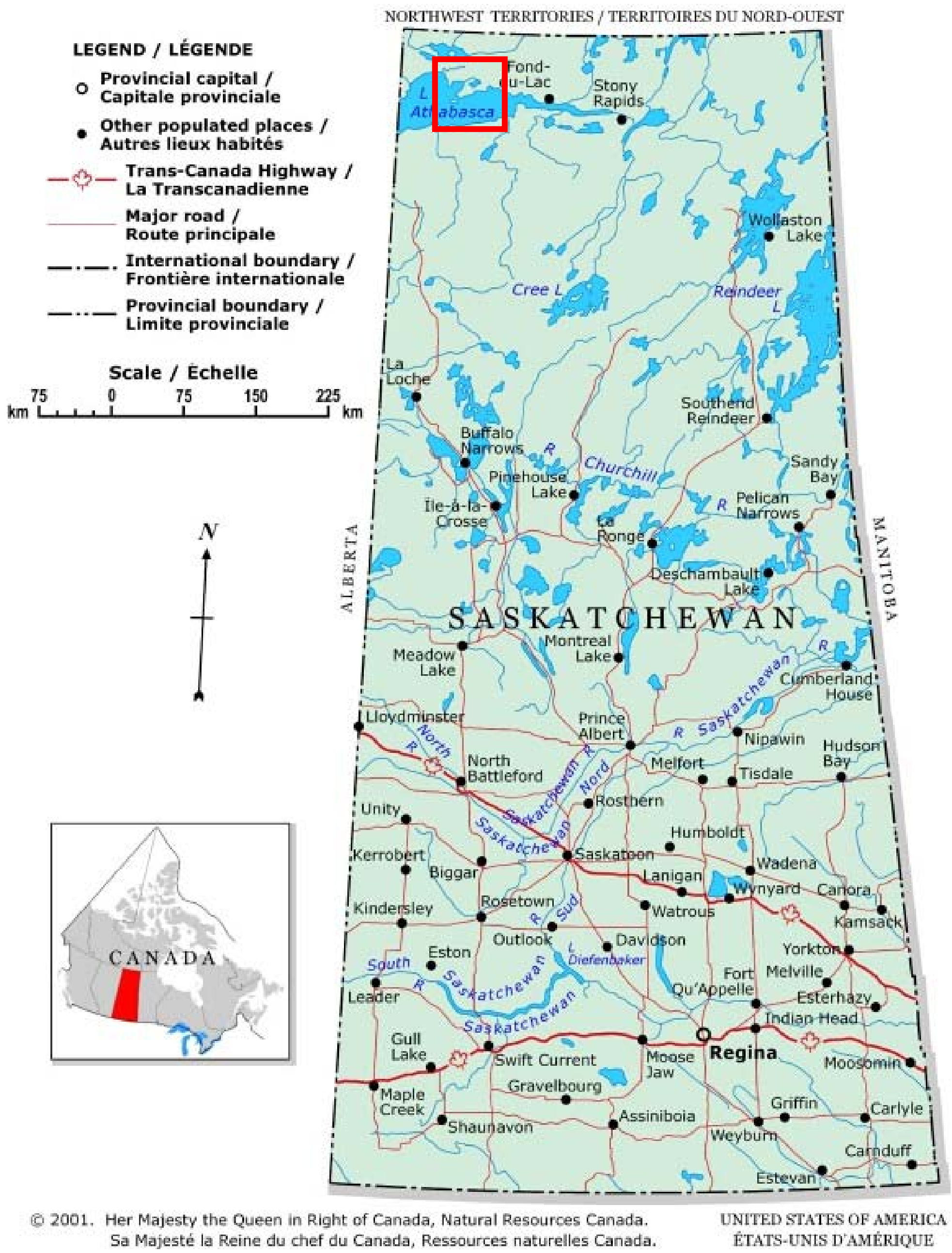
The Gunnar Main Tailings basin eventually filled with tailings solids and a small rock outcrop was blasted to allow the tailings to flow from the Main area to a small depression referred to as Gunnar Central Tailings. Once this relatively small basin was filled, the tailings continued to flow downhill, 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.

1.2 Operating History

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.



Study Area

Figure 1 Gunnar Mining Limited Location

Figure 2 Gunnar Mining Limited Location

Figure 3 Gunnar Mining Limited Site

1.2.1 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 4). The upper walls of the pit were generally mined in granite gneiss.

