



Deline Uranium Team



Indian and Northern  
Affairs Canada

Affaires indiennes  
et du Nord Canada

# PORT RADIUM MINE REMEDIATION PLAN



Prepared By:

**Contaminants and Remediation Directorate**

In Association With:

**The Canada-Déline Uranium Team**

Canada

September 2005

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MINE REMEDIATION PLAN**

**Prepared By:**

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**In Association with:**

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**and**

**SENES Consultants Limited**

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## **EXECUTIVE SUMMARY**

### ***Site overview***

This remediation plan is submitted with respect to the Port Radium site located in Echo Bay on the eastern shores of Great Bear Lake, Northwest Territories. The site is situated within the Sahtu settlement lands at the edge of the Arctic Circle, about 265 km east of the Dene community of Déline and about 440 km north of the City of Yellowknife.

Predominant access to the site is by water, although an un-maintained airstrip exists at Glacier Bay which is located about 6 km east of the Port Radium site. The site is characterized by the barren and rugged relief of the eastern shores of Great Bear Lake that features rock outcrops and sheer cliffs that rise rapidly from the lake's shoreline. Natural flat lying land is, for the most part, non-existent and soil cover is generally sparse and very shallow.

Mining and milling activities were carried out almost continuously between 1932 and 1982 for the recovery of radium, uranium, and silver. Eldorado Mining and Refining operated the site as a uranium mine from 1942 to 1960. Echo Bay Mines utilized the facilities to mine Echo Bay mine from 1964 to 1972 and Port Radium from 1974 to 1982 for silver. In total, some 37 million ounces of silver, 10.5 million pounds of copper and 13.7 million pounds of uranium oxide (U<sub>3</sub>O<sub>8</sub>) were produced over the operating life of the mines. Tailings produced from uranium and silver operations has been estimated in the order of 900,000 and 800,000 tons respectively. Most of the uranium tailings were deposited in Great Bear Lake and most of the silver tailings were discharged to McDonough (Garbage) Lake, now referred to as McDonough Tailings Containment Area (TCA).

### ***Previous closure activities***

Uranium mining operations ceased in 1960 on depletion of the then economic uranium ores. The mine and mill were shutdown, equipment was removed, and the mine was allowed to flood. Much of the usable mill and related equipment was removed from the site for re-use at Eldorado's Beaverlodge operation in Saskatchewan. In 1982, after depletion of the silver reserves the site was shutdown according to the mine safety and land use requirements of the day. Mine and mill facilities and equipment were demolished or removed and all wooden buildings, except the "Mountie" Cabin and a few cabins near Cross Fault Lake, were burned in place. Remaining structural steel, scrap metal, and equipment was deposited in McDonough TCA.

### ***Community concerns***

As a result of these past activities, the community of Déline expressed significant concerns with respect to existing contamination of their environment and in regard to potential future exposure

to radiation through their traditional use of the land. The outcome of these concerns was the establishment of the Canada-Déline Uranium Table (CDUT) which ensured that community concerns were addressed by the Federal Government in a manner acceptable to the community.

### ***Remediation planning process***

The remediation plan is the result of a multiyear process that includes the results of environmental site investigations, human health and ecological risk assessment studies, and integrates scientific principles, traditional knowledge research and community values in a thoughtful, respectful and cooperative manner. Remediation considerations and concepts were developed under the guidance and with the support of the CDUT and in association with Indian and Northern Affairs Canada (INAC). The final remediation plan has been developed under the management of the INACs Contaminants and Remediation Directorate (CARD) which has the mandate for management of all northern contaminated sites and follows federal policies and guidance on remediation approaches for contaminated sites in Northern Canada. The overall responsibility of the CARD is to minimize health and safety and environmental risks associated with the site and implement a remediation plan that meets the needs and concerns of INAC, its First Nation partners and all Northerners.

### ***Proponents and regulators***

INAC is the project proponent for the remediation plan and is responsible for securing appropriate approvals and resources, and implementation of the plan. The proposed works will need land and water licenses from the Sahtu Land and Water Board before they can be implemented. As a former uranium operation, the site needs a Waste Nuclear Substance License (WNSL) under the Nuclear Safety and Control Act. Through this license, the site will remain under the institutional control of the Canadian Nuclear Safety Commission (CNSC) in perpetuity and long term monitoring and reporting will be carried to provide assurance that the remediation works continue to perform as intended.

### ***Proposed remediation works***

A summary of the remediation plan is presented in Table S.1. The main elements of the remediation plan include activities associated with the underground mines; the general plant and yard areas; remaining surface waste rock; and the tailings containment areas. Within this context, the components considered within the remediation plan include the:

- Underground mine openings and crown pillars;
- Site Infrastructure and potential physical hazards including:
  - Remaining concrete foundations, walls and slabs;
  - Docks and dockwalls;
  - Roads;
  - Airstrip;

- Miscellaneous equipment, scrap, and debris; and
- Remaining wood frame structures.
- Contaminated areas, chemical and radiological concerns including:
  - Site Drainage;
  - Elevated gamma radiation;
  - Tailings containment areas (TCAs);
  - Exposed surface tailings areas;
  - Tailings in Great Bear Lake;
  - Fuel storage areas;
  - Hazardous materials.

### ***Schedule***

The overall schedule for the remediation program is dependent on licencing, permitting and logistics. It is currently expected to be as follows:

- Construct a winter road in 2006 and mobilize to site;
- Complete the bulk of the remediation activities from May to September 2006;
- Complete winter remediation activities prior to March 2007;
- Construct a winter road in 2007 to demobilize from site;
- Conduct five years of annual follow-up monitoring (2007-2011) to assess the performance of the remediation activities and the state of the receiving environment;
- Prepare annual site inspection reports for CNSC;
- Prepare a comprehensive Remediation Performance Assessment for submission to the Boards and CNSC by March 31<sup>st</sup> 2012 that assesses and summarizes all the monitoring information, assesses the benefits of current monitoring program and provides recommendations regarding the benefits of further monitoring; and,
- Continue with a modified monitoring plan according to the results of Comprehensive Remediation Performance Assessment.

**TABLE ES-1  
SUMMARY OF PROPOSED REMEDIATION ACTIONS**

	<b>Site Issue</b>	<b>Preferred Remediation Method</b>
<b>Access to the Underground</b>	<b>Mine openings</b>	Vertical openings will be sealed with a concrete caps, horizontal openings will be rock sealed. Where this is not possible the area will be fenced. Monitor as part of long term monitoring program.
<b>Site Infrastructure and Potential Physical Hazards</b>	<b>Concrete Foundations, Walls and Slabs</b>	Where accessible, vertical structures will be demolished and slabs on grade will be covered. All other remaining structures will be left to naturally erode. Monitor as part of long term monitoring program.
	<b>Dock Areas</b>	Dock walls will be removed to create more natural slope. Potential sediment impacts to the water will be minimized during cleanup. Monitor as part of long term monitoring program.
	<b>Roads</b>	Roads will be left to naturally re-vegetate. Where radiation levels exceed 250µR/h they will be covered. Monitor as part of long term monitoring program.
	<b>Airstrip</b>	The airstrip will remain closed to Transport Canada's standards.
	<b>Miscellaneous Equipment</b>	Drain engine fuels and dispose of equipment on site in approved areas unless it can be removed and salvaged in a safe manor.
	<b>Miscellaneous Scrap</b>	Pick up and dispose of on site in an approved location.
	<b>Wood Frame Structures</b>	All structures (Cross Fault Lake Head-frame, wooden sheds, cabins and the wooden "Mountie Cabin") will be demolished (burnt).
<b>Contaminated Areas, Chemical and Radiological Concerns</b>	<b>Site Runoff (Labine Point &amp; Inner Labine Bay Runoff)</b>	Removing any exposed tailings in identified drainage area and place a layer of coarse rock over the drainage routes. Monitor as part of long term monitoring program.
	<b>Elevated Gamma Radiation</b>	Cover flat accessible areas where gamma radiation levels exceed 250µR/h with approximately 0.5m of native cover material to reduce gamma levels to below 100µR/h. Monitor as part of long term monitoring program.
	<b>McDonough TCA</b>	Monitor water level and quality as part of long term monitoring plan.
	<b>Silver Point TCA</b>	Fill in surface depressions with tailings or native material. Cover entire TCA with engineered cover including impervious layer and protective cap. Monitor as part of long term monitoring program.
	<b>Murphy TCA</b>	Relocate exposed tailings into local depression and cover with native fill materials.
	<b>Radium (North and South) TCAs</b>	No actions required as tailings are stable, vegetation is clean and radiation levels are at background. Monitoring will continue to ensure conditions remain the same.
	<b>Murphy Bay Hillside Exposed Tailings</b>	Difficult to access area will be left undisturbed. Flat lying tailings will be covered with mine rock or native material.
	<b>West Adit/ Plant Area Exposed Tailings</b>	Excavate and dispose of exposed tailings in a management area such as: Murphy, Silver Point or McDonough TCA.
	<b>Tailings in Great Bear Lake</b>	Leave undisturbed and continue monitoring water quality and health of fish.
	<b>Fuel Storage Areas</b>	Will be covered or remain covered by rock.
	<b>Hazardous Materials</b>	If encountered, remove off-site for disposal.

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## GLOSSARY OF TERMS

**Aboriginal land claim:** A claim to a specific area of land based on legal concepts of land title and the traditional use and occupancy of that land by aboriginal peoples who did not sign treaties, nor were displaced due to war or other means.

**Absorbed dose:** In exposure assessment, the amount of a substance that penetrates an exposed organism's absorption barriers (e.g. skin, lung tissue, gastrointestinal tract) through physical or biological processes. The term is synonymous with internal dose.

**Acid generating:** Material capable of or actually producing acidic drainage.

**Acid Mine Drainage (AMD):** Any water draining mine workings or mine wastes which has a pH less than 4.5. It results from the oxidation of exposed sulphide mineralization which produces sulphuric acid and sulphate salts.

**Acid Producing Potential (APP):** The potential of a material to produce acid, generally stated as kg CaCO<sub>3</sub> equivalent per tonne of rock.

**Acid Rock Drainage (ARD):** Drainage of low pH water from mineral areas as a result of the oxidation of sulphur-bearing materials which may release metals into the environment and result in significant environmental impacts.

**Activity:** A measurement of the number of becquerels of a radioactive species in a sample.

**Adit:** A nearly horizontal passage from the surface by which a mine is entered and dewatered. A blind horizontal opening into a mountain, with only one entrance.

**Aerial photography:** Photographs taken from an aircraft either obliquely or vertically.

**Aggregate:** Sand, gravel, or crushed rock.

**As low as reasonably achievable (ALARA):** A concept in radiation protection according to which radiation exposures are kept as far below the regulatory limits as possible, taking into account the state of technology achievable and the cost of improvement in relation to: (1) benefit or risk to the environment and to public health and safety; (2) other societal and socioeconomic considerations, and (3) the use of radioactive materials in the public interest in medical diagnosis and therapy, research, the manufacturer of consumer products, and the production of electricity by nuclear power reactors.

**Algae:** Photosynthetic plants which live and reproduce entirely immersed in water. They range in size from simple, single-celled organisms to huge kelps several metres long.

**Alkalinity:** The aggregate measure of the concentration of hydroxyl, carbonate and bicarbonate ions, and dissolved CO<sub>2</sub>. Therefore, it is a general indicator of the acid-buffering capacity of the water body.

**Alpha radiation:** The least penetrating, but most strongly ionizing, of the three principal forms of radiation from radioactive materials, alpha radiation will be halted by the outer layer of dead skin cells in human skin, or by a single sheet of paper. However, alpha radiation can damage live body cells if ingested or inhaled through food, water, air, etc.

**Ambient:** The natural surrounding (background) conditions in a given area.

**Ambient air:** Any unconfined portion of the atmosphere: open air, surrounding air.

**Amplitude:** The magnitude or height of a wave, measured as the distance between the zero point of the wave to the point of maximum displacement. The amplitude is one half of the vertical distance between the crest and the trough.

**Analyte:** A compound or element being analyzed.

**Analytic detection limit:** The limit of measurement of a given parameter, below which variations in concentration are indistinguishable from one another.

**Asbestos:** A naturally occurring soft fibrous mineral commonly used in fireproofing materials and considered to be highly carcinogenic.

**Assessment endpoint:** A quantitative or quantifiable expression of the environmental value considered to be at risk in a risk assessment.

**Atmospheric dispersion:** The dispersion into the atmosphere of matter and gases that can be carried by air currents.

**Atomic radiation worker:** A person who could receive a dose of radiation in excess of the public dose limit of 5 millisieverts (mSv) per year. Once classified as such, the individual is closely monitored and is subject to a maximum exposure limit of 50 mSv per year.

**Back:** The ceiling or roof in an underground mine.

**Background radiation:** The radiation in the natural environment, including cosmic rays and radiation from naturally radioactive elements. It is also called natural radiation.

**Baseline:** See “Environmental baseline”.

**Basement:** The undifferentiated rocks (commonly igneous and metamorphic) which underlie the rocks of interest (commonly sedimentary) in a given area. In many regions the basement is of Precambrian age.

**Bathymetry:** The science of measuring the water depth relative to sea level.

**Becquerel or Bq:** A standard international unit of radioactivity, equal to one radioactive disintegration per second. The obsolete unit curie or Ci, based upon the amount of radioactivity in a gram of radium, equals  $3.7 \times 10^{10}$  Bq.

**Bedrock:** The solid rock that underlies gravel, soil or other surficial material.

**Benthic:** Refers to the bottom of a lake or river and/or the organisms that inhabit it.

**Benthos:** The whole assemblage of plants or animals living on the lake or river bottom; distinguished from *plankton*.

**Best Management Practice (BMP):** Methods that have been determined to be the most effective, practical means of preventing or reducing pollution from non-point sources.

**Beta particle:** An electron which is emitted from an atom as a result of a radioactive decay.

**Bioaccumulation:** The net accumulation of a chemical by an organism as a result of uptake from all routes of exposure.

**Bioassay:** Any method for quantitatively determining the concentration of a substance in plant or animal tissue.

**Bioavailability:** Degree of ability to be absorbed and ready to interact in organism metabolism.

**Biological diversity (biodiversity):** The variety of different species, the genetic variability of each species, and the variety of different ecosystems that they form.

**Biological indicator species:** See “Indicator species”.

**Biomagnification:** The tendency of some chemicals to accumulate to higher concentrations at higher levels in the food web through dietary accumulation.

**Biosphere:** Total of all areas on earth where organisms are found.

**Biota:** The animal and plant life of a region.

**Bog:** An acidic, poorly drained, rainwater fed peatland characterized by hummocks or sphagnum spp. Mosses with Labrador tea usually being the dominant shrub. Bogs may be treed with stunted black spruce and tamarack (muskeg) or may be open (open bogs).

**Boreal Forest:** The predominantly coniferous forest of northern Canada.

**Borehole:** Hole made with drilling equipment typically to obtain samples.

**Buffering capacity:** The degree to which a given volume of water or soil is able to neutralize acids.

**Carbonate:** Any mineral  $CO_3^{2-}$  containing (carbonate) ions.

**Carcinogen:** An agent that has the potential to cause cancer.

**Carnivore:** An animal that eats the flesh of other animals.

**Chlorite:** A group of widely distributed usually greenish, metamorphic minerals which are usually associated with micas, which they resemble.

**Clay:** Soil particles which are smaller than silt (less than 0.002 mm in diameter).

**Climatology:** The study of weather conditions or long periods of time.

**Collar:** The mount or upper end of a mine shaft or drill hole.

**Compliance monitoring:** Monitoring of operations to ensure they comply with government regulatory standards and requirements.

**Composite sample:** A sample for analysis that is made up of two or more samples from the same sample site or a number of sample sites.

**Conductivity:** A measurement of the electrical conductivity of a water body or sample in order to determine the amount of dissolved material present.

**Conservative:** As used in the term conservative estimates, this is considered a pessimistic or an overestimate of the level, effect or hazard, as the case may be.

**Consumers** (primary, secondary, tertiary): Trophic levels in an ecosystem which obtain their energy from trophic levels positioned below them, e.g. primary consumers frequently feed directly on plants (primary producers) and secondary consumers would feed on primary consumers.

**Contaminant migration:** The movement of contaminants from one location to another.

**Contamination:** Elements both radioactive and non-radioactive that are present at levels above those normally found (i.e. above background).

**Contingency plan:** A prearranged plan to be implemented in the event of some unforeseen happening of serious concern.

**Country food:** Food that is derived from the local countryside and not associated with agricultural products (e.g., moose meat and wild blueberries) purchased through a store.

**Crown or surface pillar:** A body of rock of variable geometry, which may or may not contain minerals. Located above the underground operations, it supports the surface above stopes.

**Curie:** See **Becquerel**.

**Decay:** The disintegration of the nucleus of an unstable radionuclide by the spontaneous emission of energy or particles, resulting in a decrease in the number of radioactive atoms in the sample.

**Decay chain:** The series of nuclides that form sequentially as radioactive decay progresses.

**Decommissioning:** The act of removing a regulated facility from operation and operational regulation. This usually entails a certain amount of cleanup (decontamination).

**Decontamination:** The process of removing contaminants from equipment, personnel, buildings or water.

**Delineate:** To determine the outer limits and size of something (i.e., an ore body).

**Dip:** A vertical angle measured downward from the horizontal plane to the level of an inclined plane such as a tilted sedimentary rock unit (see strike).

**Discharge:** The volume of water passing a given point per unit time, usually expressed as m<sup>3</sup>/sec.

**Dose:** See **Effective dose** (unless otherwise specified).

**Dose:** A general term used to describe the amount of radiation or chemical absorbed by a person or in some cases a particular organ. The term dose can be used to describe two concepts. The first concept is a physical quantity; for radiation, it is the amount of energy absorbed per unit mass of tissue (see absorbed dose) and for chemicals, it is the concentration in tissue. This EIS uses the term dose to refer to effective dose (a measure of radiation exposure), unless otherwise stated.

**Dose, absorbed:** The term absorbed dose is the amount of energy absorbed per unit mass. Absorbed dose is measured in units of  $\text{J/kg}^{-1}$  the SI unit of absorbed dose is the gray (Gy). Note  $1\text{Gy} = 1000\text{mGy} = 100\text{rad}$ .

**Dose, effective:** The effective dose is the sum of the dose equivalents to the individual organs each multiplied by a tissue weighing factor. The tissue weighing factors are assigned to various organs or tissue based on their sensitivity to radiation induced cancer or genetic defects. Effective dose provides a measure of risk from different types of radiation exposure. It is measured in units of  $\text{J/kg}^{-1}$ ; the SI unit of effective dose is the sievert (Sv). Note  $1\text{Sv} = 1000\text{mSv} = 100\text{rem}$ .

**Dose, equivalent:** The term equivalent dose is the absorbed dose multiplied by a radiation weighting factor or quality factor. The radiation weighting factor is based on the ability of a particular type of radiation to damage biological tissue. The radiation weighting factor for gamma radiation is 1 and for alpha radiation it is 20. Equivalent dose provides a measure of risk. It is measured in units of  $\text{J/kg}^{-1}$  the SI unit of equivalent dose is the sievert (Sv). Note  $1\text{Sv} = 1000\text{mSv} = 100\text{rem}$ .

**Drainage basin:** The area of land and water bodies therein, draining to a given point, usually a lake or river.

**Dust fall jar:** Standardized a container used for collecting air particulate fallout over a fixed period.

**Ecological Risk Assessment:** The application of a formal framework, analytical process, or model to estimate the effects of human actions(s) on a natural resource and to interpret the significance of those effects in light of the uncertainties identified in each component of the assessment process. Such analysis includes initial hazard identification, exposure and dose response assessments, and risk characterization.

**Ecosystem:** Any natural system in which there is an interdependence upon and interaction between living organisms and their physical environment. This interdependence is characterized by the transfer of energy between the organisms themselves and their physical environment in a complex series of cycles.

**Effective dose:** This term is intended to express radiation doses in a manner such that the long-term biological harm to humans will be approximately the same per unit of effective dose, regardless of the type of radiation involved or of the parts of the body exposed to radiation. To obtain effective dose in Sv, the absorbed radiation dose in Gy is multiplied by the appropriate radiation factor and, in case of partial body exposure, by the appropriate tissue weighting factors.

Both of these factors are taken to be one in the case of whole body exposure to gamma rays. Further details can be found in ACRP-13 (1991) and ICRP Publication 60 (1991).

**Element:** A substance that is comprised of one and only one distinct kind of atom.

**Environment:** The sum of all external conditions, influences and forces affecting the development and life of organisms.