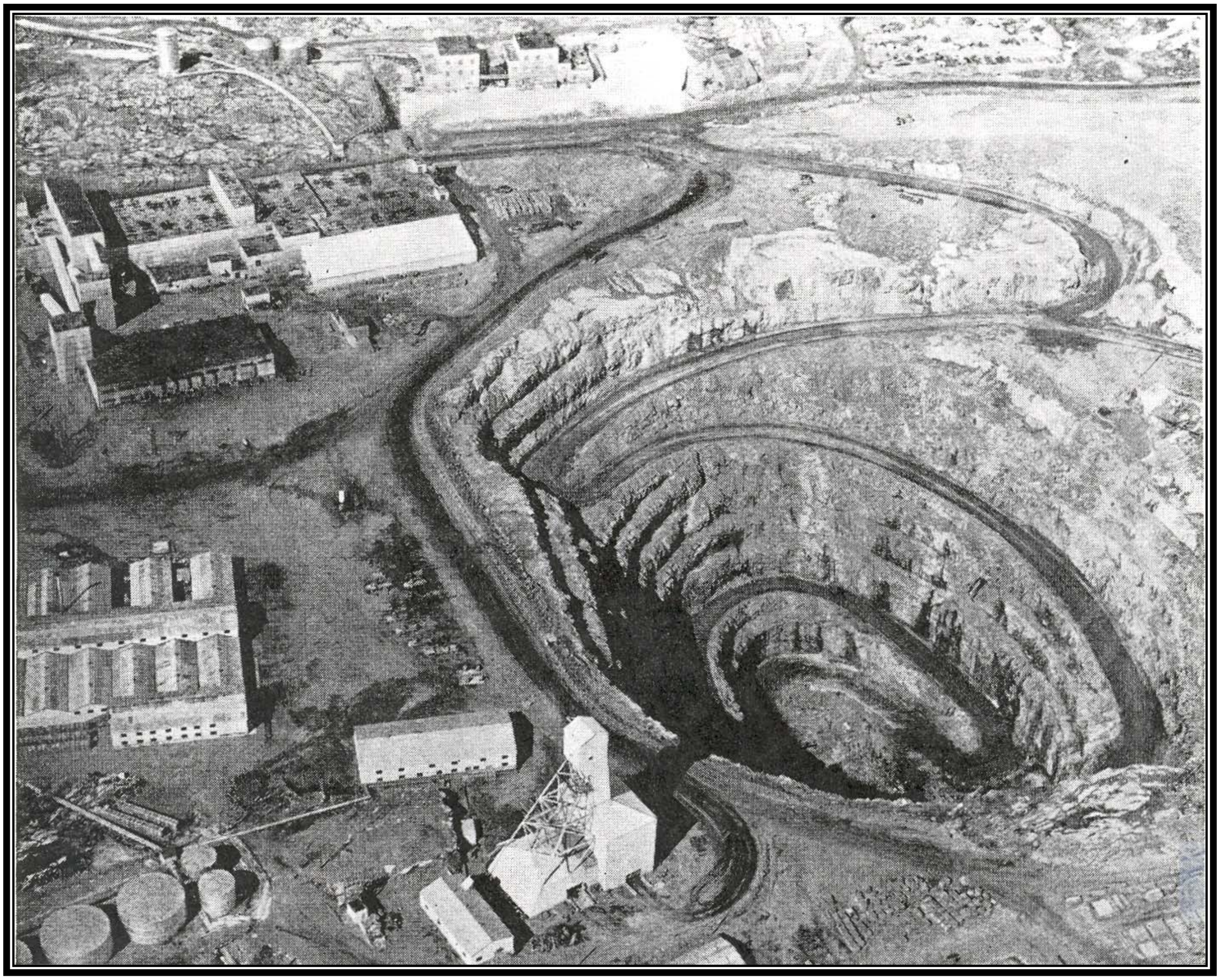


Figure 4 Gunnar Mining Ltd. Open Pit (Circa 1962)

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 55^0 except were 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 2 m 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.

1.2.2 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. 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.

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

1.2.3 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 in 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.

1.2.4 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% U_3O_8.

Table 1 Production Data - Gunnar Mining Limited

(Source: Company Annual Reports)

Year	*Daily Production (Tons of Ore Treated)*	*Mill-Head Grade (% U_3O_8)*	*Annual Production (Tons of Ore)*
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*

1.2.5 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.

Figure 5 Gunnar Site (circa 2004)

1.3 Existing facilities and infrastructure

The following provides a brief discussion of the facilities that still exist on the former Gunnar Mining Limited site. It should be noted that the facilities and infrastructure that remain are at various stages of dilapidation.

Existing facilities and infrastructure include:

- Utilidors
- Head Frame
- Mill
- Acid Plant
- Freshwater Pump House
- Geology\Mine Dry Building
- Mine Engineering
- Maintenance Shops
- Cold Storage Building - Dock Area
- Bunkhouses (Staff housing)
- Cold Storage
- Community Centre
- Curling Rink
- School
- Sewage Treatment
- Married Quarters

- Pump Shed
- Concrete Basement
- Group of Cabins West of Marina
- Group of Cabins East of Head Frame
- Barge
- Cookery Concrete Basement

Some items identified that will require specific attention throughout the project include:

1.3.1 Barrels

There are an estimated 8000 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 area of the cold storage building. 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.

1.3.2 Fluorescent Light Ballasts

Many of the lighting fixtures used on the site are fluorescent and, because of their age, potentially contain some concentrations of polychlorinated biphenyl (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.

1.3.3 Asbestos

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.

1.3.4 Waste Rock

The total volume of waste rock present on the Gunnar Mining Limited site has been estimated at 2,710,700 m^3 (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 10 percent of the readings from the 73 locations were greater than 1 mR/hr (BBT Consultants, 1986). During a 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.

A 2004 SRK Consultants investigation included a survey of the two major waste rock piles at the former Gunnar Mine site. The 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. This was inconsistent of the two previous surveys which showed a higher average measurement of the waste rock.

In August of 2009 SRC performed its own gamma survey of the entire site, the investigation revealed an average of 1.6 uSv/h with a maximum reading of 11.36 uSv/h for the waste rock piles. This data is more consistent with the first two surveys done by BBT Consultants and the CNSC staff. More detail on the gamma survey can be viewed in section 3.3.8.

1.3.5 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.

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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.

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.

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 ^{226}Ra. The reported ^{226}Ra 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.

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 analyze.

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.

Table 2 – Uranium, Thorium and Radium Concentrations

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

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

1.3.6 Flooded Pit

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.

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.

1.3.7 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 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 the 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.

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.

1.3.8 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 around 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.

However the 2004 survey took place using an Automess 6150 AD6 Gamma Metre manufactured by Automess GmbH. Based on information received from the CNSC an automess meter does not have the sensitivity for a proper release survey. It was also recommended that a scintillation type probe should be used for performing low level gamma surveys. The SRC conducted a survey of the entire Gunnar mine site using a Ludlum 2241 rate meter coupled with a 2” NaI probe collecting nearly 60,000 data points see table 3 and figure 6 for results.