**Environmental baseline:** The data collection characterizing the “natural” environment in its pre-development or pre-impact state. This data is used as a base for determining potential and actual impacts in the defined impact area.

**Environmental Impact Assessment (EIA):** A method of analysis which attempts to predict the possible impacts of a proposed major development upon the socio-economic and natural environment of the surrounding area or region and which attempts to offer means of settling conflicts and mitigating significant negative impacts.

**Environmental Impact Statement (EIS):** The document put forward by a proponent which brings together and summarizes the result of an environmental impact assessment (EIA).

**Environmental Assessment:** An environmental analysis to determine whether a site / facility would significantly affect the environment and thus require a more detailed environmental impact statement.

**Environmental Impact:** A change in environmental conditions resulting from an action or development, which may be negative, positive, or neutral.

**Erosion:** The wearing down (weathering) and removal of soil, rock fragments and bedrock through the action of rivers, glaciers, sea and wind.

**Evapotranspiration:** The total return of water from the land to the atmosphere, including the process of evaporation from the soil surface and transpiration from plants.

**Exposure:** The amount of radiation or pollutant present in a given environment that represents a potential health threat to living organisms.

**Exposure Assessment:** Identifying the pathways by which toxicants may reach individuals, estimating how much of a chemical an individual is likely to be exposed to, and estimating the number likely to be exposed.

**Exposure Concentration:** The concentration of a chemical or other pollutant representing a health threat in a given environment.

**Exposure Pathway:** The path from sources of pollutants via, soil, water, or food to man and other species or settings.

**Fan:** A mechanical device used as a means of forcing air into underground workings.

**Fault:** A fracture in bedrock along which movement has taken place.

**Foot wall:** The underlying surface of an inclined fault plane.

**Fracture (geological):** A crack, joint, fault or other break in rocks.

**Rock fracture:** The general term given to any non-sedimentary medicinal discontinuity thought to represent a surface or zone of mechanical failure.

**Gamma radiation:** The greatest penetrating power, but least ionizing, of the three principal forms of radiation from radioactive materials. Gamma radiation can completely penetrate and damage all body organs. Gamma radiation can be shielded effectively by several inches of lead, steel, or concrete, depending upon the shielding material and the energy and intensity of the gamma radiation.

**Gauging station:** A location where water depth (stage) is recorded.

**Geochemistry:** Refers to the chemical analysis of surface and subsurface water, rock alluvium, soil and plants.

**Grab sample:** A single sample taken for analysis purposes in a random manner.

**Grade:** The relative quantity or percentage of ore mineral content in an ore body (i.e., g/t Au or % U<sub>3</sub>O<sub>8</sub>).

**Grading:** The process of making a surface level or evenly sloped.

**Groundwater:** Water beneath the earth's surface, accumulating as a result of infiltration and seepage, and serving as a source of springs and wells.

**Habitat:** The natural home of a plant or animal.

**Hanging wall:** The overlying surface of an inclined fault plane.

**Hazard:** Potential for radiation, a chemical or other pollutant to cause human illness or injury. Hazard identification of a given substances is an informed judgment based on verifiable toxicity data from animal models or human studies.

**Hazard Assessment:** Evaluating the effects of a contaminant or determining a margin of safety for an organism by comparing the concentration which causes toxic effects with an estimate of exposure to the organism.

**Headframe:** The structure surmounting the shaft which supports the hoist rope pulley, and often the hoist itself.

**Heavy metals:** Any metal with a high atomic weight (usually greater than 100). They are poisonous and tend to persist in living tissue once ingested, e.g. mercury, lead, cadmium and chromium.

**Health and Safety Monitoring:** Monitoring activities associated with the identification and monitoring of potential human health and safety hazards.

**Human Health Risk Assessment:** The process of quantifying risks and determining the acceptability of those risk to humans.

**Hydraulic head:** A combined measure of the elevation and the water pressure at a point in an aquifer which represents the total energy of the water; since ground water moves in the direction of lower hydraulic head (i.e. toward lower energy), and hydraulic head is a measure of water pressure, ground water can and often does flow 'uphill'.

**Hydrogeology:** The study of subsurface waters and related geologic aspects of surface water.

**Hydrology:** The study of the characteristics, occurrence, movement and utilization of water on or below the earth's surface and within its atmosphere.

**Impervious liner:** A layer of clay or manmade material such as High-Density Polyethylene (HDPE), used to seal the bottom of containment structures in order to prevent percolation and migration of potential contaminants.

**Indicator species (or biological indicator species):** An individual plant or animal species that indicates the quality of the environment.

**Incremental:** Small increase.

**Isotope:** Differing forms of a particular chemical element. The atoms of all forms will have the same number of protons in each nucleus and the same number of electrons surrounding the nucleus. Hence, the chemical behaviour of all forms will be essentially identical. However, each version's nuclei will have a number of neutrons that is different from any other version. Thus, the isotopes (forms) of a particular element will have different physical properties, including the mass of its atoms and whether the nuclear structure of its atoms will retain its identity

indefinitely (be “stable”) or undergo spontaneous transformation at some future time (be “radioactive”).

**Lay-down area:** An open area for storing equipment or materials at a mine site prior to their use.

**Leachate:** The water which percolates through a porous medium such as soil and transports any salts or other dissolvable materials which may be found in the soil.

**Leaching:** Washing out of soluble substances by water passing down through rock or soil. In a milling sense, indicates the dissolving of ore minerals from the ground ore.

**Limnological:** Referring to the scientific study of lakes and their physical, chemical and biological components.

**Loadings:** Total mass of contaminants to a water body or to the land surface over a specified time.

**Lower limit of detection:** This is the lowest concentration of radioactive material in a sample that can be detected at the 95% confidence level with a given analytical system.

**Macrophytes:** Rooted aquatic vascular plants.

**Maintenance Activities:** activities undertaken to ensure that conditions remain in the desired state

**Manway:** Vertical opening that can be used by miners to exit the underground workings. A shaft compartment used to accommodate ladders, pipes and electric cables. Underground usually a small passage used as a travelway for miners, an airway and supply route.

**Mean:** The average value of the data.

**Measurement endpoint:** A quantitative summary of the results of a toxicity test, a biological monitoring study, or other activity intended to reveal the effects of a substance.

**Mine drift:** A horizontal (or near horizontal) passageway in a mine through or parallel to a vein, or a secondary passageway between shafts or tunnels.

**Mineral:** A naturally occurring inorganic, crystalline solid that has a definite chemical composition and characteristic physical properties.

**Mineralization:** The process by which a valuable mineral or minerals are introduced into a rock, resulting in a potential or actual ore deposit.

**Mitigation:** An action or design intended to reduce the severity or extent of an environmental impact.

**Modeling:** Using mathematical principles, information is arranged in a computer program to model conditions in the environment and to predict the outcome of certain operations.

**Monitoring:** sampling, measurement, and/or inspection.

**Muskeg:** A poorly drained bog composed of peat moss, decayed vegetable matter and black soil.

**Natural radioactivity:** The property of radioactivity exhibited by more than 50 naturally occurring radionuclides.

**Neutralizing potential (NP):** The potential of material to neutralize an acid or a base.

**Nucleus:** The small, positively charged core of an atom. It is only about 1/10000th the diameter of the atom but contains nearly all the atom's mass. All nuclei contain both protons and neutrons, except the nucleus of ordinary hydrogen, which consists of a single proton.

**Nuclide:** An atomic nucleus that contains a specific number of protons and neutrons. The nuclei of all isotopes of a given element have the same numbers of protons but different numbers of neutrons, and therefore are different nuclides.

**Ore:** Naturally occurring rock material from which a mineral or minerals of economic value can be profitably mined.

**Ore body:** A continuous well-defined mass of material containing enough ore to make extraction economically feasible.

**Outcrop:** The part of a rock formation that appears at the surface of the earth, uncovered by water or overburden.

**Overburden:** Unconsolidated soil and rock material overlying bedrock.

**Oxidation:** The process of combining with oxygen, especially at the atomic level.

**Particulate:** Consisting of particles.

**Pathway:** The physical course a chemical or pollutant takes from its source to the exposed organism.

**Pathways analysis:** A method of estimating the transfer of contaminants (e.g. radionuclides released in water) and subsequently accumulated up the food chain to fish, vegetation, mammals and humans and the resulting radiological dose to humans.

**PCB's:** A group of manufactured chemicals including 209 different, but closely related, compounds made up of carbon, hydrogen, and chlorine. If released to the environment, they persist for long periods of time and can biomagnify in the food web. They are an organic toxicant suspected of causing cancer, endocrine disruption, and other adverse impacts on organisms.

**Permafrost:** Thermal conditions remaining below 0°C continuously for more than one year.

**Permeability:** Describes the ability of subsurface features to transport water.

**pH:** A number expressing the degree of alkalinity or acidity of a substance according to the hydrogen ion concentration. A substance is said to be “neutral” if its pH is 7, acidic if less than 7 and alkaline if greater than 7.

**Phosphate (PO<sub>4</sub>):** A plant nutrient which, when present in water, may lead to excessive algal growth.

**Phytoplankton:** Any microscopic or near microscopic, free-floating autotrophic aquatic plant.

**Piezometer:** A piezometer is a small slotted standpipe, usually hand-driven into the ground, which is used to measure water pressure, seepage of groundwater, and groundwater movement. It also can be used to sample near-surface groundwater.

**Pitchblende:** The most common form of uranium. A mineral consisting of uranium oxide and two amounts of iodine, thorium, polonium and lead. Uraninite in massive form is called pitchblende.

**Population:** A group within a single species, the individuals of which can and do freely interbreed.

**Porosity:** The relative volume of open spaces within a rock or soil. (Usually expressed as a percentage of the total volume of the material occupied by the open spaces, or interstices.)

**Porewater:** Water contaminated and trapped within void spaces in soils or rocks.

**Potable water:** Water that is fit for human consumption and use.

**Precipitation:** The deposition of atmospheric moisture as rain, sleet, snow, hail, frost or dew.

**Preliminary Assessment:** The process of collecting and reviewing available information about a known or suspected waste site or release.

**Primary consumer (see “consumer”):** An organism that feeds more or less exclusively on green plants or their products, such as seeds or nuts.

**Primary producer:** A trophic level in an ecosystem which converts inorganic raw material into organic substances (e.g. plants).

**Project environment:** Includes watersheds, local air-sheds, ecosystems and other systems which interact directly with the project site.

**Prospector:** An individual engaged in the search for economic mineral deposits, identifying minerals or mineral properties visually or with the use of portable instruments.

**Pyrite:** A common yellow mineral with a brilliant metallic lustre often crystallizing into cubes. It is an important sulphur ore and is often associated with gold and copper.

**Radiation:** The emission and propagation of energy through space or matter in the form of electromagnetic waves (e.g. gamma rays) or fast-moving particles such as alpha and beta particles.

**Radioactive:** The condition of a material exhibiting the spontaneous decay of an unstable atomic nucleus into a stable or unstable nucleus (e.g. uranium-238 decays into thorium-234 (unstable) and polonium-210 decays into lead-208 (stable)).

**Radioactive decay:** The spontaneous transformation of a radionuclide into a different nuclide. The transformation results in the emission of ionizing radiation, often an alpha or beta particle. In some cases, gamma radiation is emitted along with the alpha or beta particle.

**Radionuclide:** An element or isotope which is radioactive as a result of the instability of the nucleus of its atom (e.g. radium or uranium).

**Radon:** A radioactive element in the U-238 decay chain produced by the radioactive decay of radium-226. Radon occurs as an inert gas. The half-life of Rn-222 is 3.8 days. Short-lived radon decay products or, daughters, are the principal radiation hazard in the underground mine. Decay of radon-222 and short-lived decay products produces lead-210.

**Range:** The upper and lower limits of a data set.

**Reagent:** A Substance used to cause a reaction (i.e., chemicals used in milling or water treatment).

**Receptor:** A human or ecological entity exposed to a contaminant released to the environment.

**Reclamation:** Restoration of a site to a beneficial use which may be for purposes other than the original use.

**Remediation:** The improvement of a contaminated site to prevent, minimize or mitigate damage to human health or the environment. Remediation involves the development and application of a planned approach that removes, destroys, contains or otherwise reduces the availability of contaminants to receptors of concern.

**Remediation Issue:** Issues of concern for a specific aspect of the site.

**Risk:** A measure of the probability that damage to life, health, property, and/or the environment will occur as a result of a given hazard.

**Risk Assessment:** Qualitative and quantitative evaluation of the risk posed to human health and/or the environment by the actual or potential presence and/or use of specific pollutants.

**Risk Characterization:** The last phase of the risk assessment process that estimates the potential for adverse health or ecological effects to occur from exposure to a stressor and evaluates the uncertainty involved.

**Roentgen (R):** The roentgen is a historical unit used to measure radiation exposure, the number of ionizations in a mass of air. The roentgen can only be used to describe the amount of X or gamma radiation, and only in air. In metric units, one roentgen is equal to depositing in dry air enough energy to produce  $2.58\text{E-}4$  coulombs per kg.

**Run-off:** The part of rainfall that is not absorbed directly by the soil but is drained off in rills or streams.

**Screening:** A preliminary stage of the assessment process for quick evaluation of relatively simple and routine activities, or for determining the level of effort required for evaluating more complex projects.

**Sediment:** Loose, solid particles resulting from the breakdown of rocks, chemical precipitation or from organisms.

**Seiche wind effects:** A standing wave or rhythmic increase in water level of a body of water resulting from strong and persistent winds.

**Seismic:** Pertaining to, characteristic of, or produced by earthquakes.

**Sievert or Sv:** A unit of equivalent or effective dose. In theory, the unit Sv should only be applied at low doses and low dose rates. Equivalent and effective doses are frequently expressed as millisievert (mSv), equal to one-thousandth of a sievert, or as microsievert ( $\mu\text{Sv}$ ), equal to one-millionth of a sievert.

**Slumping:** Sagging or physical subsidence of materials.

**Spalling:** Material breaking off from a surface, typically due to freeze/thaw processes.

**Staff Gauge:** A pole or 'staff' graduated in standard units of measurement for the purpose of measuring depth.

**Stopes:** Underground mine working from which one has been extracted for processing and metal recovery.

**Strike:** Refers to the direction taken by a structural surface as it intersects the horizontal plane e.g. bedding or fault plane. The strike is at right angles to the direction of dip.

**Structure (geological):** Features produced by deformation or displacement of the rocks, such as a fold or fault.

**Suiphides:** Any mineral compound characterized by the chemical linkage of sulphur with a metal e.g. galena ( $\text{PbS}$ ), pyrite ( $\text{FeS}_2$ ).

**Sulphuric acid ( $\text{H}_2\text{SO}_4$ ):** A toxic, corrosive, strongly acid, colourless liquid that is miscible with water and dissolves most metals.

**Taiga:** The northern forest of coniferous trees that lies just south of the arctic tundra.

**Tailings:** Finely ground rock particle material rejected from a mill after most of the recoverable ore minerals have been extracted.

**Tailings:** Residue of raw material separated out during the processing of mineral ores.

**Tailings Containment Area or TCA:** an area designated for the purpose of receiving and containing milling residues.

**Tank farm:** An area designed to contain various size tanks holding various types of liquids or gases, most commonly propane or petro-chemicals.

**Thermistor:** A thermistor is a thermally sensitive resistor of which its primary function is to exhibit a change in resistance accompanying a change in temperature.

**Thermocline:** The transition layer separating the upper warm layer (epilimnion) from the lower cold water layer (hypohmmon) in lakes which is characterized by a rapid decline in temperature.

**Thermoluminescent dosimeter (TLID):** A device used to measure individual gamma radiation exposure.

**Till:** An unsorted heterogeneous mixture of rock debris carried and deposited directly by a glacier, with very little subsequent reworking by melt water.

**Topographic map:** A map showing elevations by means of contour lines (i.e. lines joining points of equal elevation).

**Total dissolved solids (TDS):** The sum of all the concentrations of dissolved ions in a solution usually expressed as mg/L.

**Total suspended solids (TSS):** The sum total amount of suspended solid material in a sample, usually expressed as mg/L.

**Track-etch cup:** A device for measuring alpha radiation associated with radon gas and its progeny.

**Traditional knowledge:** Refers to the ancient understanding of philosophy, events and things passed on orally through generations by aboriginal people.

**Traditional land use:** Refers to land use by aboriginal people which reflect the historic activities of their people prior to European settlement (i.e. hunting, fishing, gathering).

**Traditional lifestyle:** Refers to the lifestyle of aboriginal people prior to European settlement.

**Total suspended solids:** Defined as all the material in a sample of water which can be removed by a 0.45 µm glass fiber filter.

**Turnover:** A period of lake wide circulation in spring and fall when surface water layers and bottom water layers are able to mix together.

**Uncertainty:** A quantitative expression of error.

**Uraninite:** Black uranium ore, mineral commonly called pitchblende (composition ranges from  $UO_2$  to  $U_3O_8$ ).

**Uptake:** The process/act by which a contaminant (e.g. a radionuclide) enters a biological organism (e.g. inhalation, ingestion by humans).

**Vent:** An (vertical) opening used for input of fresh air or exhausting used air from underground.

**Ventraise:** See **Vent**.

**Waste rock:** That rock or mineral which must be removed from a mine to keep the mining scheme practical, but which has no economic value.

**Watershed:** A drainage area or basin into which all surface water from a particular area collects and is transported.

**Winter Road:** A substandard, seasonal road passable only during the winter when the ground, muskegs and lakes it passes over are frozen.

**Zooplankton:** Any microscopic or nearly microscopic animals that move passively in aquatic ecosystems.

## UNITS AND ABBREVIATIONS

Bq	becquerel (1 disintegration per second, or 27 pCi)
Ci	curie ( $3.7 \times 10^{10}$ disintegrations per second)
g/cm <sup>3</sup>	grams per cubic centimetre
g/m <sup>3</sup>	grams per cubic metre
g/y	grams per year
h/d	hours per day
kg/d	kilogram per day
kg/m <sup>2</sup>	kilogram per square meter
kg/y	kilogram per year
K <sub>d</sub>	distribution coefficient
L/h	litres per hour
L/d	litres per day
LLD	lower limit of detection
m	metre
m <sup>2</sup>	square metre
m/s	metre per second
m <sup>3</sup> /h	cubic metres per hour
m <sup>3</sup> /y	cubic metres per year
µrem	microrem ( $1 \times 10^{-6}$ rem, or 0.01 µSv)
µrem/y	microrem per year
µr/h	micro Roentgen per hour
µSv	microsievert ( $1 \times 10^{-6}$ Sv, or 100 µrem)
µSv/y	microsievert per year
NaI	sodium iodide scintillation detector
Pb-210	lead-210
pCi	$1 \times 10^{-12}$ Ci, or 0.037 Bq
pCi/g	picocuries per gram
pCi/L	picocuries per liter
PHC	Petroleum hydrocarbon
Po-210	polonium-210
Ra-224	radium-224
Ra-226	radium-226
Ra-228	radium-228

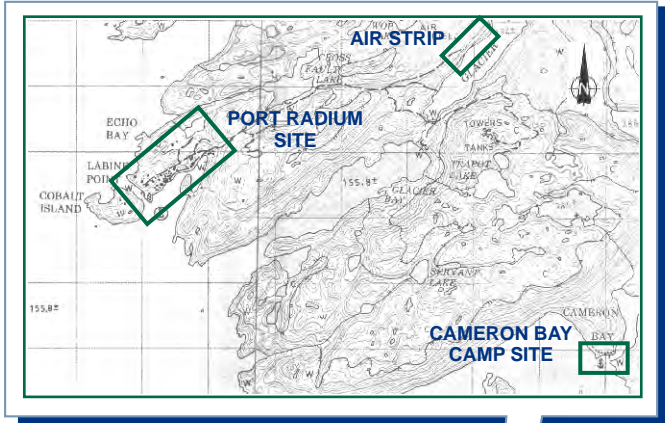
Radtrak <sup>®</sup>	alpha track detectors (Landauer Inc.)
SI	the International System of Units
Sv	sievert (100 rem)
TCA	Tailings Containment Area
Th-228	thorium-228
Th-230	thorium-230
Th-232	thorium-232
TLD	thermoluminescent dosimeter
U	uranium
U-234	uranium-234
U-235	uranium-235
U-238	uranium-238

## CHEMICAL SYMBOLS

Aluminum	Al
Ammonia	NH <sub>3</sub>
Arsenic	As
Barium	Ba
Beryllium	Be
Cadmium	Cd
Calcium	Ca
Chloride	Cl
Chromium	Cr
Cobalt	Co
Copper	Cu
Dissolved Organic Carbon	DOC
Fluoride	F
Iron	Fe
Lead	Pb
Lithium	Li
Magnesium	Mg
Manganese	Mn
Molybdenum	Mo
Nickel	Ni
Nitrate + Nitrite	NO <sub>3</sub> + NO <sub>2</sub>
Particulate Organic Carbon	POC
Particulate Organic Nitrogen	PON
Phosphorous	P
Potassium	K
Selenium	Se
Silver	Ag
Sodium	Na
Strontium	Sr
Sulphate	SO <sub>4</sub>
Vanadium	V
Zinc	Zn

# Section 1

# INTRODUCTION



## 1.0 INTRODUCTION

### 1.1 OVERVIEW OF THE PROJECT

#### *Location*

Port Radium site is located in the Northwest Territories at Echo Bay on the eastern shores of Great Bear Lake. The site is situated at the edge of the Arctic Circle about 440 km north of the City of Yellowknife and about 265 km east of the Dene community of Déline, within the Sahtu settlement lands. Predominant access to the site is by water, although un-maintained airstrip exists at Glacier Bay which is located about 6 km east of the Port Radium site.