Table 3 Gamma Survey Results

Location	Number of Readings	Average uSv/h	Max uSv/h
Waste Rock	6459	1.6	11.63
Tailings Area	8793	4.63	12.43
Mine\Mill Area	13927	1.09	4.76
Residential	6888	0.57	2.94

Figure 6 Gamma Survey Gunnar Site

1.3.9 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 ($_{226}$Ra). $_{222}$Rn is an inert gas with a radiological half-life of 3.82 days. The release to the atmosphere of $_{222}$Rn and its decay produces lead-210 ($_{210}$Pb, with a half life of 22 years) and polonium-210 ($_{210}$Po) 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.

Radon Monitoring Results

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

Table 4 Ambient Radon Historic Averages

Station	**Station Location**	**Gunnar - Ambient Radon (pCi/L)**	
		1985 (BBT) Average (n=3)	2004 - 2007 (SRC) Average (n=9)
A1	Town Site	4.45	1.1
A2	Radio Residence	4.29	3
A3	Head Frame	5.01	1.3
A4	Tailings Line	5.02	3.1
A5	Waste Rock	5.97	1.4
A7	Northern Tailings	3.49	1.3
A8	Western Tailings	6.31	2.7
A11	Airport Road	3.73	1.4
A13	Langley Bay	4.31	1.3
A14	Airport		2
	Gunnar Site Average	**4.7**	**1.9**

A review of the monitoring data since 2004 shows the average ambient radon concentration at the Gunnar site was 1.9 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 and Saskatchewan and Saskatoon radon concentrations of 1.64 and 1.67 pC/L respectively reported by Health Physic (1994).

1.4 Site and Safety Considerations

1.4.1 Posting of Warning Signs

A total of (50) 4 ft. x 8 ft. coroplast signs were installed at various locations throughout the Gunnar Mining Limited site to warn casual visitors to the site of the danger posed by radiation, asbestos and the unsafe structural condition of the buildings. 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.

1.4.2. 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.

2.0 Lorado Uranium Mill Site

2.1 The Site

The Lorado mill was operated by Lorado Uranium Mines Ltd. from 1957 to 1960 and was designed to treat ore from the Lorado mine and from smaller satellite mines in the region, including the Cayzor, Rix Leonard, and the Cinch Lake mines. The Lorado mill was closed in 1961 due to a lack of feeder ore from the Lorado mine and the satellite mines. The Lorado mine site is several kilometres away from the Lorado mill site and is not included in the Lorado mill site rehabilitation plan. There are no mine workings at or immediately adjacent to the Lorado mill site.

The Lorado mill was designed to process up to 750 tonnes of ore per day; however, the actual amount of ore processed was significantly less due to depleting ore reserve shortages and milling problems. At the end of production, the Lorado mill was estimated to have processed between 305,000 and 550,000 tonnes of ore.

Tailings from the mill were deposited on the ground and into Nero Lake adjacent to the mill. At the end of operations, the tailings had covered an area of about 14 hectares, including the tailings submerged in Nero Lake.

The Lorado mill was abandoned with no significant decommissioning activities. The mill existed for several years much as it did when it was abandoned. From the time of closure, the condition of the mill worsened due to vandalism and natural deterioration. Eventually, the mill was completely dismantled in 1990. The remaining concern at the site is with the exposed tailings which continue to lie on the ground surface from where they become windblown, generate acid and leach metals into the ground and surface water. Several studies have been performed on the area to determine the effect the tailings have on water quality, wildlife and vegetation.

The primary and public safety consideration at the Lorado mill site is the presence of unconfined tailings which pose a gamma radiation concern. Windblown tailings also present a public safety consideration due to the mobile nature of the fine tailings and their ability to be transported great distances by the wind. From an environmental perspective, the primary issue is the presence of radionuclides and heavy metals having the potential to enter the environment via the surface and groundwater systems. In particular, the discharges from the tailings have adversely affected the water quality of Nero Lake. This has the potential to result in the migration of contaminants to downstream receptors including humans and wildlife.

2.2 Project Information

2.2.1 Location

The Lorado mill site is located just north of Lake Athabasca in the northwest part of Saskatchewan, (59°31’10”N, 108°41’40”W), approximately 830 kilometres north of Saskatoon (Figure 6).

Figure 7 Location of Lorado uranium mill site

2.2.2 Site Map, Regional

Figure 7 indicates the location of communities, First Nations lands, and parks in the region. Communities within 100 kilometres of the Lorado mill site include: Northern Settlement of Uranium City, Northern Settlement of Camsell Portage, and Fond du Lac Denesuline First Nation. First Nations lands located within the 100 kilometres radius include Fond du Lac in Saskatchewan and Collin Lake in Alberta.