#### *Setting*

The site is characterized by the barren and rugged relief of the eastern shores of Great Bear Lake that features rock outcrops and sheer cliffs that rise rapidly from the lake's shoreline. Peak elevations in the region around the site rise to more than 300 m above Great Bear Lake, with peak elevations at the site being in the order of about 60 m above Great Bear Lake water level. Natural flat lying land is, for the most part, non-existent at the site and the surrounding areas as shown on the contours map in Figure 1.1-1. Soil cover is generally sparse and, to the degree that it exists, is generally very shallow.



Within the immediate area of the site, sparse soil cover and vegetation exist primarily in the shallow low-lying area to the south-west of the West Adit on Labine Point, on some of the hillside areas around the site, and in undisturbed areas to the north and east of the site. For the most part, the steeper slopes along the shoreline consist of bare rock surfaces with limited or no vegetation cover. Only sparse vegetation consisting of lichen, grasses, bushes, and pine trees cover the undisturbed areas of the site. Exposed bedrock predominates the area in general, and

in the area of the former mine and plant site, although some of the parts of the site are covered by waste rock or road fill. These areas are also associated with former mine facilities including tailings covers, the causeway, buildings, and plant lay down areas.

### ***Operation***

Following discovery of a pitchblende seam at the Port Radium site in 1930, some manner of mining and milling activity was undertaken almost continuously between 1932 and 1982. Initially, radium was mined and processed. Subsequently, uranium, and silver ores were mined and milled at various times throughout history. Eldorado Mining and Refining took the site over in 1942 because of the uranium potential. From 1942 to 1960 uranium was mined and processed. Portions of the townsite and milling facilities were later re-activated in association with the development and operation of the nearby Echo Bay mine from 1964 to 1972. From 1974 to 1982, Echo Bay Mines Ltd. mined the Port Radium underground workings for silver. Upon depletion of the reserves in 1982, the site was decommissioned.

Records indicate that in total, Eldorado and Echo Bay mining and milling operations combined produced some 37 million ounces of silver, 10.5 million pounds of copper and 13.7 million pounds of uranium oxide (U<sub>3</sub>O<sub>8</sub>) before final shutdown and closure in August 1982. While detailed records are not available, the amount of gangue material (tailings) produced from the processing of uranium ore has been estimated to be in the order of 910,000 tons, most of which were deposited in Great Bear Lake. It is estimated that a total of about 800,000 tons of tailings were generated from the silver operations, most of which were discharged to the McDonough (Garbage Lake), now referred to as McDonough Tailings Containment Area (TCA).

### ***Previous closure activities***

Over the mine's life, activities at Port Radium were shut down several times due to economic and reserve factors. The first shutdown occurred in 1940 due to a dramatic reduction in world radium prices. At that time, closure work commenced on the site in the summer of 1940, and by August, extensive grouting of the mine had been completed. In 1941 the mine was re-started, although not as a radium mine, but rather as a uranium mine. Uranium mining operations ceased in 1960 on depletion of the then economic uranium ores, and the mine and mill were shutdown. Equipment was removed from the mine and it was allowed to flood. Much of the usable mill and related equipment was removed from the site for re-use at Eldorado's Beaverlodge operation in Saskatchewan.

From 1964 to 1975 Echo Bay Mines Limited used the Port Radium town site and mill to facilitate the operational needs of their silver mine located approximately 1 kilometre northeast of the Eldorado mine. In 1976 after depletion of this ore body, Echo Bay Mines re-opened the former Eldorado mine shaft #1, and mined silver from its workings until depletion in 1982. When the silver operations stopped, the site was shutdown according to the mine safety and land use requirements of the day. Equipment and facilities were either demolished or removed with

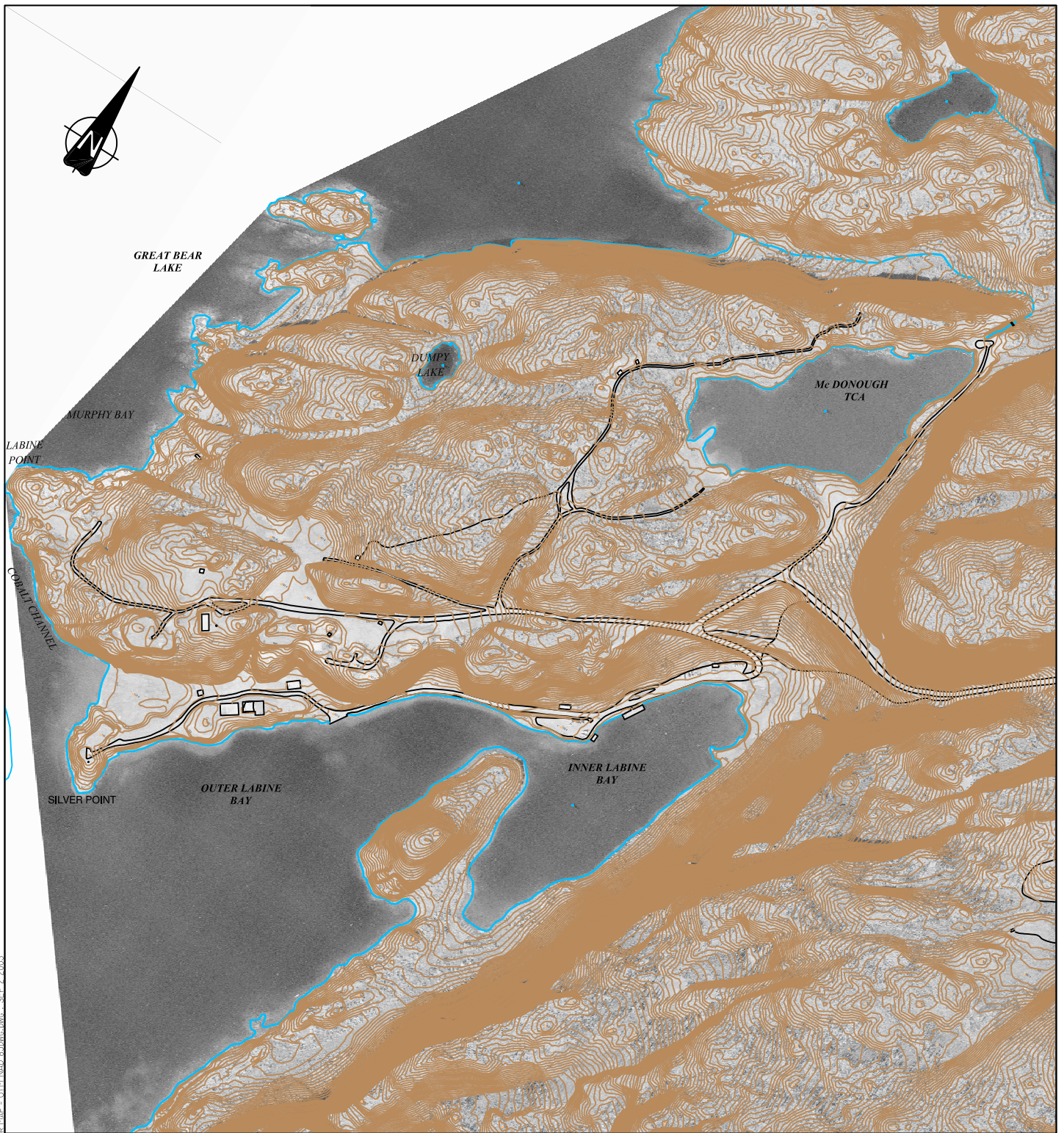


FIGURE 1.1-1

PORT RADIUM MINE  
 ORTHORECTIFIED SITE  
 CONTOUR MAP



remaining structural steel, scrap metal and equipment being disposed of in the east end of McDonough TCA and all wooden buildings (except the “Mountie” Cabin and a few cabins near Cross Fault Lake) being burned.

### ***Community concerns***

As a result of these past activities, both at the site and in association with ore/concentrate transportation, the community of Déline expressed significant concerns with respect to existing contamination of their environment and in regard to potential future exposure to radiation through their traditional use of the land. In addition, the community also had concerns with respect to past exposure to radiation by local labourers who handled the ore and concentrate bags from Port Radium. These concerns were expressed by the community through Chief and Council to the Government of Canada in the late 1990s. The community concerns included questions with respect to the quality and extent of information on current site and vicinity conditions. The community expressed its desire that these concerns be resolved in a clear and transparent manner, in a way in which they are directly involved. The outcome of these concerns resulted in the establishment of the Canada-Déline Uranium Table (CDUT) which ensured that the community and Federal Government concerns were addressed in a manner acceptable to the community.

### ***Proposed remediation***

The current remediation plan provides the basis for moving forward with addressing concerns associated with the site in an agreed-to manner through the CDUT. The remediation plan is based on the results of environmental site investigations, human health and ecological risk assessment studies, integrating scientific principles, traditional knowledge research and community values in thoughtful, respectful and cooperative manner.

The remediation plan is the outcome of a unique, wide ranging, and intensive co-operative effort between Canada and the community of Déline through the CDUT. It is based on careful consideration of the environmental status of the site, precedent practice, regulatory requirements, and site goals determined jointly, by Canada and Déline, through the CDUT. It is the agreed-to outcome of more than 5 years of focussed and determined effort by Canada and the community of Déline, which minimizes potential future impacts from the site and ensure long term environmental and public health and safety. As a former uranium operation, the site will remain as a licensed facility, and through this license process will remain under institutional control in perpetuity. Long term monitoring and reporting will be carried out at the site to provide ongoing assurance that the remediation works continue to perform as intended.

## **1.2 INAC’S RESPONSIBILITIES**

Indian and Northern Affairs Canada (INAC) is the project proponent for the remediation of Port Radium. It is INAC’s responsibility to develop the remediation plan, secure appropriate

approvals and resources, and implement the plan. As the site will be under a Nuclear Safety and Control Act License, a long-term monitoring and care and maintenance plan will be approved by the Canadian Nuclear Commission as well as by the Sahtu Land and Water Board.

### **1.2.1 Approach to Preparation of the Remediation Plan**

#### ***Overview***

Section 39 of the Northwest Territories Waters Act provides the authority for INAC to assume management of abandoned sites in the North to make sure that any risks to the environment or to human health and safety are adequately managed.

Due to community related concerns which arose in the late 1990s, INAC in cooperation with Déline reassessed the environmental conditions at Port Radium and conducted a full environmental site assessment and a human health and ecological risk assessment for the site.

The Port Radium Mine site is under the management of the Contaminants and Remediation Directorate (CARD) of INAC in Yellowknife. The CARD works within a broader management system for all northern contaminated sites. This being the case, the CARD must follow several guiding documents while managing and developing final remediation plan for the Port Radium Mine. The following federal policies or guidance documents provide a broad context as to how the CARD approaches remediation of contaminated sites in Northern Canada:

- A federal approach to Contaminated Sites (CSMWG 2000);
- Contaminated Sites Management Policy (INAC 2002a) and Northern Affairs Program Contaminated Sites Management Policy (INAC 2002a); and
- Treasury Board Federal Contaminated Sites Management Policy (Treasury Board 2002).

Although the INAC Mine Site Reclamation Policy for the Northwest Territories (INAC, 2002b) was not intended for abandoned properties such as the Port Radium Mine, some parts of the policy are generally applicable and have also been considered.

The overall responsibility of the CARD is to minimize health and safety and environmental risks associated with the site and implement a remediation plan that meets the needs and concerns of INAC, its First Nation partners and all Northerners.

In addition to the guidance and regulations associated with conventional mine sites, Port Radium, as a former uranium mine, is subject to the regulations of the 1997 Nuclear Safety and Control Act, as approved in May of 2000. The Canadian Nuclear Safety Commission administers the Act and its regulations and will license the site through a Waste Nuclear Substance License into perpetuity.

### ***General Principles***

Principles, relevant to the Port Radium Mine, from Federal policy and guidance documents were combined with community of Déline objectives and future land use conditions, determined in public workshops (see meeting notes in Appendix A for details). These guiding principles provide the site-specific approach for the development of the Remediation Plan.

CDUT site goals were chosen from the Federal guiding principles and the community criteria, which are described below.

Federal guiding principles for the Port Radium Mine Remediation Plan are listed below in two categories:

- Federal policies; and
- Partnerships with First Nations.

### ***Federal Policies***

The following general principles were adopted for the Port Radium Remediation Plan from federal policy and guidance documents referenced above. Specifically:

- Meet the overall INAC objective to contribute to a safer, healthier, sustainable environment for Aboriginal peoples and northern residents by striving to preserve and enhance the ecological integrity of the environment (INAC 2002a);
- Take immediate and reasonable action to protect the environment and the health and safety of persons (Treasury Board 2002);
- Meet federal and INAC policy requirements and legal obligations regarding the management of contaminated sites (INAC 2002a);
- Ensure sound environmental stewardship of federal real property by avoiding contamination and by managing contaminated sites in a consistent and systematic manner that recognizes the principle of risk management and results in the best value for the Canadian taxpayer (Treasury Board 2002);
- Provide a scientifically valid, risk management based framework for setting priorities, planning, implementing and reporting on the management of contaminated sites (INAC 2002a);
- Develop a Remediation Plan to be sufficiently flexible to allow adjustments as the remediation progresses, including the flexibility to adapt to new and improved technologies and methodologies (INAC 2002b); and
- Adopt solutions tailored to the northern environment and peoples wherever possible; (INAC 2005- management framework).

### ***Partnerships with First Nations***

The following principles regarding partnerships with First Nations were adopted from the policy and guidance documents referenced above specifically for the Port Radium Mine Remediation Plan:

- Promote Aboriginal and northern participation and partnership (INAC 2002a);
- Promote respect and sharing of knowledge, experience and resources in partnerships/teamwork with clients and partners;
- Promote the social and economic benefits that may accrue to First Nations and northern communities (INAC 2002a);
- Plan, where appropriate, the scale and pace of remediation/risk management in keeping with northern and Aboriginal capacity to be involved (INAC 2002a); and
- Incorporate economic opportunities, to the extent possible, for northern and Aboriginal communities in the management and remediation of the site (INAC 2002a).

### ***CDUT Site Goals***

The following site goals were agreed to by the CDUT and were used to evaluate remediation options specifically for the Port Radium mine remediation:

- Minimize human health and safety risks at Port Radium Mine Site;
- Protect fish, wildlife and vegetation;
- Protect Great Bear Lake water quality;
- Minimize environmental impacts during remediation;
- Return the site to its original condition where possible;
- Minimize long term care and maintenance; and
- Is cost-effective.

### ***Remediation Planning Team***

The Remediation options were selected by the CDUT and compiled into the Remediation Plan. This plan will be recommended to Canada and Déline governments as the agreed-upon remediation plan for the site.

The INAC Project Manager for managing and obtaining approval of the Remediation Plan is Ms. Julie Ward of the CARD in Yellowknife.

The technical team responsible for the development of the plan, conducting studies and reporting on the necessary technical information includes members of INAC staff, in Yellowknife and Ottawa, community member is Déline, as well as engineers, scientists and firms registered in the Northwest Territories:

- SENES Consultants Limited;
- CDUT;

- Déline Band Chief and Council;
- Public Works and Government Services Canada;
- INAC, Water Resources; and
- INAC, Contaminants and Remediation Directorate (CARD).

### **1.2.2 Community Consultation and Involvement in the Evaluation Process**

#### ***Approach to consultation***

Although long a concern in the community, the issues surrounding the Port Radium mine first received national attention when they were brought forward by the Déline Uranium Committee (DUC) at a meeting in Ottawa in June 1998. The DUC presented the document “They Never Told Us These Things” to the Federal Government. The document details the community’s concerns and outlines 14 points of redress.

After this meeting, Canada prepared three draft papers (called “First Thoughts papers”) to: produce terms of reference for structuring a Déline-Canada Committee; identify the types of health and environmental assessments required to address concerns; and engage a fact-finder(s) to establish a common understanding on the factual information relating to the concerns. The DUC representatives did not agree with the results of the meeting as reported by Canada. Dialogue was stalled for nearly one year, as the community was divided on whether to engage with the government in partnership or pursue remedy in the courts.

Finally, in August 1999, at a self-government meeting between Canada and Déline, Canada asked the Déline First Nations to indicate formal support for a new cooperative process. This was accomplished in September 1999 by the passing of the BCR 003-99 Resolution which mandated a joint process.

#### ***Community support***

In October 1999, the Canada-Déline Uranium Table (CDUT) was formed. The CDUT is comprised of representatives from the community of Déline and from Indian and Northern Affairs Canada (INAC). INAC represents Canada on behalf of Health Canada and Natural Resources Canada, with assistance from the Government of the Northwest Territories on issues of health service delivery in the Northwest Territories.

Further background information can be found in the Final Report on Action Plan Activities Sept. 2005.

The CDUT then hosted a “scoping” workshop in May 2000 and an “expert’s” workshop in October 2000 to identify specific questions and concerns regarding the mine and to scope future CDUT work (forming the Action Plan).



**Experts Workshop - May 2000**

### ***Meetings with Affected First Nations***

Affected First Nations are identified by their interest in the land. Port Radium site is within the Sahtu Settlement Area for the Sahtu Dene and Métis Comprehensive Land Claim Agreement, (signed in 1993) in particular it is within Déline District of Sahtu (See Figure 2.1-1). The site also sits within the Akaitcho Territory Dene First Nations Interim Measures Agreement Area signed in 2001 with varying commitment coming into effect in 2002 and 2004. When approached, Akaitcho Territory chose not to comment on the remediation options at Port Radium. A number of meetings have taken place which progressed from identifying the issues at site to determining the preferred plan to address the issues. Communications are as follows:

#### Major Presentations:

- March 2000 Scoping Exercise for the CDUT;
- October 2000, Community and Experts Workshop, Déline;
- March 2003 CDUT, Chief and Council, Ottawa;
- November 2004, Cleanup objectives for Port Radium Site presentation to CDUT and Chief and Council, Déline;
- December 2004, Site Options Presentation to CDUT and Chief and Council, Déline; and
- June 2005, Site Assessment and Remediation of Port Radium community meeting, Déline.

A number of CDUT meetings occurring ~ monthly from 2001 to present. Meetings took place in a variety of locations (Déline, Quebec/Ottawa, Yellowknife and Edmonton), as well as through teleconference. A copy of the remediation presentations and minutes to evaluation meeting with attendance can be found in Appendix A.

### ***Site Tours***

In addition to having community members work on the site assessments and other CDUT projects related to the site cleanup, there were several opportunities for others not connected with the project to see the site. Site tours are important for people to become familiar with the site and for understanding the scale and scope of the proposed remediation. A number of site tours have occurred over the past few years including the following:

- A Federal Contaminated Site Working Group Tour with Environment Canada, Department of Fisheries and Health Canada occurred on the 23<sup>rd</sup> of August 2005. This was to inform the program advisory group of the remediation activities occurring at the site and to get advise on possible impacts of work;
- A community tour with elders and youth occurred on the 22<sup>nd</sup> of August 2005. The purpose of this tour is to inform the broader community what remediation activities are occurring at the site;
- A chief and council site tour of the site was held on the 15<sup>th</sup> of July 2005. The purpose of this tour was to familiarize the new Chief and Council and CDUT advisors with the site and the current proposed Remediation Options;
- A chief and council and CDUT advisor site tour of the site was held on the 9<sup>th</sup> of September 2004. The purpose of this tour was to get Chief and Council familiar with the site in order to select their preferred Remediation Options;
- A federal central agency tour was held on the 1<sup>st</sup> of September 2004 with a number of representatives of Environmental Canada, Fisheries and Oceans, CNSC, INAC-HQ, Treasury Board and PCO. The purpose of this trip was to help get federal agencies who are involved in funding the remediation of this and other sites become familiar with the sites;
- A tour of Port Radium for Déline staff and First Nations staff was held on 24<sup>th</sup> of August 2004. The purpose of this tour was to become familiar with the site and to learn about water monitoring while assisting with the sampling;
- July 2003 CNSC, INAC-HQ and INAC-YK staff carried out a Great Bear Lake tour with Déline advisors for CNSC site inspection and survey of other abandoned sites;
- Government officials and community members visited the site for a tour and CNSC site inspection in July 2000; and
- Community members and CDUT staff did some spring water runoff water sampling and toured the site May 2000.



**Federal Agency Tour - 1<sup>st</sup> September 2004**

### ***Evaluation Meetings***

As a first step in the evaluation of remediation options, SENES Consultants presented the findings of the site assessments, human health and ecological risk assessment assessments, and remedial consideration and options document to the CDUT and the Chief and Council in Déline on December 3<sup>rd</sup> 2004.

Evaluation meetings were held in conjunction with the January 31<sup>st</sup> to February 2<sup>nd</sup>, 2005 CDUT meeting in Yellowknife and the March 18 to 19<sup>th</sup>, 2005 CDUT meeting in Déline. Prior to these evaluation meetings Déline Uranium Team (DUT) staff held a community presentation and workshop to determine community site goals; SENES Consultants had presented the remediation options to the CDUT, Chief and Council and CARD. A peer review of remediation options has also been conducted by Jacques Whitford Ltd., who agreed that SENES Consultants had presented an appropriate range of options for consideration by the CDUT.

The CDUT then ranked the remedial options against the agreed-upon site goals as listed below:

- Minimize human health and safety risks;
- Protect fish, wildlife and vegetation;
- Protect Great Bear Lake water quality;
- Minimize environmental impacts during remediation;
- Return the site to original conditions where possible;
- Minimize long term care and maintenance; and
- Is cost effective.

The overall approach to evaluating remediation actions for the site was as follows:

1. Divide the site into various issue (as outlined in Remediation Plan Guidelines for the NWT, 2001);
2. For each issue determine the remediation options (as presented in the Remediation Options for Port Radium SENES 2004 or as per best practices);
3. Rank the options on how well they meet CDUT site goals:
  - High- meets objective;
  - Medium- partially meets objective;
  - Low- does not meet objective.
4. Then determine if the option is:
  - P = preferred
  - A = acceptable
  - NA = not acceptable

A series of summary evaluation tables that resulted from the meeting are provided in CDUT meeting minutes in Appendix A. All of the evaluation information was carried forward directly into the selection of preferred remediation activities, as described in Section 5.

### **1.3 OVERVIEW OF AVAILABLE INFORMATION**

#### ***Initial Information Base – Prior to CDUT***

Historical radium and uranium mining operations at the Port Radium mine site had left a legacy of both tangible and perceived concerns for which numerous studies had been conducted over more than 25 years in an attempt to resolve these concerns. Water, sediment, tailings, fish and vegetation samples were collected as part of these investigations and subsequently subjected to a battery of testing protocols to determine both chemical and radiological content. Many of the early environmental investigations concentrated on the standard chemical parameters (e.g., pH, conductivity, heavy metals) and paid little attention to the issue of radioactivity. It was not until the latter part of the 1970s that radiological issues formed a larger part of the site investigations. Studies conducted between 1971 and 1999 included surface water, fish, soil, sediments and gamma radiation, however, data gaps and inconsistent sampling and analytical methodologies made it difficult to compare the results and reach conclusions. The CDUT efforts were put into addressing these data gaps and inconsistencies. Comments on these efforts are provided below.

#### ***CDUT Sponsored site assessments***

Since 1999, various projects have been carried out under the direction of the Canada-Déline Uranium Table (CDUT) to assess the site conditions and identify potential remediation considerations with respect to the Port Radium Mine site on Great Bear Lake in the Northwest Territories.

Preliminary site assessment activities (1999 to 2002) included the development and implementation of a detailed testing program to provide information for use in: characterization of on-site hazards and contaminant sources; identification of potential pathways of contaminant migration; assessment of ecological and human health risks; and, identification of remediation considerations and potential decommissioning options. The objectives of the programs included:

- acquisition of details and definition of site conditions;
- delineation of the boundaries of identified contamination;
- identification of contaminant pathways, particularly with respect to carrying out a human health and ecological risk assessment;
- collection of information on contaminant sources and other site information necessary to finalize environmental quality remediation guidelines/risk assessment and to support the development of a Remediation Plan; and
- provision to CDUT with materials that could be used in support of development of the Remediation Plan and assist in specification and tender document development.

**Project Chronology**

- 1999 Experts Workshop
- 2001 March/October Field Programs, Hazard and Site Assessments
- 2001/2002 Assessments
  - On land measurements, mapping, sampling
  - Lake sampling
  - Initial Risk Assessment and comments on possible Actions
- 2003 Soil, vegetation, water sampling, lakebed mapping and characterization
- 2004 Risk Assessment and Possible Actions Update
- 2004 Remediation Options and Considerations
- 2005 Site Investigations.

In keeping with the program objectives, a preliminary assessment of the environmental conditions at the site was carried out in early winter and spring of 2001. Subsequently, a program was developed to refine the boundaries of identified contamination, site conditions and contaminant pathways potentially relevant to risk assessment and/or site remediation planning. This more detailed assessment of site conditions was carried out in the fall of 2001.

In 2002, a series of reports were developed that summarized the findings of the 2001 site work, provided the results of the initial quantitative human health and ecological risk assessment, and presented a summary discussion of decommissioning and closure considerations for the site. These reports were provided to CDUT and INAC for internal and external review and finalized thereafter.

The fieldwork and risk assessment studies undertaken up to 2002 showed, within the data limitations to that time, that with the exception of a surface opening on Labine Point, the site does not pose an immediate risk to human health or the environment, and that off-site impacts on Great Bear Lake are minimal. However, some issues were identified including elevated metal levels in exposed tailings, local surface drainage, and vegetation collected in the vicinity of the West Adit; and elevated metals levels measured in lake sediments (characteristic of tailings).

In 2003, field programs were carried out to: collect additional vegetation and soil samples for chemical analyses from across the site; collect additional water and sediment samples for chemical analyses; and continue radiation monitoring (gamma and radon) at the site and at background locations. Thereafter work began on updating the 2002 human health and ecological risk assessment.

In 2004, the human health and ecological risk assessment report was completed incorporating the results of the 2003 sampling program. Using this latest information, a report on “Remediation Options and Considerations” was developed for the CDUT review.

In 2005, remediation concepts and supporting information was collected therefore determining details necessary to carryout the preferred remediation options.

Details associated with these program elements are contained in the following separate SENES documents. All reports developed by SENES under the direction of the CDUT were independently reviewed by peer reviewers selected by the CDUT. References to earlier and related works are provided in the bibliography.

*Preliminary Assessment of Environmental Conditions at the Former Port Radium Mine Site, July, 2001 (SENES 2001);*

*Port Radium Site Assessment - Data Analysis Report for the 2001 Field Program, Final Report October, 2002 (SENES 2002a);*

*Port Radium Site Assessment – Human Health and Ecological Risk Assessment, Final Report, October, 2002 (SENES 2002b);*

*Port Radium Site Assessment – Summary Report on Site Conditions and Decommissioning Considerations, Final Report, October 2002 (SENES 2002c);*

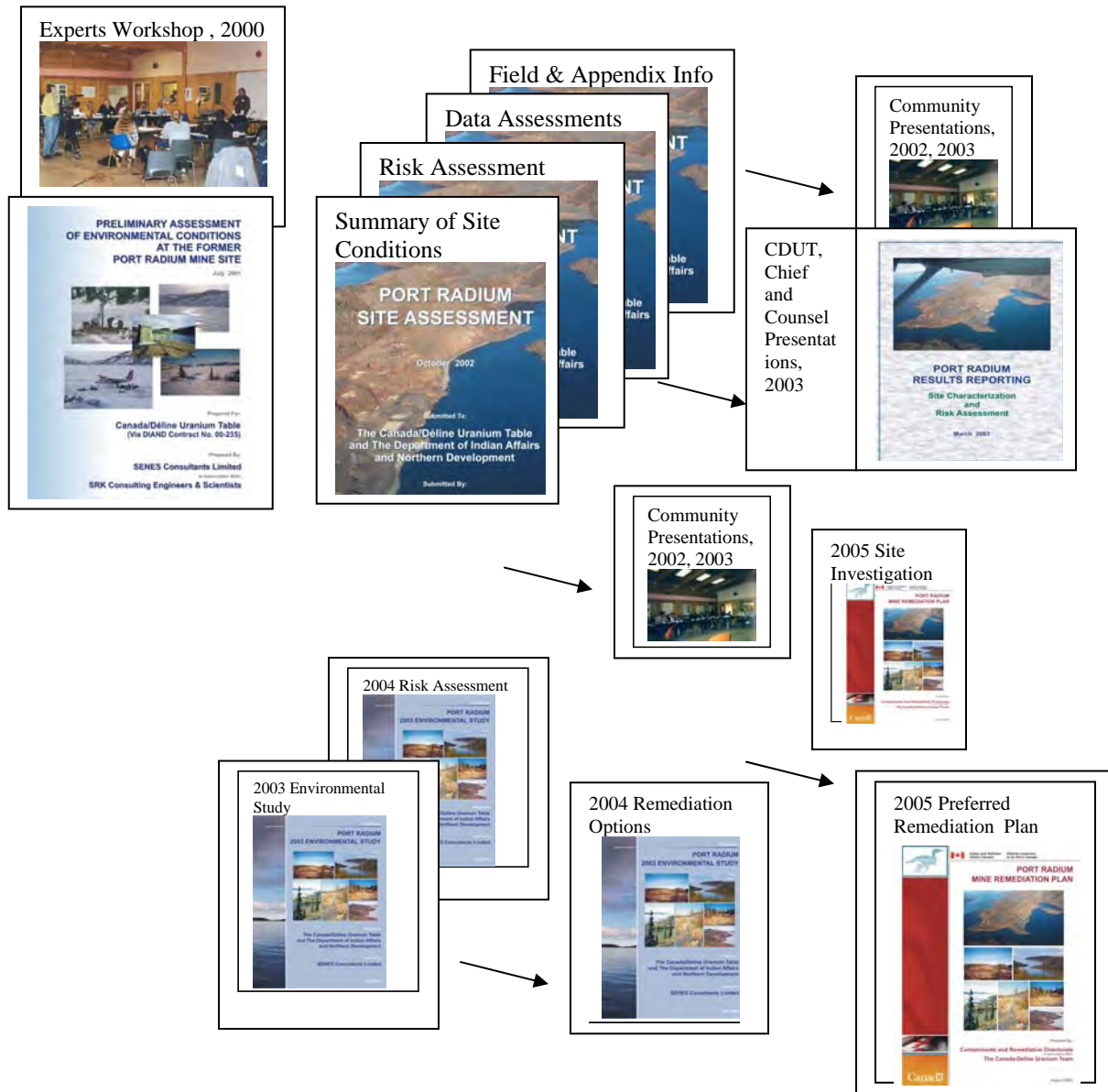
*Port Radium - 2003 Environmental Study, Final Report, April, 2004 (SENES 2004a);*

*Port Radium - Human Health and Ecological Risk Assessment, Final Report, April 2004, (SENES 2004b);*

*Port Radium – Discussion of Remediation Options and Considerations, Draft Report, October 2004, (SENES 2004c);*

Port Radium – Draft field report (SENES 2005).

**Graphical Illustration of CDUT Sponsored Port Radium Studies and Reports**



**Structure of Remediation Plan**

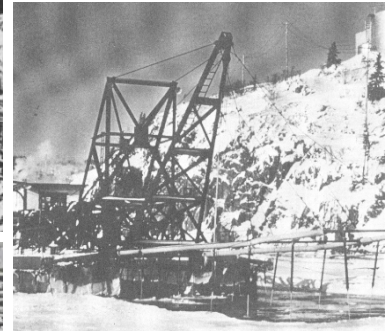
In addition to this introductory chapter, the following information is provided in this report:

- Chapter 2 provides additional details on current land use and the history of the site including former operations, past closure activities;
- Chapter 3 provides a description of the environmental setting in which the site is located; Chapter 4 provides a detailed description of the major site components, their current status, and potential issues and concerns; and
- Chapter 5 presents the proposed remediation plan including the process, guiding principals, and proposed remediation action for each major component.



## Section 2

# LAND USE AND HISTORY OF PORT RADIUM AND SURROUNDING AREA



Canada

## **2.0 LAND USE AND HISTORY OF SITE AND SURROUNDING AREA**

### **2.1 LAND USE**

#### **2.1.1 Great Bear Lake Watershed**

The Port Radium site is located within the Great Bear Lake watershed and the Sahtu settlement area, in particular within the Délı̄ne district outlined in the Sahtu Dene and Metis comprehensive land claim agreement (see Figure 2.1-1). It should also be recognized that Port Radium site is also within the boundaries of land which is currently in negotiation with the Akaitcho Territory Dene First Nations. Negotiations are moving towards their Interim Measures Agreement; rights under this agreement will also be recognized.

Prior to contact with the first Europeans, the area served as part of the traditional territories of several First Nation groups, including the Dogrib, Hare, Slavey, Yellowknives, and Inuit. In the centre of this region, the Sahtu Dene people practiced traditional lifestyles by hunting caribou, trapping fur-bearing animals, and catching fish Great Bear Lake (Johnson 1975c). Not surprisingly, the Sahtu Dene were, and remain today, strongly connected to the Great Bear Lake ecosystem.

Following the appearance of fur traders, explorers and missionaries during the 19th Century, there were substantial changes to the culture, economy and social structure of the region. By the early 19th Century, Fort Franklin had been established on the southern shore of the lake near the Great Bear River (Morris 1973). Subsequently, the formerly semi-nomadic existence of the Sahtu Dene was replaced by a settlement existence.

In 1930 radium, pitchblende, and silver were discovered in the vicinity of Port Radium. Soon thereafter (i.e., early 1930s), mining operations were developed at this location to extract uranium ore. Other mines also developed in the watershed, primarily to extract silver ore from the Camsell River drainage basin (EBA 1993). None of these mines are currently in operation and responsibility presently resides with the crown.

During the 1950s, interest in tourism and sport fishing increased within the watershed. To meet the expanding demand for services, a total of five fishing lodges were established on Great Bear Lake. With the increased fishing pressure on large, trophy-sized lake trout, fisheries management agencies and stakeholders took steps to limit fishing pressure due to the sensitivity of the lake trout population to over-harvesting (including catch-and-release fishing on trophy-sized fish).



### 2.1.2 Land Uses by the Sahtúgot'ine (Bear Lake People)

Dene people have lived, since time immemorial, on and around the shores of Great Bear Lake. More recently, the term Sahtúot'ine has been adopted to refer to the aboriginal people of this



district. The Sahtúot'ine have an intimate and direct link to the lands and waters in and around Great Bear Lake (also known as the Sahtu). Until about 50 years ago, the Sahtúot'ine lived a traditional Dene lifestyle as semi-nomadic hunters and gatherers, practicing their traditional way of life and culture throughout the lands and waters of the Sahtu region.

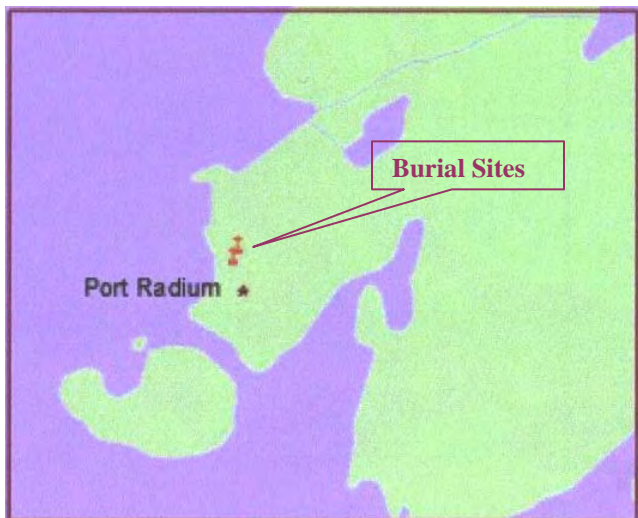
In 1799, the Northwest Company built a trading post at the head of the Bear River, the site of traditional annual meetings for the people living around Great Bear Lake. This site came to be known as Fort Franklin after the Franklin expedition used the post as its winter headquarters in 1825. In the 1950s, the establishment of a Roman Catholic Mission and a school drew Dene people to settle permanently at the site. Today, the community is known by its Dene name of Déli'ne, which means “place where the river flows”.

### 2.1.3 Traditional Knowledge

Traditional Knowledge (TK) was used extensively in studies carried out through CDUT. Some of the ways in which TK was used include:

- collecting information regarding historical use and current day use of the site;
- deciding research needs, project goals and selecting remediation options; and
- developing communication products.

One specific area where TK was used was in a Land Use mapping project (Phase I and II) in which grave sites were identified at Port Radium. There are 2 sites on the northwest side of the site (these locations are located away from any remediation activity). Aside from these 2 sites, there is another grave which is situated in the middle of the mine site, burial having taken place during mining operations. There are also 2 monuments which are located at Silver Point and Radium S. TCA.



## **2.2 CURRENT LAND USES**

### **2.2.1 Sahtu Land Uses**

Déłı̄ne residents today maintain strong links to their traditional Dene way of life. In 1993 the Sahtu Dene and Metis Comprehensive Land Claim Agreement was signed to, among other things, “recognize and encourage the way of life of the Sahtu Dene and Metis which is based on the cultural and economic relationship between them and the land”<sup>1</sup>. Great Bear Lake remains the central defining feature of the community and the traditional territory of the Sahtúot’ı̄ne.

As people continue to harvest the plants and animals of the region for food and fuel, the Sahtu provides not only physical sustenance for the people of Déłı̄ne, but also the spiritual and cultural sustenance that comes from practicing the skills and lifestyle of their ancestors. While caribou and fish are harvested most frequently, smaller animals and various plants and berries are also important traditional foods.

### **2.2.2 Port Radium Uses**

Due to its isolated location, and community concerns about human health and ecological impacts at the site, the Port Radium site currently receives limited land uses. Sahtúot’ı̄ne who travel the lake in the summer, typically stay at other locations and not stay directly at the site. The site has been visited on an opportunistic basis by INAC staff over recent years; however, as there are no licenses associated with the site, no formal INAC inspections have taken place. Site sampling programs were carried out from 2001 through 2005, and community tours and healing visits led by Déłı̄ne staff also took place during this period.

Prior to the fire destruction of Branson’s Lodge in Cameron Bay, the airstrip and dock at Port Radium were used as a staging point by Plummer’s Lodge. Clients’ supplies were flown by fixed wing aircraft to the airstrip at Glacier Lake, after which they were moved by bus to Inner Labine Bay and then picked up by boat and brought to the Branson Lodge in Cameron Bay. Since the fire, the Cameron Bay facilities are no longer used as a primary sport lodge, but rather are treated as a remote wilderness camp that receives little commercial sport attention and only occasional visits.

The airstrip at Glacier Bay has served as a campsite and staging point for mineral exploration in the area, and it was used in a similar fashion during the 2001 fall sampling campaign and the 2005 field season. Currently, the airstrip is listed in Transport Canada’s “Canada Flight

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<sup>1</sup> Sahtu Dene and Metis Comprehensive Land Claim Agreement.

Supplement” as an abandoned aerodrome and does not have status as an active strip. To this end, any aircraft landing at the strip does so at their own risk and peril.

### **2.2.3 Active Mineral Claims**

The Port Radium Area has a number of Active Claims with varying years of expiration from 2007 to 2194. Figures 2.2-1a and 2.2-1b show the current active claims for the site. There are also 3 mineral leases that expire in 2023.

### **2.2.4 Conformity with the Sahtu Land Use Plan**

The activities proposed for the site are not in conflict with the land use plan. The site is listed in the “Places We Protect” document and is recommended to obtain territorial and federal heritage status. Currently the draft Great Bear Lake Management Plan also proposes that the site be ranked as heritage.