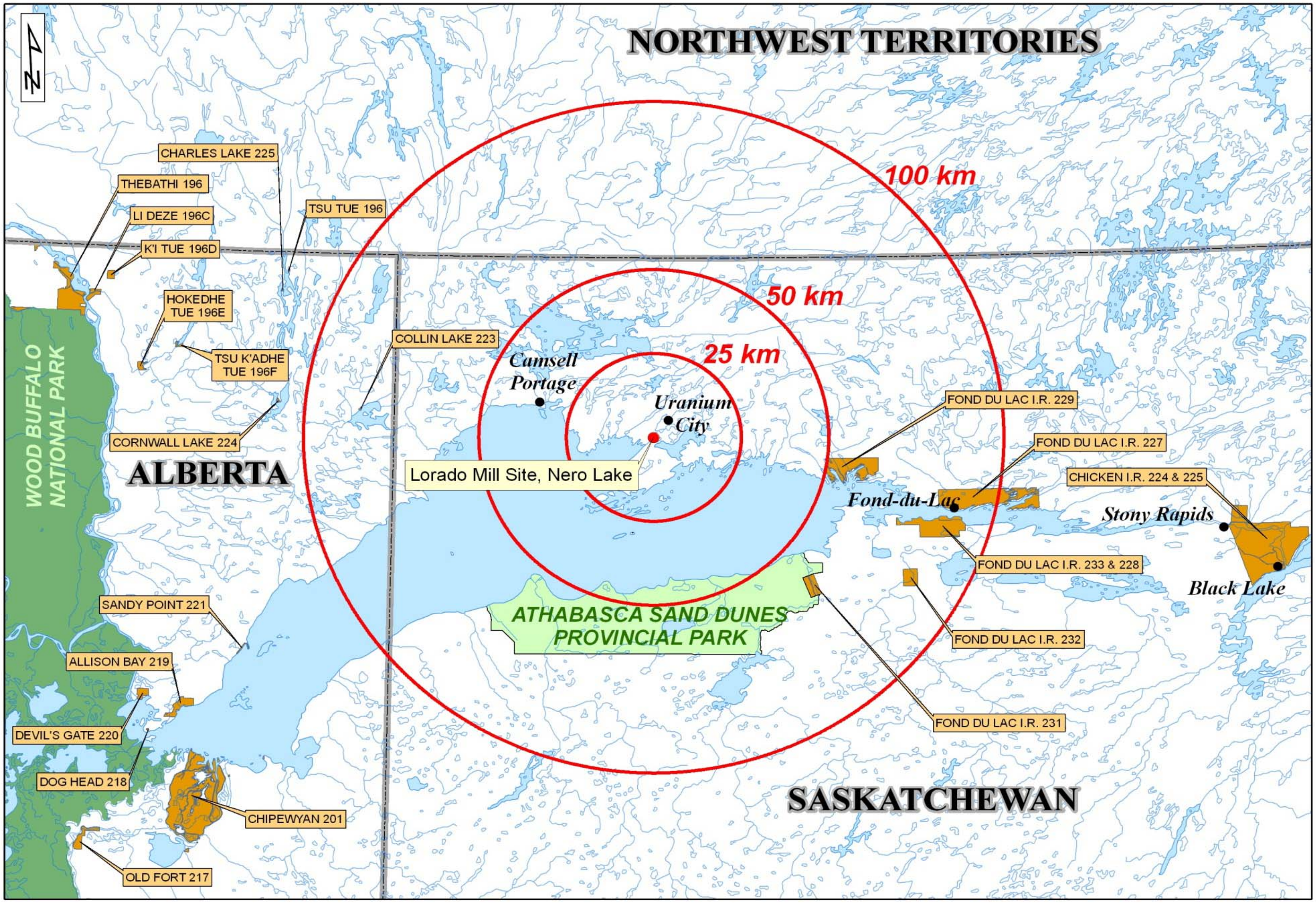

Figure 8 Location of parks and First National lands in the Lorado uranium mill area
(Basemap: Canada Centre for Cadastral Management, Geomatics Canada, Natural Resources Canada)

2.2.3 Site Map, Local

Access to the north shore of Lake Athabasca, is constrained, due to the absence of an all weather road link to the Saskatchewan highway network. Seasonal wheeled vehicle access is gained from Fond du Lac, the northern terminus of the Saskatchewan highway network, via an ice road. The ice road heads west along the northern shoreline of Lake Athabasca and is in service during late February through to early March. During the open water season, a barge service is operated on Lake Athabasca out of Fond du Lac. There is a paved airstrip located approximately eight kilometres east of the community of Uranium City. Uranium City, the largest community in the area (population approx. 84) is located 10 kilometres north of the Lorado mill site.

Figure 8 shows the location of the Lorado mill site relative to Uranium City and Beaverlodge Lake. The hatched area was designated as a reclamation area by the Saskatchewan Ministry of Environment.