### **2.2.5 INAC Authorizations**

There are currently no land use permits or water licences associated with this site and there is an exemption from a Waste Nuclear Substance Licence until remediation begins. The remediation of Port Radium will require a Type “A” Land Use Permit, a Type “A” Water Licence, a Waste Nuclear Substance Licence and a fisheries authorization. Once the site is remediated, and long term monitoring begins, only the Waste Nuclear Substance Licence will remain in effect.

## **2.3 HISTORY OF MINING**

### **2.3.1 Discovery of the Mine**

The Port Radium Mine is located in Echo Bay, on the eastern shores of Great Bear Lake in the Northwest Territories. The mine site is situated approximately 440 km north of Yellowknife and about 265 kilometres across the lake from the Dene community of Délı̄ne, which is located near the outflow of Great Bear Lake at Great Bear River. The topography of the mine site is characterized by its rugged relief and shoreline setting on one of North America’s largest fresh water lakes.

According to histories passed down through Dene oral tradition, pitchblende was first discovered at the Port Radium site by a local Dene man known as Old Beyonnie. He was traveling with a group of people to go hunting at Caribou Point and the party camped at Port Radium on the way. Beyonnie picked up a strange looking rock and later gave it to a prospector, who in turn passed on the rock to Gilbert Labine. Labine visited and staked the site in 1930 and sent samples of

pitchblende, which he correctly believed to be rich in radium, to the Department of Mines in Ottawa for analysis.



The discovery of the pitchblende seam at the Port Radium site initiated an era of mine development, operation, and related activities on the eastern shores of Great Bear Lake that lasted for more than fifty years. While the Port Radium Mine on Echo Bay was the primary driver of development, other mines were also operated for various periods in the Camsell River region

to the south and east of Port Radium. As mine operations grew, supporting infrastructure was developed both at the mine and in the nearby area of Cameron Bay, as well as along the transportation route and at the various communities providing supplies and provisions.

### 2.3.2 Overview of Production History at Port Radium

Mining operations took place at Port Radium almost continuously between 1932 and 1982. Radium, uranium and silver and copper were mined at different times at this site.

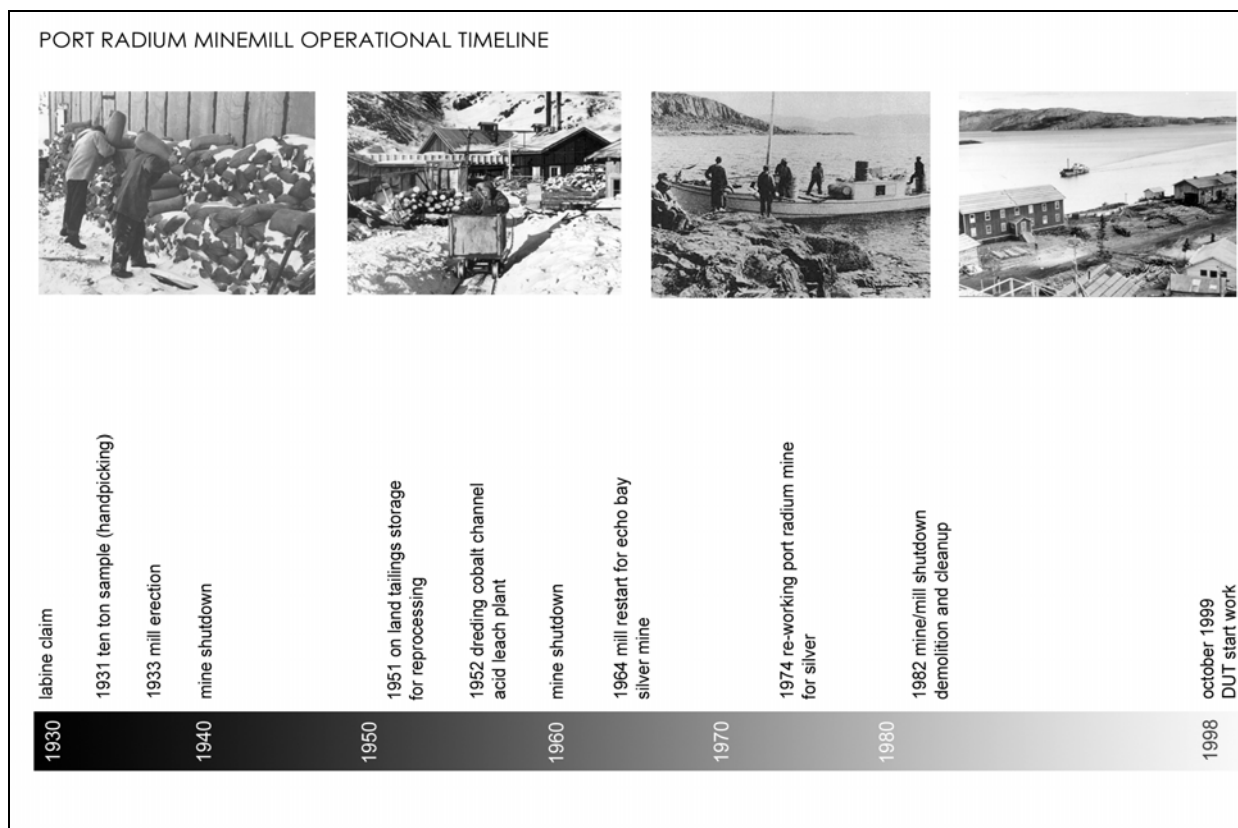


Figure 2.2-1a

# ACTIVE MINERAL CLAIMS MAP

SOURCE: DIAND GIS Department

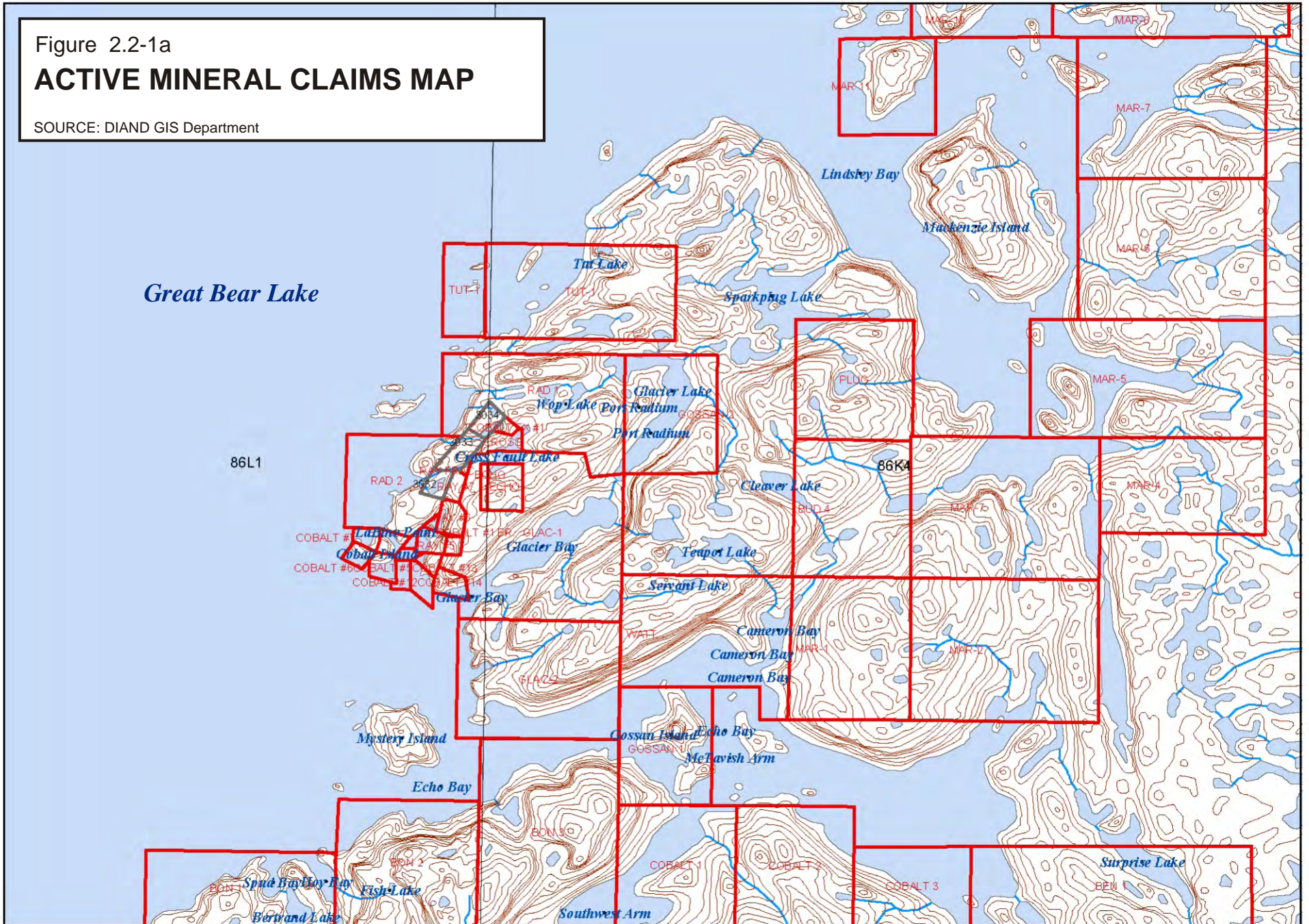
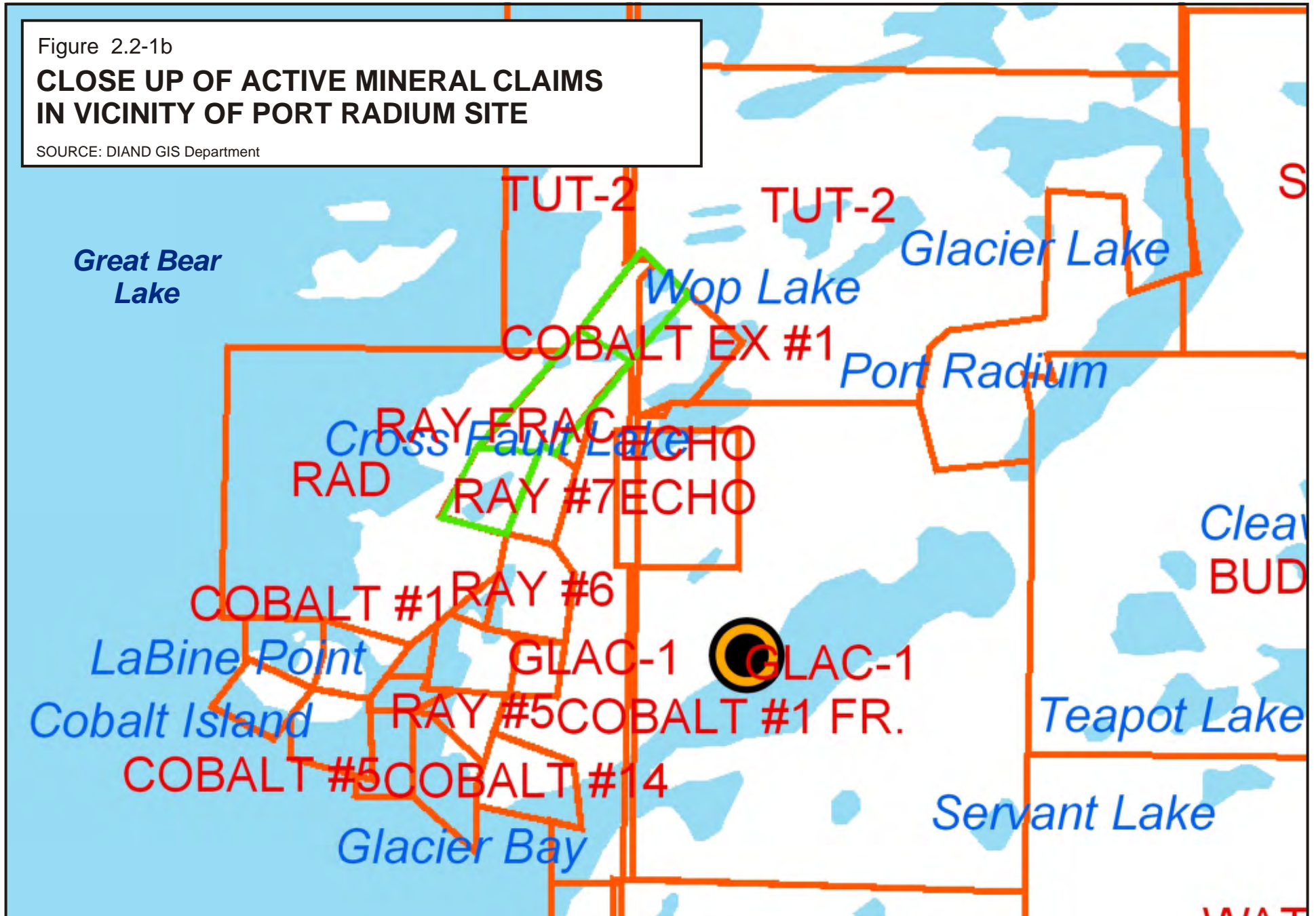


Figure 2.2-1b

**CLOSE UP OF ACTIVE MINERAL CLAIMS  
IN VICINITY OF PORT RADIUM SITE**

SOURCE: DIAND GIS Department





From the time of its initial discovery until 1940, the site was mined for radium-containing pitchblende. From 1942 to 1960, the site was operated as a uranium mine by the then Crown-owned Eldorado Mining and Refining operation. The site was subsequently used by Echo Bay Mines, a private company, for silver mining purposes. From 1964 to 1975 parts of the town site and former facilities were used in support of mining the Echo Bay Mine at the east end of Inner Labine Bay, and from 1976 to 1982 silver was mined from the former Port Radium workings.

Records indicate that during the mine's life, Eldorado and Echo Bay operations produced 37 million ounces of silver, 10.5 million pounds of copper and 13.7 million pounds of uranium oxide ( $U_3O_8$ ) before final shutdown and closure in August 1982. Total tailings production is estimated to be in the order of 910,000 tons of uranium tailings and about 800,000 tons of silver tailings. Assessments of historical records and discussions with past operators have confirmed that the majority of silver tailings were deposited into McDonough Tailing Containment Area (TCA). Through the on-land site sampling program assessment work, it is estimated that about 170,000 tons of tailings, or 19% of the total amount of uranium tailings, were placed within local surface depressions or in the Silver Point area of the site. The remaining 740,000 tons of tailings (81%) were deposited in an unconfined manner at various locations into Great Bear Lake.

### 2.3.3 Description of Port Radium and Echo Bay Mine Operations

#### *Eldorado Mines*

In April 1931, about 10 tons of ore were taken from the site for analysis, resulting in the decision to commence the sinking of a mining shaft in 1932. Initially the high grade of the ores allowed identification by sight and weight. Ore from the mine went straight to the docks for crude manual sorting (hand-cobbing) to produce the final product for and bagging prior to shipment. Hand-cobbing ceased in 1933, when a mill was erected near the water's edge to process the ore.



The initial mill circuit used gravity separation methods to recover the silver, pitchblende (for radium recovery) and copper contained in the ores. Separation was achieved through an assortment of conveyor belts, crushers, and jigs. As metallurgical process knowledge advanced over the years, process improvements and mill refinements were made including the addition of chemicals to aid in the recovery process.

Other advances in metallurgy were also tested and implemented at the mine over time. Of particular note, were the installation of a pilot leach plant in 1950 and the construction of the

full-scale leach and acid plants by 1952. The addition of these plants to the recovery circuit increased the recovery of concentrate from the ores, and also allowed for the reprocessing of tailings previously disposed of in Great Bear Lake and in the two small land locked basins (Radium and Murphy TCA's). The leach plant concentrate products were further enhanced with the addition of a solvent extraction plant in 1958. By 1960, the combination of reduced demand, reduced ore reserves, and diminished grades resulted in the mine being considered uneconomic and thereby shutdown and closed out by Eldorado Mines.

### ***Echo Bay Mines***

On site activities were re-started several years later, first, through a period of using existing plant facilities and infrastructure for silver milling of Echo Bay Mine ores from 1964 to 1972, and next, by a period of re-working the Port Radium underground mine (D zone) for silver and milling from 1974 to 1982, prior to the final mine shutdown in 1982.

At mine shutdown, the mine workings were allowed to flood, mine openings were secured, buildings and facilities were removed, demolished, or disposed, and the area was cleaned to the standards of the day.

### **2.3.4 Transportation during mining**

Numerous logistical challenges were associated with the development and operation of a major mine on the eastern shores of Great Bear Lake. Supplying the mine, including the provision of construction materials, operating consumables and supplies, as well as the shipment of product, all required careful planning, management and execution given the remote location of the site and the seasonal constraints of the far north that included such factors as a short (typically three month) shipping season.



The transportation of men and materials to and from the mine varied over time and included the use of air, water, and land transport. While water transport moved the majority of the materials going to and from the mine, air transport also played a significant role in its ongoing sustainability.

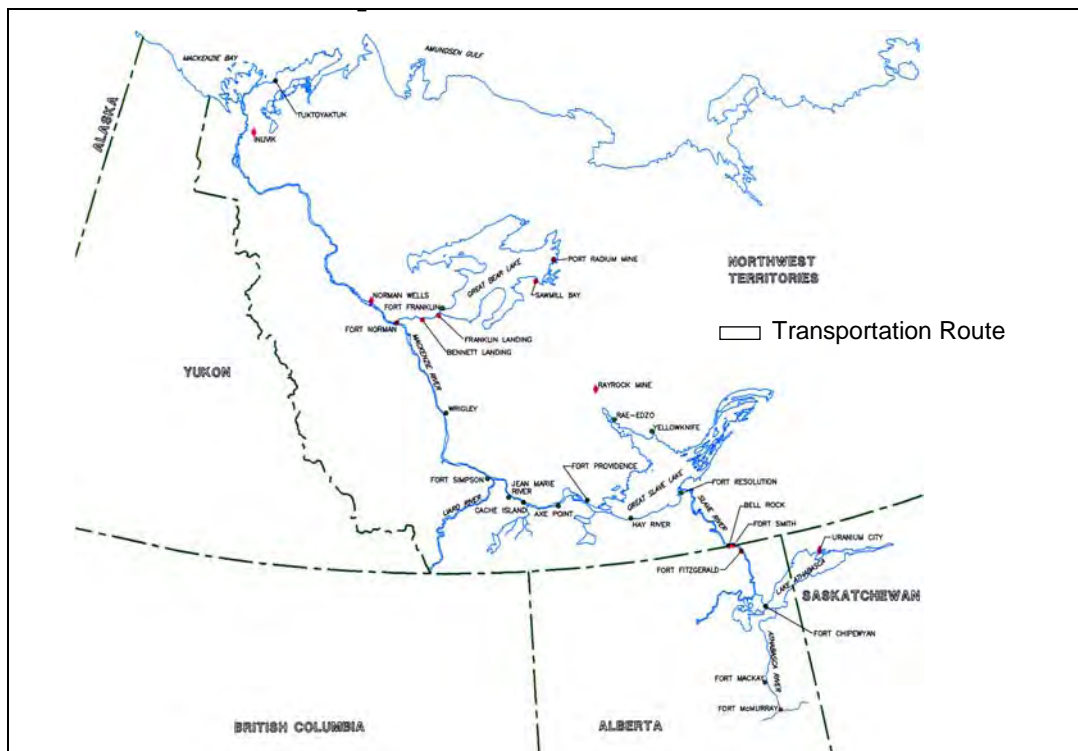
Water transport to/from the Port Radium mine and the railhead at Waterways (Fort McMurray), Alberta consisted of a route approximately 2100 kilometres (1300 miles) long that involved passage through Great Bear Lake, the Great Bear River, the Mackenzie River, Great Slave Lake, the Slave River, Lake Athabasca, the Athabasca River and the Clearwater River.

As the movement of concentrate product to the south represented only a small fraction of the tonnage that was handled in association with the mine, several modes of movement were used over the course of the mine's life. While air transport was used in support of exploration, most of the initial (1932 and 1933) ore shipments from Port Radium mine were transported by boat from the mine to Waterways, Alberta, however, as water transport was very expensive, beginning in 1934, ore was flown out using a single engine Bellanca aircraft. As mine and mill production increased substantially, use of aircraft for the transportation of the concentrate became increasing less efficient, and by 1937 water transport regained its importance for ore shipment.