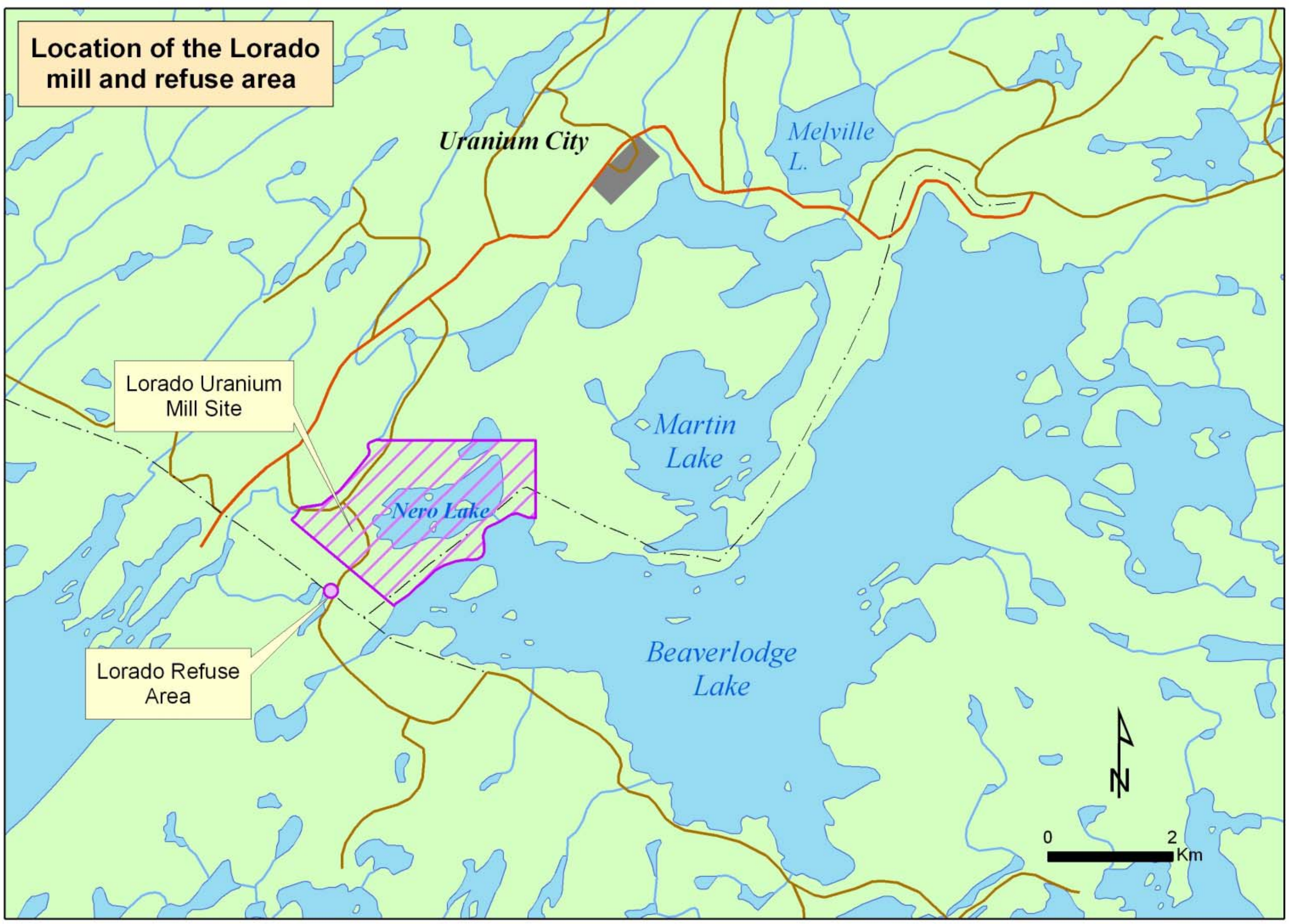

Figure 9 Location of the Lorado mill "reclamation area" (Saskatchewan Ministry of Environment)

2.2.4 Site Photographs

Photo 1: Lorado mill and tailings looking east towards Nero Lake (circa 1978 - prior to mill dismantling)

Photo 2: Lorado mill and tailings looking west (circa 1978 - prior to mill dismantling)

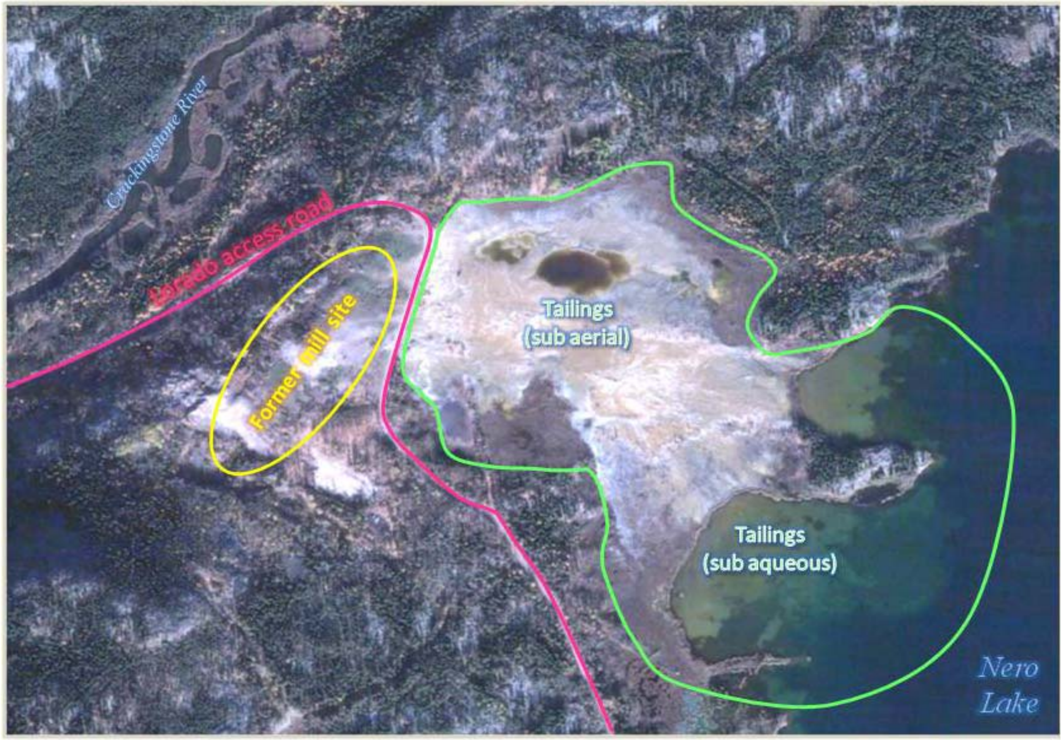

Photo 3: Satellite image of Lorado mill and tailings site (base map courtesy of Google Earth)

Photo 4: View of exposed tailings from former mill site towards Nero Lake (2007)

2.3 Project Components and Activities

The objective of the project is to develop and implement a remediation plan for the former Lorado mill site, such that the work is conducted in an environmentally sound and responsible manner.

Generally, subject to regulatory approvals, it is anticipated that the rehabilitation activities may consist of:

- Appropriate disposal of refuse from the site;
- Relocation of the road access to bypass the former Lorado mill site;
- Containment and stabilization of all or a portion of the exposed mill tailings;
- Rehabilitation of affected aquatic environment as warranted;
- Rehabilitation of additional risks as warranted;
- General site clean-up; and
- Appropriate monitoring during and after rehabilitation.

2.3.1 Tailings

The most significant feature on the former mill site is the uranium mill tailings. The volume of this material is estimated to be 177,000 m^3 on land and an additional 50,000 m^3 under the water of Nero Lake, resulting in a total of 227,000 m^3 of uranium tailings at the Lorado mill site (Golder, 2008).

The tailings are acid producing which is not unexpected given the large amounts of sulphuric acid used in the milling process. The pyrite (used to manufacture the acid) in the tailings is oxidizing and is creating sulphuric acid that is draining into Nero Lake. The tailings are also subjected to wind and surface water erosion.

The tailings are composed of up to four metres of silt and sand overlying peat. Sands occur at the top of the pile, at higher elevations, and the tailings become finer grained with depth, with the silts occurring at the base of the pile. The oxidized zone of the tailings pile varies in thickness from a low of 0.1 metres to a high of 2.2 metres (Whiting et. al., 1982).

Two seepage paths flow in an easterly and southeasterly direction, likely draining into Nero Lake. It is estimated that the combined maximum seepage rates are approximately 12 to 13 m^3/day (Whiting et. al., 1982). The groundwater flow from the tailings towards the Crackingstone River Valley is reported to be negligible (Golder, 2008).

The concentration of radium-226 in the tailings collected near the mill was determined to be 215 pCi/g (Ruggles et. al., 1978).

2.3.2 Nero Lake

Nero Lake has been severely affected by the uranium mill tailings. The pH of the water is reported to be low (3.98-4.00). Levels of alkalinity and bicarbonate were low while concentrations of aluminum copper, lead, manganese, nickel, titanium, and zinc were elevated relative to a reference area (Golder, 2008).

Lorado tailings were deposited in a low area near the shore of Nero Lake. Eventually the low area was filled, and the tailings extended into Nero Lake, forming a beach. Some of the tailings were deposited below the surface of the lake, but the majority of the tailings remained exposed at the surface. The tailings beach covers about 14 hectares. The beach is acid generating and the drainage from the tailings has depressed the pH.

The Environmental Protection Service of Environment Canada and the Saskatchewan Department of Environment (currently Saskatchewan Ministry of Environment) carried out a joint study in 1976. Samples of water, zooplankton and sediment were collected from abandoned mines in the Uranium City region in an attempt to understand the effects the abandoned sites have on the environment. The data indicated that discharges of waste into Nero Lake had severely affected water quality. The pH was 3.5, acidity was 272 mg/L (sulphates), chloride was 61 mg/L, and radium-226 was 26-32 pCi/L.

A study performed in 1978 entitled '*A study of Water Pollution In The Vicinity of Two Abandoned Uranium Mills in Northern Saskatchewan*' (Ruggles, et al., 1978), revealed that the water quality of Nero Lake has suffered substantially due to the presence of the Lorado mill tailings. Ruggles et al. found water quality parameters that closely matched those measures in 1976. High concentrations of sulphate (1,100 - 1,500 mg/L), chloride (51 - 61 mg/L), calcium (200 mg/L), magnesium (120 - 150 mg/L), iron (5.5 - 5.95 mg/L), sodium (48 - 50 mg/L), potassium (4.7-4.9 mg/L), zinc (0.28-0.31 mg/L) and lead (0.042-0.051 mg/L) were found in Nero Lake. At the time of the study, the lake had a pH of between 3.3 and 3.4 and there was no presence of alkalinity. These results are very typical of acid rock drainage.

The Ruggles et al. study identified that the flushing rate of Nero Lake is very slow as there are no defined inlets to the lake. This lack of inlets implies that there are limited natural buffering mechanisms available to offset the acid production of the waste.
Radionuclide levels found in Nero Lake were high with radium-226 concentrations ranging from 45 to 62 pCi/L; lead-210 concentrations ranging from 48-56 pCi/L and Uranium ranging from 0.66 to 0.99 parts per million (ug/g). Thorium-230 was also present in a wide variation of concentrations (8.8-61 pCi/L).

In summary, the acid draining from the tailings into Nero Lake have resulted in the destruction of the natural alkalinity of the water and a low pH, caused a reduction in the diversity of the planktonic and benthic communities of the lake, and increased the concentration of radionuclides in the water. The invertebrate communities of Nero Lake were restricted to those tolerant of an acidic environment. The dense growth of aquatic moss on the bottom of Nero Lake are acting as a concentration sink for radionuclides in the lake system. These radionuclides are eventually making their way into Beaverlodge Lake (Ruggles, et al., 1978).

The low pH in Nero Lake has caused a reduction in the diversity of the planktonic and benthic communities of the lake. The invertebrate community of Nero Lake is restricted to acid tolerant species.

2.3.3 Beaverlodge Lake

The water level of Nero Lake is approximately 3 metres higher than that of Beaverlodge Lake. These lakes are separated by a narrow land bridge or berm, constructed during operation of the mill, to increase the elevation of Nero Lake. Movement of water, through or over, this land bridge is of critical importance to the contaminant migration from the uranium mill tailings site.

The bridge is very porous and allows for the movement of water between the two lakes. A localized effect on the water quality in Beaverlodge Lake is evident from a plume of water moving from Nero Lake to Beaverlodge Lake. The plume can be readily identified from the air and appears to be caused by the precipitation of metals (such as aluminum) when the water from Nero Lake reaches Beaverlodge Lake. The low pH (3.5 - 4) water of Nero Lake contains dissolved metals. When this water enters the near neutral pH water of Beaverlodge Lake (pH 7.1 - 7.8), the metals precipitate out of solution. A number of white, reddish brown and black coatings, are evident on rocks along the shore of Beaverlodge Lake adjacent to the bridge. An analysis of the staining indicates that the white and redish brown precipitate is generally composed of aluminum with lesser amounts of iron, sodium and silicate. There is no significant occurrence of radium-226 in the precipitates but they are high in uranium (Whiting, et. al., 1982).