The water transportation network was operated by the Northern Transportation Company Limited (NTCL). The history of the NTCL and its handling of uranium ore dates back to 1936 when the Northern Waterways Company was purchased by Gilbert and Charles LaBine. From 1937 onward, NTCL's fleet of tugboats and barges grew as tonnages increased. For context, the entire NTCL route between the Port Radium mine and Waterways is presented on Figure 2.3-1 below.

**FIGURE 2.3-1  
NORTHERN TRANSPORTATION ROUTE**



## **2.4 DECOMMISSIONING**

From an industry perspective and given its former land-use history, site conditions are generally clean, neat and stable, with little evidence of surface runoff or erosion. Aside from the cover over the Radium TCA, which is generally quite smooth, the areas overlain by mine rock are typically quite coarse. Site areas where tailings are exposed were covered with waste rock for the most part, but some exposed dry tailings exist in Murphy Drainage and in the vicinity of the West Adit.

### **2.4.1 Eldorado Mines**

Eldorado Mines operated the mine and related facilities through to exhaustion of economic uranium reserves in 1960. Closure activities carried out at the mine included the removal and relocation of salvageable equipment to Eldorado's Beaverlodge Mine in Saskatchewan, as well as the sealing, closure, and flooding of the mine.

### **2.4.2 Echo Bay Mines**

The Port Radium site was closed, decommissioned and reclaimed when Echo Bay mines ceased mining operations in 1982. At that time, the standards of the day were applied to the mine closure, and records from INAC files<sup>2</sup> indicate that the land cleanup was considered to be excellent by the responsible authorities. Closure activities included covering most tailings and garbage with waste rock, sealing the mine openings moving all valuable equipment to nearby mining operations, demolishing and burning on-site structures, and the general cleanup of the site. The refuse from mine decommissioning was disposed of in McDonough TCA and covered with rock. After closure, the land reverted back to the Crown.

Since the closure of the mine, reclamation standards have evolved and many jurisdictions have implemented reclamation codes. The overall principles behind these codes are to:

1. Protect public and worker health and safety;
2. Minimize environmental effects; and
3. Restore the land to its original state or similar acceptable land use.

The Port Radium site is situated in a remote location. The key long-term issues for the site include assurance that:

- the site is safe from physical hazards (mine openings);

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<sup>2</sup> Whitehead, G. file memo Government of Canada 10 September 1985.

Stephen W. Director of Renewable Resources, Letter to Echo Bay Mines, March 1986.

- the site is physically stable (tailings are not exposed to wind and water erosion);
- that radiation exposures meet regulatory standards and that exposures to persons accessing the site are kept as low as reasonably achievable (ALARA) considering social and economic factors; and
- the site is not causing material environmental damage.

## **2.5 SITE FEATURES**

As can be seen in the figure, former activities have resulted in the extension or creation of several areas of flat, or slightly sloping, land features across the site. Near the lake's edge, these areas include the Silver Point TCA, the lower mill and plant site areas, the docking and loading area in Inner Labine Bay and the lower site roadway, as well as a portion of the Labine Point near the West Adit. At a higher elevation, these areas include the former town and campsite, the Radium and Murphy TCA's and yard storage areas, the former leach plant area, and the remaining waste rock pile.

An overview of the site and vicinity features as they exist at this time are shown in Figure 2.5-1. This figure provides a map of the site overlain with land use blocks/polygons that were assigned for the purposes of the assessment of the site. The configuration of the various polygons was selected based on a series of considerations including previous land use activities and physical setting and topography. The numbering and nomenclature used to identify these areas builds on the methodology initially used in the March 2001 field studies, as subsequently reported in the July 2001 SENES assessment report.





## Section 3

# DESCRIPTION OF ENVIRONMENT



## **3.0 DESCRIPTION OF ENVIRONMENT**

### **3.1 LOCATION AND TOPOGRAPHY**

#### **3.1.1 Location**

The Port Radium site in the Northwest Territories is located at Echo Bay on the eastern shore of Great Bear Lake, one of North America's largest fresh water lakes. The site, located at 66°05'N and 118°02'W is situated approximately 440 km north of the City of Yellowknife, 265 km east of the Dene community of Déline and 52 km south of the Arctic Circle. The site area falls within the eastern boundary of the Sahtu Settlement Lands.

#### **3.1.2 Setting**

The site is located on a point of land extending into the lake in an west to southwest trending direction. The area is characterized by its rocky and rugged relief that features rock outcrops and sheer cliffs that rise rapidly from the lake's shoreline. Peak elevations in the region around the site rise to more than 456 m a.s.l. (above sea level), approximately 300 m above Great Bear Lake, while peak elevations at the site proper are in the order of 220 m a.s.l., or about 60 m above Great Bear Lake water level. Natural flat lying land is, for the most part, non-existent in the area of the site or in the surrounding vicinity. Figures 1.1-1 and 2.5-1 provided an overview of the site with the various features.

#### **3.1.3 Physiographic Features**

The site lies within the Great Bear Lake watershed, an area located in the northeastern portion of the NWT. The Great Bear watershed spans two major physiographic regions, the erosion-resistant Precambrian Shield to the north and southeast and the Mackenzie Lowlands to the south and west (Morris 1972).

The Precambrian shorelines are generally steep, rocky and irregular with sparse soil, while the Plains tend to be sloped, sandy and regular. The dominant physiographic feature of the area is Great Bear Lake, which, with a surface area of 31,000 km<sup>2</sup> and volume of 2240 km<sup>3</sup> (or 2240 million m<sup>3</sup>), is the largest lake wholly contained within the borders of Canada (Johnson 1975b). Its watershed of approximately 146,000 km<sup>2</sup> (Environment Canada 2002), includes Great Bear Lake and Great Bear River and their respective watersheds. The major tributaries to the lake include the Camsell, Johnny Hoe, Dease, Haldane, Whitefish, and Sloan rivers.

Great Bear Lake lies adjacent to the three terrestrial ecozones, the Southern Arctic ecozone along its northern shore, the Taiga Plains to the west and south, and the Taiga Shield to the east. The Southern Arctic ecozone includes sprawling shrublands, wet sedge, meadows, and cold clear

lakes, while the Taiga Plains ecozone is an area of low-lying plains centred on the Mackenzie River and its tributaries. The Taiga Shield in which Port Radium is situated is at ecological crossroads (i.e., transitional area) where climate, soil, flora and fauna of the Arctic meet those of the northern temperate zone.

### **3.2 BEDROCK GEOLOGY**

The underlying rocks of the Precambrian Shield region are comprised of sedimentary and metamorphic deposits, with igneous intrusions forming dykes and sills (Johnson 1975a). These rocks can be classified into four main groups, including: complex sedimentary and volcanic rocks of the Echo Bay group intrusions of diorite, grandiorite, and granite; relatively undisturbed conglomerate, sandstone, and quartzite of the Hornby Bay group; and mafic dykes and sills (Kidd 1933). By comparison, the Great Bear Plain is largely underlain with Mesozoic strata of undivided limestone that is rarely exposed (Bostock 1970).

The geology of the site is dominated by the Port Radium sandstone and siltstone formation with northeasterly-trending faults containing high-grade pitchblende ore veins. There were two distinct types of ore at Port Radium: high silica-gangue type pitchblende; and carbonate barite gangue type pitchblende that also contained silver.

### **3.3 GLACIAL HISTORY AND SURFICIAL GEOLOGY**

#### **3.3.1 Glacial History**

Great Bear Lake was formed by the scouring action of the Laurentide ice-sheet during the Pleistocene Epoch (1.8 million to 11,000 years ago). At the height of the most recent glaciation the majority of the land to the east of the MacKenzie River was covered by the Laurentide ice-sheet, but an unglaciated region occurred to the west of Great Bear Lake along the front dividing the Laurentide from the Cordilleran ice-sheets (Johnson 1975a).

About 10,000 years ago, the ice-margin coincided with the Shield boundary. The ice-sheet crossed the northward slope of the land blocking drainage thus giving rise to a very large proglacial lake, Glacial Lake McConnell, which covered the area now occupied by Great Bear Lake, Great Slave Lake, Lake Athabasca and the land between them. This immense lake drained to the southeast towards the Gulf of Mexico.

Following retreat of the ice, drainage developed to the northwest around the edge of the Shield, resulting in the drainage pattern that we see today. With the retreat of the ice, the land rebounded unequally causing a noticeable tilt to the strand-lines and the formation of an outlet at the western end of the lake (i.e., Smith Arm; Johnson 1975a). As the land surface continued to

change, the outlet switched from this region to its present location at the western end of Keith Arm. Archaeological evidence suggests that this outlet was established by about 4000 years ago, at 12 m above the present lake level (Johnson 1975a). The present lake level was initially established about 2600 years ago.

### **3.3.2 Surficial Geology**

The soils in the Great Bear watershed differ between the two major physiographic regions. In the Precambrian Shield region, soils are sparse and rocky outcrops abound. Thin layers of weathered sedimentary rock, glacial till, and alluvium can be found in small areas of lower elevation. In contrast, the soils of the Interior Plains region are far more substantial and occur over thick glacial till (Johnson 1975a). Alluvial and lacustrine deposits (i.e., soils deposited from flowing waters and those associated with lake sediments) occur at lower altitudes (Johnson 1975a).

Site investigation and observations confirmed that soil cover in the vicinity of the site is generally sparse, and to the degree it exists, is generally very shallow. In addition to these shallow soils, fill and placement for roads and surface covers extend over about 20 ha of the site. Within the immediate area of the site, sparse soil cover and vegetation exist primarily in the shallow low-lying area to the south-west of the West Adit on Labine Point (see Figure 2.5-1), on some of the hillside areas around the site, and in undisturbed areas to the north and east of the site. Exposed bedrock predominates the area in general and in the area of the former mine and plant site (see Figures 1.1-1 & 2.5-1). For the most part, the steeper slopes along the shoreline consist of bare rock surfaces with no, or limited, vegetation cover. The sparse vegetation covering much of the undisturbed areas of the site consists of lichen, grasses, bushes, and pine trees (see Appendix B Photographs).

### **3.4 SITE ACCESS**

Access to the site is limited given its remote location at the eastern edge of Great Bear Lake. The site can be accessed in the summer months by boat or float plane; and in the winter months by snow machine, ski equipped plan or winter road. No winter roads have been constructed to the site for over 20 years. The nearest winter roads terminate at Déline, 265 km to the west, and at Rae Lakes, 205 km to the south. From both locations, winter roads once existed to Port Radium. Figure 3.4-1 shows various historic routes to the mine from which, one will be decided on to transport supplies and equipment to site.

A former Hercules capable airstrip, built at Glacier Lake by Echo Bay Mines, can be used to access the site; however, use of the airstrip does not provide easy and casual access, as it is some 6 km from the airstrip to the site.

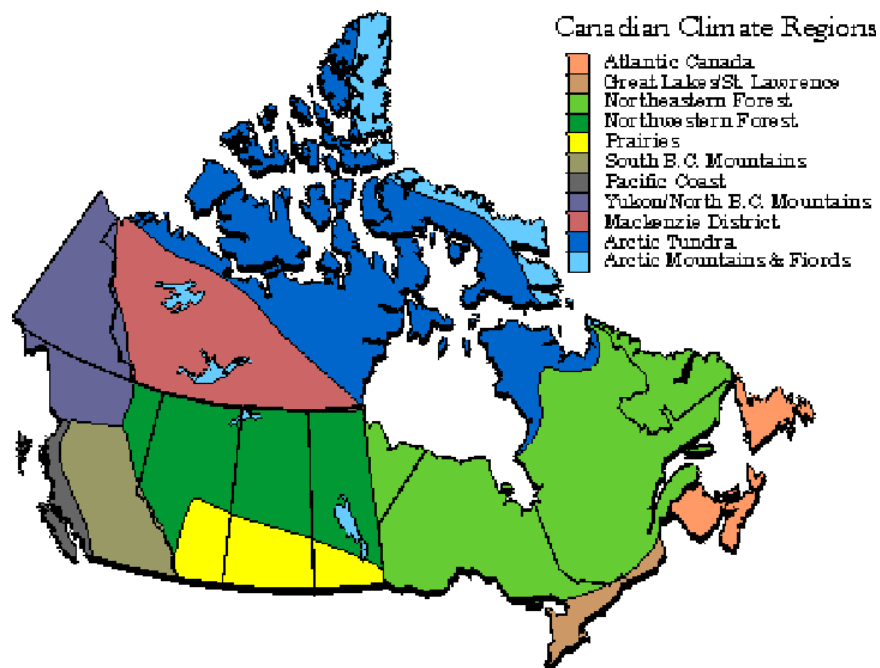
The former Branson Lodge facility is located to the south of the site in Cameron Bay, at a distance of some 13 km. While access to the site can be achieved via boat from Cameron Bay, the Branson Lodge site generally receives little use by fly in fisherman and only for a very short duration.

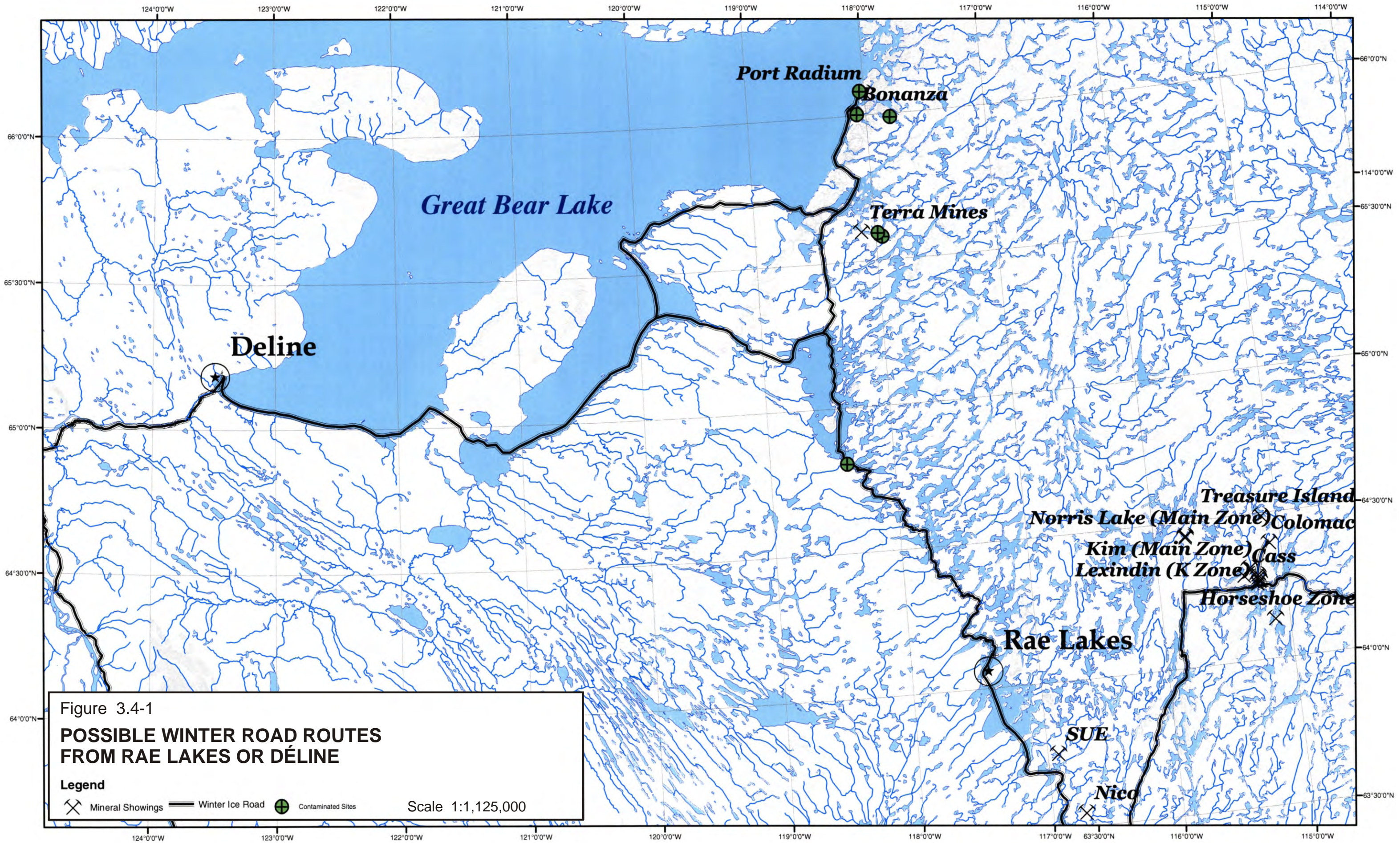
### 3.5 CLIMATE AND CLIMATE CHANGE

#### 3.5.1 Climate and Temperature

The climate zones of the Arctic, as described by J.M. Bullas from Environment Canada's Prairie and Northern Region, comprise three zones (Figure 3.5-1): a large tundra region, a somewhat smaller region bisected by the Mackenzie River, and the mountains and fjords of the far northeast. The Port Radium mine site is located in the Mackenzie District. The Mackenzie regional climate is characterized by long and cold winters, short and cool summers, large annual ranges in temperature, and little precipitation (Johnson 1975a). In winter, the region is dominated by the Arctic air mass, while in summer incursions of Pacific air are common.

**FIGURE 3.5-1  
CANADIAN CLIMATE REGIONS**

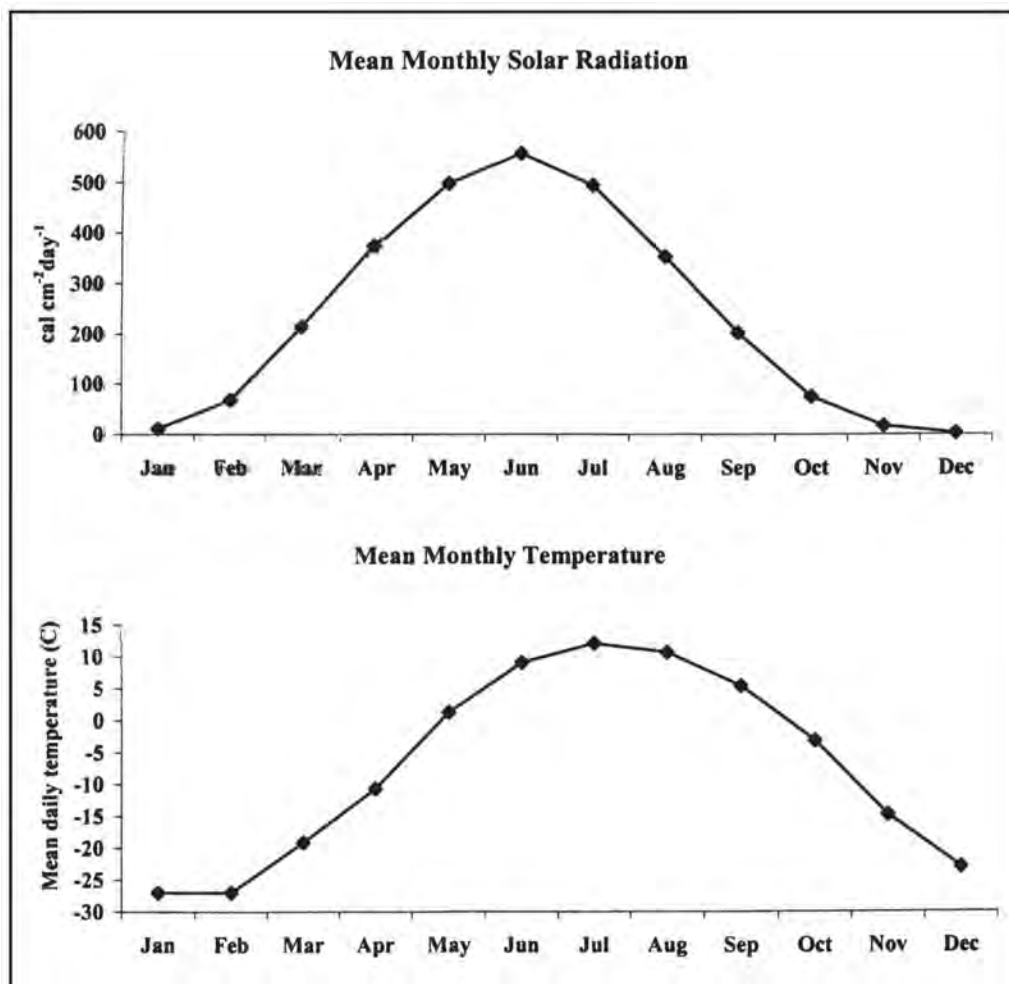




SOURCE: Map from DIAND GIS Department

Analysis of air temperature measurements collected at the Port Radium site between 1950 and 1974 (Johnson 1975a) showed that the maximum temperatures are typically recorded in July, with the highest reading on record being 29°C. The mean air temperature at Port Radium in July for the period of record was 12°C. The lowest air temperatures occurred in January, when the mean air temperature was -27°C and the extreme low was -52°C (Johnson 1975a). In summer, the sun was above the horizon for 24 hours per day between June 12 and 20; but, in December, the days were short with the sun barely appearing (Johnson 1975a). Figure 3.5-2 shows mean monthly solar radiation (recorded at Norman Wells) and mean daily air temperature (recorded at Port Radium). According to Johnson (1975a) there were only 60 frost free days per annum in the study area.