The pH of Beaverlodge Lake ranged from 7.3 to 7.7 and the alkalinity ranged from 61 to 65 mg/L (Ruggles, et. al., 1978). Radium-226 and lead-210 concentrations ranged from 1.3 - 1.9 pCi/L and 2.5 - 3.5 pCi/L, respectively. Uranium concentrations ranged from 0.13 to 0.27 mg/L. The concentration of thorium-230 ranged from 1.1 - 31 pCi/L and appeared to be more concentrated near the surface.

The stratigraphy of the bridge is described by Whiting et. al., (1982). The base is a pink till overlain by a lower unit composed of gray silt. The lower gray silt is overlain by a gray till. The gray till is overlain by an upper gray silt. The upper gray silt is overlain by a postglacial silt. The postglacial silt is overlain by a layer of peat.

Whiting et. al. (1982) hypothesized that the till layers control the rate of water entering Beaverlodge Lake from Nero Lake. It is possible that the pink till and an assumed zone of crushed bedrock immediately below it, provide a path of groundwater flow from Nero Lake into Beaverlodge Lake. The pink till is a calcareous material that has the potential to neutralize some of the contaminants transmitted through the bridge. The peat near the surface has the potential to absorb some of the radionuclides.

There are a number of ways that water from Nero Lake can enter Beaverlodge Lake. Migration can occur through a partially collapsed culvert that exists underneath the road on the top of the bridge, or by water splashing over the bridge during high water levels, or as groundwater seepage through the upper till fill and the lower pink till. An investigation of the bridge of land roadway between the lakes was undertaken by a consultant working for Saskatchewan Environment in 2001. The investigation concluded that the culvert did not ensure peak flood events can be readily and safely passed from Nero Lake to Beaverlodge Lake. As a result, rehabilitation of the berm was undertaken in 2005/06 (see Photo 6).

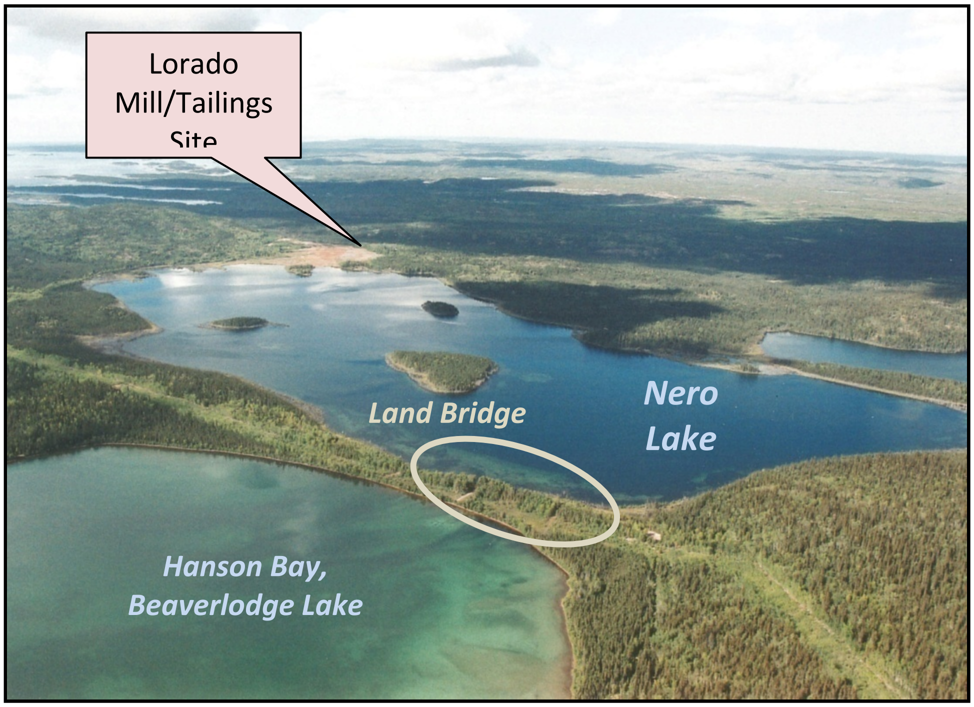

Photo 5: Air photo of Land Bridge between Nero Lake and Beaverlodge Lake

Photo 6: Photo of armored spillway constructed to improve land bridge stability (looking towards Beaverlodge Lake)

2.3.4 Refuse Pile

The Lorado mill ceased operation in 1960 and the buildings were demolished in 1990. Presently, there are a few remaining concrete slabs and footings still on the mill site.

There is a small refuse area associated with the construction, operation, and decommissioning of the Lorado mill facility located approximately 1.5 kilometres beyond the mill site that may require remediation pending an inventory of refuse contained at the site (see Figure 7).

2.3.5 Radiological Inventory

The Lorado mill operated from 1957 to 1960 with a rated production rate of 700 tons/day. It is estimated that a total of 305,000 tonnes of ore was milled at the Lorado uranium mill facility (Barsi and Ashbrook, 1992). Ore was delivered to the mill from several uranium mines in the area, the major sources were: Lorado mine, Lake Cinch, National Explorations, Rix-Athabasca, and Eldorado. Ore was crunched and ground to 60% minus 200 mesh and then leached with sulphuric acid to dissolve the uranium mineral. The pregnant solution passed through ion exchange columns and the uranium collected on resin. The resin was then washed with a dilute hydrochloric acid (HCl) solution to remove the uranium which was then precipitated by magnesium oxide (MgO). Tailings were initially discharged in a topographic depression adjacent to the west shore of Nero Lake. Total volume of tailings has been estimated to be 227,000 m^3.