**FIGURE 3.5.2**  
**MONTHLY SOLAR RADIATION AND TEMPERATURE**



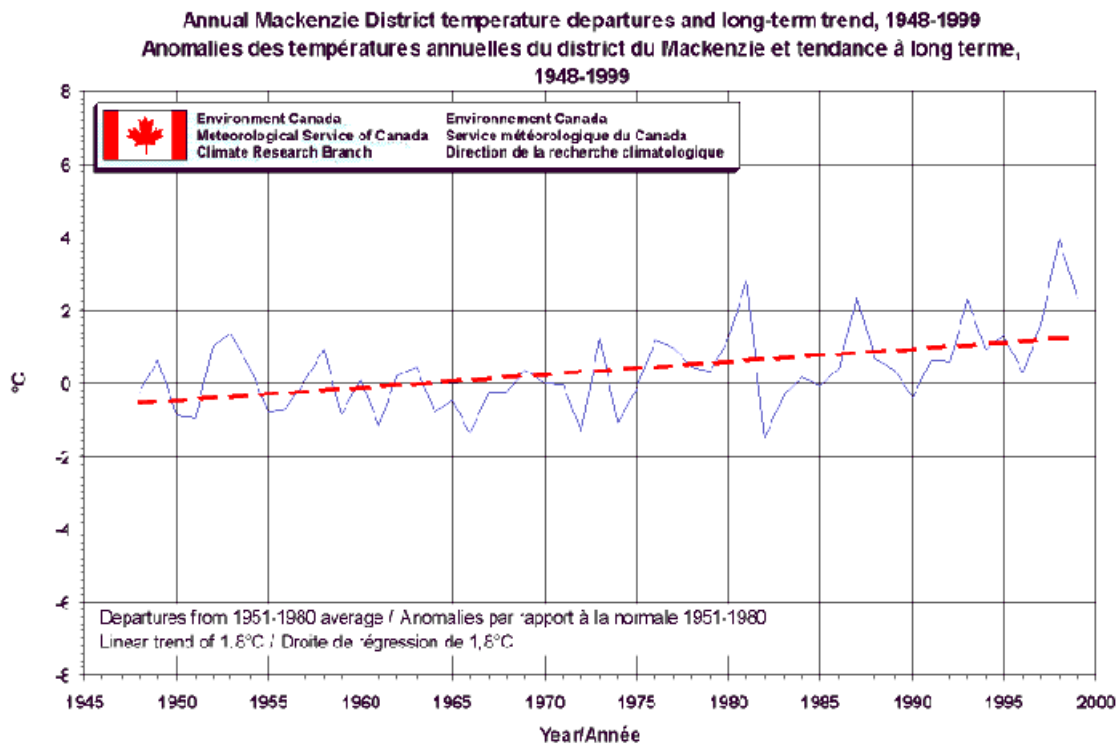
SOURCE: MacDonald, D.D., et al, 2004

Note: Radiation Norman Wells, Temperature Port Radium

Changes in the climate of the Arctic and sub-Arctic regions have been a topic of intense investigation in recent years. Figure 3.5-3 shows the average trend in annual mean temperature for the Mackenzie District. The temperature profile exhibits a clearly identifiable overall positive trend (about 1.5 degrees/century), comprised of a weak cooling trend into the seventies followed by a warming trend to 1999.

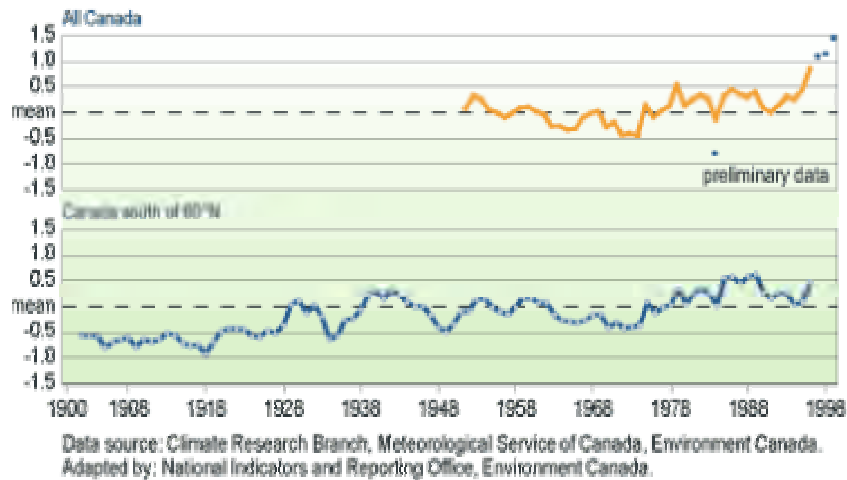
In the Mackenzie District, warming has occurred mainly in winter and spring. There is a very weak warming trend exhibited in the summer, and temperatures in autumn have been gradually decreasing.

**FIGURE 3.5-3**  
**Annual MacKenzie District Temperature Trends**



The average temperature in the Arctic has risen at almost twice the rate as the rest of the world in the past few decades. As the world's climate changes, temperature changes are anticipated to be greater in the North and greater in winter than in summer. According to recent climate models run by Environment Canada, annual temperature increases of greater than 5°C in the Arctic are possible by the year 2100. Figure 3.5-4 shows changes in Canadian temperatures versus the 1961 to 1990 climate normal period. Temperature records in the North are shorter than temperature records in the South of Canada, hence the longer trend for areas south of 60°N.

**FIGURE 3.5-4**  
**Average Canadian and Global Temperatures**  
 Average Canadian and global temperatures are rising  
 Change in Canadian temperatures (°C) from 1961-1990 mean (five-year averages)



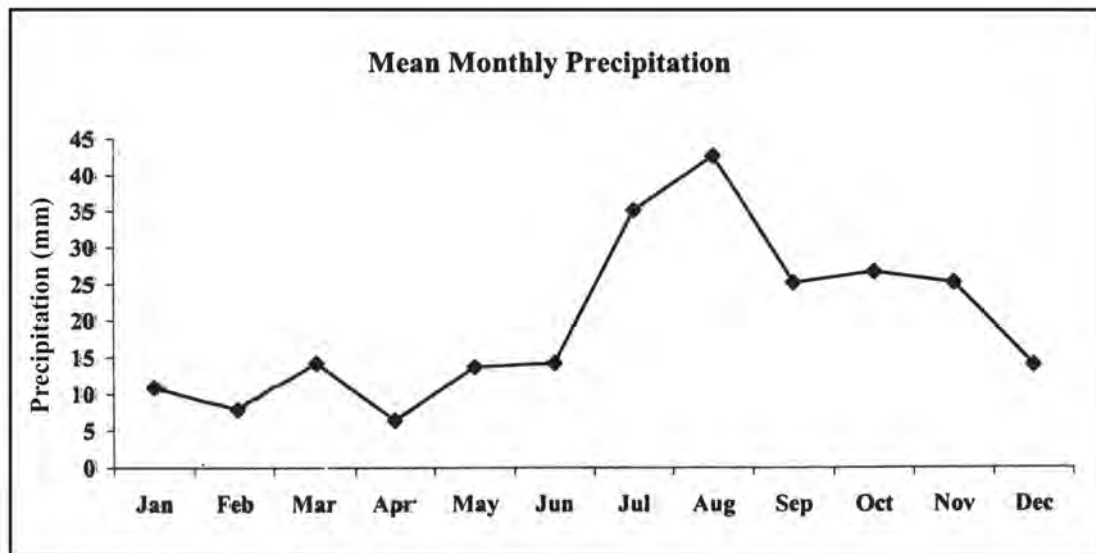
Source: [http://www.ec.gc.ca/soer-ree/English/Indicator\\_series/](http://www.ec.gc.ca/soer-ree/English/Indicator_series/)

### 3.5.2 Precipitation

Climatic data was collected initially at Port Radium and, more recently, at Déline. From the data collected at these sites (1950 to 1974), it is apparent that annual precipitation was low (i.e., ranging between 250 and 350mm); more than half of this precipitation fell as rain during the summer months (Figure 3.5-5). Close to half of the total precipitation was lost by evaporation or evapotranspiration. While southeast winds predominate in this region, summer storms lasting one to two days may arise from any direction.

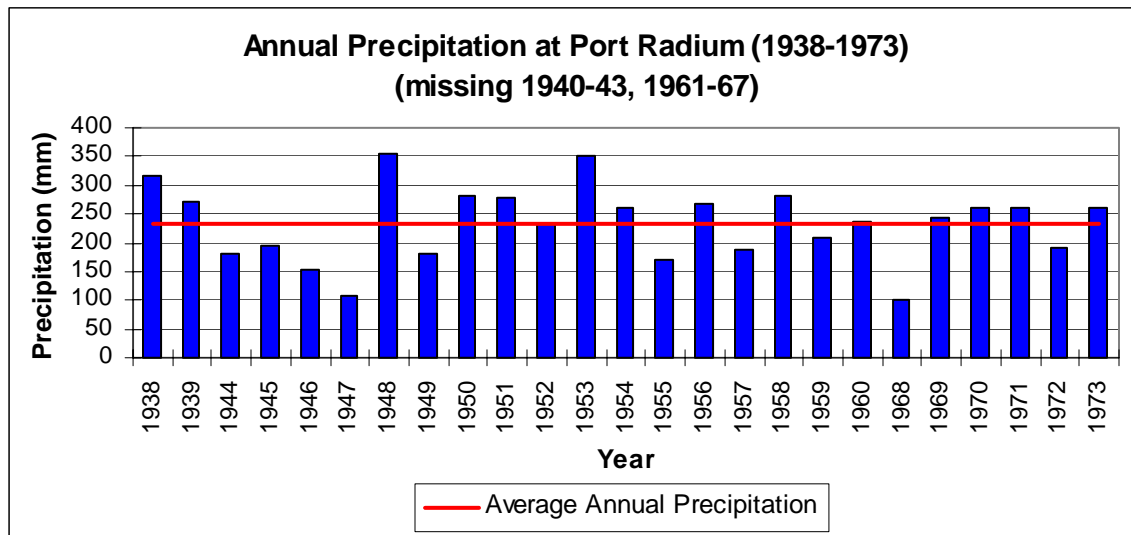
Site specific precipitation data from 25 years of annual precipitation measurements provide valuable information on the hydrology of the site. Figure 3.5-6 shows the total annual precipitation measured at Port Radium beginning in 1938. Based on these data it can be seen that the average annual precipitation recorded at the site was 234 mm. Maximum and minimum annual precipitation recorded at the site equaled 355 mm in 1948 and 102 mm in 1968, respectively.

**FIGURE 3.5-5  
MONTHLY PRECIPITATION DATA FOR PORT RADIUM**



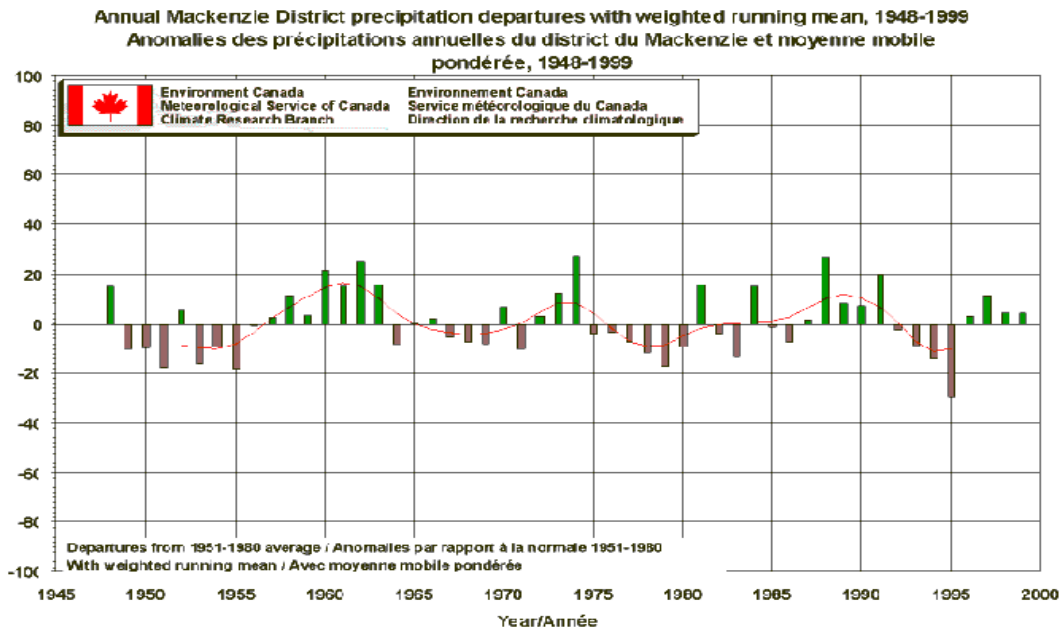
SOURCE: MacDonald, D.D., et al, 2004

**FIGURE 3.5-6  
ANNUAL PRECIPITATION AT PORT RADIUM BETWEEN 1938 AND 1973**



Because of the year-to-year variability, precipitation trends are more difficult to discern. Figure 3.5-7 shows that there is no clear trend in the long term record of precipitation for the Mackenzie District. On a seasonal basis, the warming in the winter in the Mackenzie District has been accompanied by a decrease in winter precipitation, while summer precipitation is somewhat higher and apparently more variable.

**FIGURE 3.5-7  
DEPARTURES OF PRECIPITATION IN MACKENZIE DISTRICT WITH WEIGHTED  
RUNNING MEAN OVER 1948 TO 1999 PERIOD**



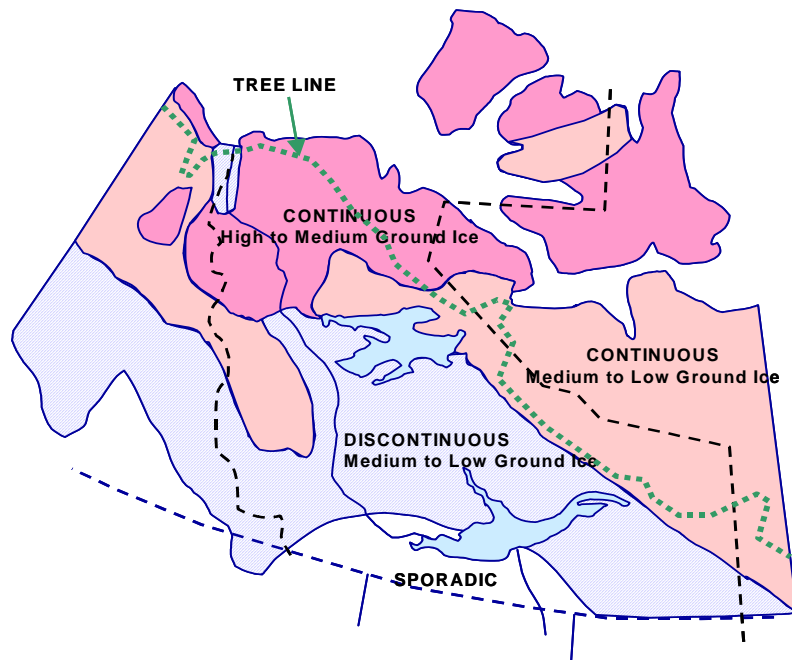
### 3.6 PERMAFROST

The Northwest Territories has a total area of about 1,346,000 km<sup>2</sup>; with about 13 percent of this area being fresh water. The uniqueness of the NWT is that it is located within the permafrost region and access to most of its areas is difficult. A large part of the NWT depends on winter roads and air transport for access and supplies. More than 50 percent of the permafrost is classified as sporadic and discontinuous and is readily disturbed by construction resulting in ground thawing and potential physical instability.

Design and construction of projects in the NWT permafrost environment is considerably more difficult than in the southern temperate parts of Canada. Challenges are created by the existence of frozen ground that may thaw due to construction disturbance and/or by warming due to climate change. Sensitive areas are located in high ground ice areas in both continuous and discontinuous permafrost, and in all discontinuous and sporadic permafrost regions as

highlighted in Figure 3.6-1. As can be discerned from Figure 3.6-1, the Port Radium site borders on the area between discontinuous and continuous permafrost.

**FIGURE 3.6-1  
SIMPLIFIED NRC PERMAFROST MAP MCR 4177  
(NRC 1995)**



The presence of permafrost and the magnitude of ground temperature are dependent on many factors, such as air temperature, vegetation, snow cover, orientation of the terrain and ice content. As previously discussed, there is strong evidence that the mean annual air temperature is rising in the NWT. As ground temperature is very dependent on air temperature, it is expected that permafrost will degrade in some areas as the mean annual air temperature rises.

To show how the temperature increases across NWT are expected to impact on permafrost, mean annual air temperature (MAAT) data for four locations were analyzed as follows:

- rate of temperature increases were obtained from the linear trends;
- the MAATs for 2000 were derived from the linear trends, and
- the number of years it will take for the ground to reach 0°C were estimated.

The results from this exercise are given in Table 3.6-1.

**TABLE 3.6-1  
MEAN ANNUAL AIR AND GROUND TEMPERATURES AT FOUR  
REPRESENTATIVE NWT LOCATIONS AND ESTIMATED NUMBER OF YEARS  
FOR GROUND TEMPERATURE TO REACH 0°C**

Locations	MAAT In 2000	MAGT In 2000	Avg. warming	Years to reach 0°C
	°C	°C	°C/100 yrs	MAGT
Yellowknife	-4.3	0.2	3.4	0
Normal Wells	-4.9	-0.4	3.2	14
Invuvik	-7.7	-3.2	7.0	48
Lupin	-10.6	-6.1	8.4	78

Note: MAAT = mean annual air temperature; MAGT = mean annual ground temperature.

The results in Table 3.6-1 indicate that:

- ground temperature at Normal Wells will warm to 0°C in about 14 years;
- at Inuvik it will take about 48 years to warm to 0°C; and
- at Lupin, it will take about 78 years.

Permafrost conditions at Port Radium would accordingly be expected to degrade in the next two to three decades should air temperature continue to rise as suggested by measurements recorded in recent times.

### 3.7 AIR QUALITY

Air quality is determined by the concentrations of pollutants in the atmosphere, which are, in turn, affected by the dispersion of pollutants from emission sources. Air pollution is caused by both natural and anthropogenic (human-induced) emission sources, and is defined as “the presence in the atmosphere of substances that are toxic, irritant, or otherwise harmful to people or damaging to vegetation, animals, or property.” Air pollution has a number of manifestations on various scales: regional and local – smog and acid rain; continental – transport of persistent toxics (e.g. mercury and PCBs); and global - climate change, ozone layer depletion.

A principal source of air pollution is the combustion of fuels to produce heat and/or energy. Major sources of anthropogenic emissions include:

- transportation;
- stationary fuel combustion (e.g. electrical utilities, industrial and residential heating);
- industrial processes (e.g. mining, oil and gas extraction, solvent use); and
- other (e.g. forest fires, agriculture).

Weather plays an important role in the dispersion of air pollutants. Meteorology is a vital part of predicting air quality. The parameters of particular importance to air pollutant dispersion are wind speed and direction, and atmospheric stability. The amount of sunshine also directly influences the photochemical production of secondary pollutants.

### **3.7.1 Conventional Pollutants**

The concentrations of conventional pollutants (i.e. total suspended particulate - TSP, sulphur dioxide - SO<sub>2</sub>, nitrogen oxides - NO<sub>x</sub>) at the Port Radium site are expected to be low as there are no significant sources of these pollutants in the local study area. Nonetheless, an ambient air sampling program was initiated at the Port Radium Site during the fall 2001 field program to measure TSP. The sampling program included a short-term component using battery-powered air samplers and a long-term component using dustfall jars. The dustfall jars were established in October 2001 and were recovered in April 2002 (see Figure 4.2-1). At that time, a second monitoring campaign was initiated and the samples were recovered in September 2003.

Each sample was measured for total dust fall, as well as being partitioned into its inorganic and organic fractions. The results of the analysis of the samples collected in the second campaign are presented in Table 3.7-1.