Based on the total Lorado mill production of 1,522,780 pounds of U_3O_8, the radiological inventory of the Lorado mill waste, is estimated to be $7.5x10^{13}$ Bq (Golder, 2008).

2.3.6 Gamma Radiation

In the summer of 2004, a gamma radiation survey was conducted in the vicinity of the Lorado mill and tailings by Golder (2008). Readings, recorded in microsieverts/hour, were taken approximately 1 metre above ground on a 100 metres x 100 metres grid spacing. Gamma readings obtained over all non-tailings areas ranged from 0.25 to 1.0µSv/hr. Gamma readings over the tailings ranged from 1.0µS/hr to a high of 13.0µSv/hr. Golder concluded that the sources of significant gamma radiation are confined to the actual tailings area.

2.3.7 Radon

Radon gas levels were monitored in the fall of 2004 with the installation of eight, Landauer™ "Track-Etch" outdoor air radon samplers at the Lorado mill/tailings site (Golder, 2008). The outdoor air radon detectors were deployed beginning in July 2004 and removed in December 2004. The average radon concentration varied from 18.5 to 55.5 Bq/m^3 (average 31.45 Bq/m^3).

2.3.8 Area to be Affected

The "reclamation area" as defined by Saskatchewan Ministry of Environment, is shown on Figure 8. This area is approximately 640 hectares in size and includes all of the tailings, mill building area and Nero Lake. The area is bounded to the northwest by the Crackingstone River and to the southeast by Beaverlodge Lake.

2.4 Emissions, Discharges and Waste

2.4.1 Atmospheric Contamination

The Lorado tailings, for the most part, are not covered with vegetation, making them susceptible to wind erosion. In an attempt to reduce windblown tailings, an array of dust control fencing was placed on the exposed portion of the tailings area during the summer of 2004. These measures were reported to be effective in the reduction of blowing tailings. In 2008, SRC took action to repair several sections of the dust control fencing which had become dilapidated.

Any remediation activities proposed for the Lorado tailings area will have to mitigate the effects of windblown tailings.

2.4.2 Liquid Discharges

Sources of liquid discharges may be related to spills of fuels and other hazardous substances during the rehabilitation project. All regulations related to the safe and environmentally acceptable methods of fuel handling will be adhered to.

2.4.3 Waste and Disposal Plans

A major component of this project will be the containment of the tailings in and adjacent to Nero Lake. The final strategy for the containment of these tailings will be included in the Former Lorado Uranium Mill Site Final Rehabilitation Plan.

There is a relatively small refuse pile associated with the construction, operation, and decommissioning of the Lorado mill facility located approximately 1.5 kilometres beyond the mill site that will require appropriate cleanup and remediation. The final strategy for the disposal of this refuse will be included in the Former Lorado Uranium Mill Site Final Rehabilitation Plan.

2.5 General Physical and Biological Information

2.5.1 Vegetation

Golder (2008) collected data in a study area of approximately 300 km^2 (29,996 hectares) including and surrounding the Lorado mill site. Table 5 summarizes the Ecological Land Classification (ELC) unit results of the study. Anthropogenic disturbances (i.e., Lorado tailings, Uranium City, airstrip, Bushell Bay, and gravel pits) account for less than 1% of the total study area (Golder, 2008).

Table 5 Percent Ground Cover and Area for Ecological Land Classification Units within the Study Area

Ecological Land Classification Unit	Area (ha)	Percent (%)
Deep Water	8,885	29.7
Shallow Water	1,360	4.5
Aspen	2,011	6.7
Mixed Wood	1,371	4.6
White Spruce Dominant	312	1.0
Black Spruce Dominant	5,666	18.9
Bog	897	3.0
Bedrock	317	1.1
Sand	4	0.0
Burn	27	0.1
Burn Regeneration	391	1.3
Jack Pine Mature	3,129	10.4
Jack Pine Immature	4,919	16.4
Graminoid Wetland	544	1.8
Disturbance	133	0.4
Total	**29,966**	**100.0**

(Source: Golder, 2008)

2.5.2 Terrestrial Wildlife

The Golder (2008) study also identified several wildlife species in the area including moose, red squirrel, snowshoe hare, beaver, ruffed grouse, white-tailed deer, willow ptarmigan, pileated woodpecker, and black bear. Several small mammals were also identified including red-backed vole, meadow vole, deer mouse, pygmy shrew, and masked shrew.

2.5.3 Aquatic Wildlife

The low pH in Nero Lake has resulted in a reduction in the diversity of the planktonic and benthic communities of the lake. The invertebrate community of Nero Lake is restricted to acid tolerant species.

The more normal chemical conditions encountered at Beaverlodge Lake resulted in more diverse biological communities compared with those found in Nero Lake. The total number of phytoplankton species observed in Beaverlodge Lake was almost twice that of Nero Lake (41 species compared to 22 species) (Ruggles et al. 1978). In addition, the only observed potential affect on fish habitat within Hanson Bay (Beaverlodge Lake) was the white precipitate covering the sediment, creating a physical (and possibly a chemical) barrier to use of the affected zone by fish and food organisms. The lowest abundance of benthic invertebrate community in Hanson Bay was within the area of the precipitate plume, which indicated the potential degradation of the affected habitat (Golder, 2008).

Saskatchewan Parks and Renewable Resources (1991) reported 14 species of fish present in Beaverlodge Lake, including;

- Northern Pike;
- Walley;
- Lake Trout;
- Lake Whitefish;
- Cisco;
- Burbot;
- White Sucker;
- Lake Chub;
- Pearl Dace;
- Ninespine Stickleback;
- Emerald Shiner;
- Spottail Shiner;
- Slimy Sculpin; and
- Deepwater Sculpin.

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