**TABLE 3.7-1  
DUSTFALL JAR RESULTS FOR APRIL 2002 TO SEPTEMBER 2003 CAMPAIGN**

Sample Location	Mass (mg)	Inorganic Fraction			Organic Fraction
		(%)	(g/518days/m <sup>2</sup> )	(mg)	(%)
Eldorado #1 Headframe Area	390	18	0.007	70.2	82
Labine Point	360	22.2	0.008	80	77.8
Inner Labine Bay	740	25.7	0.02	190.2	74.3
Lower Mill Site	910	13.2	0.01	120.1	86.8

As the NWT has not established a dust fall standard, the results were compared to the Ontario Ministry of the Environment (MOE) annual standard of 4.6 g/m<sup>2</sup> (MOE 1994). Given that the dust fall jars were open to the atmosphere for more than one year (518 days), Table 3.7-1 illustrates that the dust fall collected at the Port Radium site is far below MOE's annual standard (i.e. 4.6 g/365 days/m<sup>2</sup>). The findings from this survey were consistent with earlier findings, and confirmed that site conditions have minimal impact on dust fall in the region where the samples were collected.

In addition, the results of the site-monitoring program found that particulate loadings were well below the Ambient Air Quality Standard (AAQS) for the Northwest Territories suggesting that the air at the Port Radium site is very clean.

### **3.7.2 Other Pollutants**

Besides conventional pollutants, there has been considerable work done in the north to measure levels of three main contaminant groups of concern; persistent organic pollutants (POPs), heavy metals and radionuclides. This interest has been generated by the fact that the movement of air currents in the Northern Hemisphere is such that the air gravitates towards the Arctic and eventually carries pollutants into Northern Canada. Subsequently, these pollutants become trapped in the cold temperatures and can enter the food chain.

The findings reported in the Canadian Arctic Contaminants Assessment Report II indicate that the Canadian northern atmosphere contains lower levels of POPs and heavy metals than those found over most other circumpolar countries. Levels of most contaminants are reported to be declining slowly right across the circumpolar Arctic, however it is noted that it is still too early to tell whether mercury levels are increasing or decreasing. Most POPs are declining in the Canadian northern atmosphere, with the exception of dieldrin and endosulfan. Decreases in the hexachlorocyclohexanes (HCHs) and toxaphene are undoubtedly a result of international controls on their use. Lindane is expected to continue to be transported northward for some years from residues in Canada, France and China.

Several new contaminants not previously studied under the Northern Contaminants Program are now being found in the Canadian northern atmosphere, but it is still too early to tell whether levels are increasing. These include the brominated flame retardants, chlorinated paraffins and chlorinated phenols. The flame retardants are widely used and may be of concern in the future as they easily enter the food web.

None of the above pollutants are expected to be an issue at the Port Radium site. Because dust and TSP levels are low at the site, radionuclide concentrations in the air are likewise low.

### **3.8 TERRESTRIAL RADIATION**

The environmental radiation monitoring program included measurements of gamma and radon levels on the mill/plant areas and the tailings containment areas and surrounding mine locations. To measure gamma levels over long periods (i.e. six to twelve months), passive thermoluminescent dosimeter (TLD) devices were set out at each monitoring location and recovered at approximately six-month intervals. For the radon monitoring program, Radtrak<sup>®</sup> alpha track detectors were deployed and recovered at approximately six month intervals. A summary of the findings of these investigations follows. All measured and calculated radiation dose rates and radioactivity concentrations are reported in SI (International System of Units). Where the results of measurements were reported by laboratories in non-SI units, the original

values and units have been included in parentheses for traceability, and results were converted to SI units using the following conversion factors:

- 1  $\mu\text{rem} = 0.01 \mu\text{Sv}$ ;
- 1 pCi = 0.037 Bq;
- 1 pCi/L = 37 Bq/m<sup>3</sup>;
- 1 pCi d/L = 37 Bq d/m<sup>3</sup>.

### 3.8.1 Gamma Radiation Measurements

#### *i) Background Terrestrial Gamma Dose Rates*

Gamma monitors were placed at several locations in the study area to measure background radiation. The sites are identified in Table 3.8-1. One of the locations chosen for the study was at Branson’s Lodge, situated approximately 13 km south of the Port Radium site. The rocks and soils in the vicinity of the Lodge are of local origin, and no materials were known to have been transported to the lodge site from the Port Radium site. At the Outhouse (OH) at the Lodge, period average gamma dose rates measured outdoors ranged from 0.102 to 0.107  $\mu\text{Sv/h}$  (10.2 to 10.7  $\mu\text{rem/h}$ ) and averaged 0.104  $\mu\text{Sv/h}$ . At another location at the Lodge, a 6-month average dose rate of 0.115  $\mu\text{Sv/h}$  was measured.

**TABLE 3.8-1  
BACKGROUND TERRESTRIAL GAMMA DOSE RATES**

	Average, $\mu\text{Sv/h}$	Minimum, $\mu\text{Sv/h}$ ( $\mu\text{rem/h}$ )	Maximum, $\mu\text{Sv/h}$ ( $\mu\text{rem/h}$ )
<b>Branson’s Lodge OH</b>	0.104	0.102 (10.2)	0.107 (10.7)
<b>Branson’s Lodge</b>	0.115	-	-
<b>Garage at Airstrip</b>	0.114	0.112 (11.2)	0.116 (11.6)
<b>Cobalt Island</b>	0.103	0.099 (9.9)	0.111 (11.1)
<b>Small Lake (north of Murphy TCA)</b>	0.130	0.125 (12.5)	0.135 (13.5)
<b>McDonough TCA (top of ridge)</b>	0.154	0.133 (13.3)	0.179 (17.9)

Gamma dose rates were measured locally at the garage on the airstrip, 6 km east of the Port Radium site, and at Cobalt Island. The airstrip was constructed with local borrow material from the nearby hill, and the gamma dose rate was measured at an average of 0.114  $\mu\text{Sv/h}$ . On Cobalt Island, the gamma dose rate was measured at an average of 0.103  $\mu\text{Sv/h}$ .

The monitor locations at the small lake north of Murphy TCA and at the top of the ridge at McDonough TCA were remote to, and were not within the sight-line of, disturbed material from the Port Radium mine or mill. Therefore, the measured average dose rates of 0.13 and

0.154  $\mu\text{Sv/h}$ , respectively, are believed to indicate natural radiation levels from undisturbed mineralized formations on the surface of the peninsula where the Port Radium facilities are situated.

***ii) Port Radium Site Terrestrial Gamma Dose Rates***

Gamma dose rates were measured at several locations on and near areas containing waste rock and tailings on the Port Radium site. The mean, minimum and maximum dose rates measured are presented in Table 3.8-2.

**TABLE 3.8-2  
PORT RADIUM SITE TERRESTRIAL GAMMA DOSE RATES**

	Average, $\mu\text{Sv/h}$	Minimum, $\mu\text{Sv/h}$ ( $\mu\text{rem/h}$ )	Maximum, $\mu\text{Sv/h}$ ( $\mu\text{rem/h}$ )
<b>Murphy TCA (top of ridge)</b>	0.161	0.136 (13.6)	0.19 (19.0)
<b>McDonough TCA</b>	0.176	0.17 (17.0)	0.186 (18.6)
<b>Road to #5 Vein Raise Fan House</b>	0.179	0.166 (16.6)	0.20 (20.0)
<b>Murphy Bay</b>	0.204	-	-
<b>Inner Labine Bay</b>	0.225	0.206 (20.6)	0.242 (24.2)
<b>Mountie Cabin</b>	0.313	0.275 (27.5)	0.385 (38.5)
<b>Radium TCA</b>	0.610	0.559 (55.9)	0.683 (68.3)
<b>Murphy TCA</b>	0.741	0.705 (70.5)	0.779 (77.9)

The lowest dose average dose rates were in the range 0.16 to 0.18  $\mu\text{Sv/h}$  measured at three monitoring locations:

- Murphy TCA (top of Ridge);
- McDonough TCA; and
- Road to #5 Vein Raise and Fan House.

These monitoring locations are the furthest from the waste rock and tailings areas, but are either within line of sight of elevated radiation sources or are located near roadways constructed from waste rock.

The highest dose rates were measured near the Radium TCA and Murphy TCA. The average dose rates were at 0.61 and 0.74  $\mu\text{Sv/h}$ , respectively. Average dose rates at Murphy Bay, Inner Labine Bay and the Mountie cabin ranged between 0.20 and 0.31  $\mu\text{Sv/h}$ .

The measured gamma dose rate, approximately 0.31  $\mu\text{Sv/h}$  (31  $\mu\text{rem/h}$ ) at adit #4 of the Echo Bay mine indicates mineralization in materials in the vicinity that may have been excavated from the Echo Bay mine. The mineralization is likely responsible for at least part of the high radon concentrations in air measured at this location, as discussed below.

### **3.8.2 Site and Vicinity Radon Monitoring**

Based on the low radon concentrations expected in the vicinity of the site, high sensitivity detectors were selected for this monitoring program. The lower limit of detection (LLD) for the high sensitivity detectors is reported to be 222 Bq d/m<sup>3</sup> (6 pCi d/L) (i.e., the detection limit is 37 Bq/m<sup>3</sup> based on 6 days exposure). Therefore, the lower limit of detection (LLD) at 180 days exposure is approximately 1.2 Bq/m<sup>3</sup>.

Outdoor levels of radon gas were measured at 2 m above ground level at 14 monitoring stations at the Port Radium site. Radtrak® alpha track detectors were provided and read by Landauer Inc. Detectors were set out at a total of eight locations for the first 6-month exposure, and additional detectors were set out at a total of 14 locations for the remainder of the program. The duration of three exposure periods was 6 months and one period was extended to 12 months. The results of the radon surveys are summarized in Table 3.8-3.

#### ***i) Background Outdoor Radon Levels***

Outdoor radon levels were measured at Branson's Lodge located approximately 13 km south of the Port Radium site. The rocks and soils in the vicinity of the Lodge are of local origin and no materials were known to have been transported to the lodge site from the Port Radium site. Radon concentrations measured in outdoor air ranged from 0.74 to 6.3 Bq/m<sup>3</sup> (0.02 to 0.17 pCi/L) and averaged 4.1 Bq/m<sup>3</sup>. These levels were considered indicative of background radon concentrations in air in the vicinity of Port Radium mine site.

Background radon levels measured at Branson's Lodge are consistent with background levels measured in northern Saskatchewan. For comparison, annual average radon concentrations were measured at 6.7 Bq/m<sup>3</sup> (0.18 pCi/L) near the Wheeler River, at a distance of approximately 14 km from the Key Lake Mill in Saskatchewan. The winter and summer averages were 5.6 and 11.1 Bq/m<sup>3</sup> (0.15 and 0.30 pCi/L), respectively.

#### ***ii) Local Airborne Radon Levels***

Airborne radon levels were measured locally near the garage at the airstrip, approximately 7 km east of the Port Radium site. One six-month measurement averaged 9.6 Bq/m<sup>3</sup> (0.26 pCi/L). This value was somewhat higher than expected considering that the airstrip was constructed with

local borrow material from the nearby hill. The result is also inconsistent with environmental gamma measurements for the area, as the environmental TLD measurements at the garage and the area gamma survey by NaI detector both indicated low background radiation at approximately 0.11µSv/h (11 µrem/h) ambient dose.

***iii) Port Radium Site Airborne Radon Levels***

Airborne radon levels were measured at several locations on and near areas containing waste rock and tailings on the Port Radium site. The lowest radon concentrations were measured in the vicinity of McDonough TCA. Average levels ranged from 5.6 to 7.0 Bq/m<sup>3</sup> at three monitoring stations: the top of ridge near McDonough TCA; the McDonough TCA station; and the station near the Road to #5 Vein Raise and Fan House. While generally remote from actively worked site areas, the latter two stations are located somewhat in the proximity of waste rock used for roadway construction or as cover material.

The highest radon concentrations were measured near the Murphy TCA and Radium TCA. Radon concentrations averaged 44.4 and 24.8 Bq/m<sup>3</sup>, respectively. The average radon concentrations measured at the remainder of the stations ranged from 10 Bq/m<sup>3</sup> at Cobalt Island to 18.9 Bq/m<sup>3</sup> at Murphy Bay.

**TABLE 3.8-3  
SITE OUTDOOR RADON LEVELS**

	<b>Average, Bq/m<sup>3</sup></b>	<b>Minimum, Bq/m<sup>3</sup> (pCi/L)</b>	<b>Maximum, Bq/m<sup>3</sup> (pCi/L)</b>
<b>McDonough TCA(top of ridge)</b>	5.6	1.1 (0.03)	10 (0.27)
<b>McDonough TCA</b>	5.9	1.5 (0.04)	8.5 (0.23)
<b>Road to #5 Vein Raise and Fan House</b>	7.0	3.3 (0.09)	14 (0.38)
<b>Cobalt Island</b>	10.	6.3 (0.17)	12 (0.33)
<b>Murphy TCA (top of ridge)</b>	10.7	1.9 (0.05)	11 (0.30)
<b>Inner Labine Bay</b>	13.7	6.3 (0.17)	20 (0.54)
<b>Mountie Cabin</b>	15.1	8.1 (0.22)	24 (0.66)
<b>Murphy Bay</b>	18.9	15 (0.40)	27 (0.74)
<b>Radium TCA</b>	24.8	17 (0.47)	31 (0.84)
<b>Murphy TCA</b>	44.4	31 (0.84)	63 (1.7)

**iv) Echo Bay Adit #4**

Radon concentrations were measured at 28 and 56 Bq/m<sup>3</sup> (0.76 and 1.5 pCi/L) during winter and summer sampling periods, respectively, and averaged 42 Bq/m<sup>3</sup> at the Echo Bay Adit #4. These values are uncharacteristically high considering the remoteness of this area from the Port Radium tailings and waste rock areas.

Radon concentrations averaged 13.7 Bq/m<sup>3</sup> at Inner Labine Bay, which is located between the adit and the waste rock and tailings areas. Thus it is suspected that the Echo Bay Adit #4 and nearby vent raise are sources of radon gas in air exhausted from mineralization in underground workings.

**3.9 TERRESTRIAL VEGETATION**

A recent report by Macdonald (2004) provides a good overview of the terrestrial environment of the Great Bear Lake watershed. Hence, only a brief overview of terrestrial vegetation found in the study area is provided below.

**3.9.1 Local Vegetation**

The Port Radium study area lies within the north-eastern fringes of the subarctic boreal forest zone and the Canadian Shield. It is located 52 km south of the Arctic Circle and 70 to 120 km



south-west of the northern limit of trees. As the climate in the region is dominated by long, dark and cold low arctic winters, relatively low precipitation, and moderately warm summers with 24 hours of day light, the growing season is about 3.5 to 4 months from late-May/early-June to about mid-September.



The mine site and surrounding area consists of typical subarctic coniferous and mixed boreal forest including old growth of trees up to 15 to 20 m tall in some wind-protected locations (Plates 14 and 15). The vegetation ground cover in most habitats is closed-mat except for considerable areas with exposed bedrock and sparse vegetation, and areas impacted by mining activities. Forest floors are well-developed with shrubs, berries, Labrador tea, herbs, lichens and mosses. Well-drained hills and slopes are dominated by white spruce, paper birch and black spruce, and poorly drained depressions; lowlands and wetlands by black spruce, paper birch, scattered larch and balsam poplar. Forests climb up on mountainous slopes to meet the tree line in higher elevations and on plateaus that contain a transition zone of

forest and tundra, and parcels of arctic tundra with alpine character. Thus, the study area and the adjacent land provide different ecosystems bordering and intermingling with each other within a relatively small area.

### **3.9.2 Port Radium Soil and Vegetation Sampling Programs**

An opportunistic site sampling program was carried out on site in October 2001 (locations are described but not shown on figures) followed by a more comprehensive soil and vegetation sampling campaign in September 2003, as shown in Figure 3.9-1 (St.#). Soil and plant samples were collected in areas of tailings and waste rock at the Port Radium mine site and at control sites in September 2003, and analysed for a wide range of metals and radionuclides. Vegetation and soil samples were collected at 13 sampling stations including 10 contaminated and three background. Details of the program are provided in Appendix D1 of the SENES Human Health and Ecological Risk Assessment document (2004a).

Both surface and subsurface soil samples were collected for metal and radionuclide analyses. Summaries of the metal and radionuclide levels measured on the soil samples are provided on Tables 3.9-1 and 3.9-2. No difference was found in metal concentrations between surface (0-2 cm) and subsurface (5-10 cm) soils on the site. Pooled soil samples showed significant differences between the tailings/waste rock sites and control sites, particularly for uranium and arsenic. Uranium in the soil at one drainage area was over 100 times higher than at the control sites while arsenic at another site was over 80 times higher than the control site. When all samples from disturbed areas were pooled, arsenic was over 30 times higher than controls, followed by chromium, which was 28 times higher. Uranium in the pooled data was 16 times higher than controls. Other metals which had high levels of enrichment were vanadium, manganese and silver. Lead-210 and radium-226, two nuclides in the natural uranium decay chain, reached maximum levels in soils of 37 Bq/g, while remaining below detection at the control sites.

Plant species collected for metal and radionuclide analyses were chosen for their importance to the Sahtu Dene or because they are food for wildlife. Metal concentrations in plants followed similar trends but were much lower than those sampled in 2001 as part of the site assessment. A summary of the metals analyses is provided on Table 3.9-2. The three species that were sampled at several disturbed sites and a control site showed significant spatial trends, with the highest concentrations usually found in one of the drainage areas. Concentrations of uranium, arsenic and copper were all higher in dwarf birch, willow and Labrador tea than the same species in control sites, although high variability indicates that there are large differences between and within the sampling areas. Although relatively few lichen samples were available, both snow lichen and green reindeer lichen had significantly higher concentrations of uranium and arsenic than similar samples at background sites. Mushrooms also showed some enrichment of metals

and a single puffball sample from the west adit area had high levels of both arsenic and copper. This is significant because there was considerable evidence of large and small mammals, and birds, feeding on mushrooms on the sites. One of the highest concentrations of arsenic (58.1 mg/kg) in plants was observed in a single sample of horsetail (*Equisitum* sp.) from the McDonough TCA. There was evidence that these plants had also been grazed recently by moose. The data indicate that plants growing on disturbed areas of tailings and waste rock accumulate higher concentrations of uranium, arsenic and several metals than in the control site.

**TABLE 3.9-1  
SUMMARY OF ANALYTICAL RESULTS FOR NON-RADIONUCLIDES FOR THE  
2003 and 2001 SAMPLING CAMPAIGNS – SOIL SAMPLES**

Location	Sampling Period	Depth	# of Samples	Ag µg/g	Al µg/g	As µg/g	B µg/g	Be µg/g	Cd µg/g	Co µg/g	Cr µg/g	Cu µg/g	Mn µg/g
Background #1	Oct2001		2	< 2	61500	<20		1.75	< 30	15.5	102	21.5	1850
Background #2	Sep2003	0-2 cm	6	2.8	1258	39.4	5.5	0.11	1.09	39.7	1.58	218	683
	Sep2003	5-10 cm	6	1.8	1024	47.2	3.9	0.10	0.80	22.2	1.2	145	114
Cobalt Drainage #1	Oct2001	Surface Tailings	2	56.5	59000	4250		3.55	< 30	218	64.5	6000	990
	Sep2003	0-2 cm	3	22.7	12460	2220	25.4	1.20	0.74	131	19.6	3240	746
	Sep2003	5-10 cm	3	24.0	23167	2793	25.9	2.08	0.68	226	29.9	3880	843
Cobalt Drainage #2	Oct2001	Surface Tailings	1	54.0	46000	4000		2.50	< 30	37	120	1400	360
	Sep2003	0-2 cm	3	29.7	18567	2840	28.3	1.64	2.36	1138	19	6670	4133
	Sep2003	5-10 cm	3	34.3	21733	3503	28.4	2.07	1.84	816	21.2	7797	2600
Murphy TCA	Oct2001	Surface Tailings	3	7.0	48333	3300		2.93	<30	1623	50.3	3900	1233
	Sep2003	0-2 cm	3	12.0	17433	2547	22.5	1.50	0.52	1146	15.1	3227	5183
	Sep2003	5-10 cm	3	12.0	22233	3510	23.9	1.81	0.73	1508	19	2763	8697
CCME Soil Quality Guidelines	Residential/Parkland			20		12		4	10	50	64	63	
	Commercial/Industrial			40		12		8	22	300	87	91	

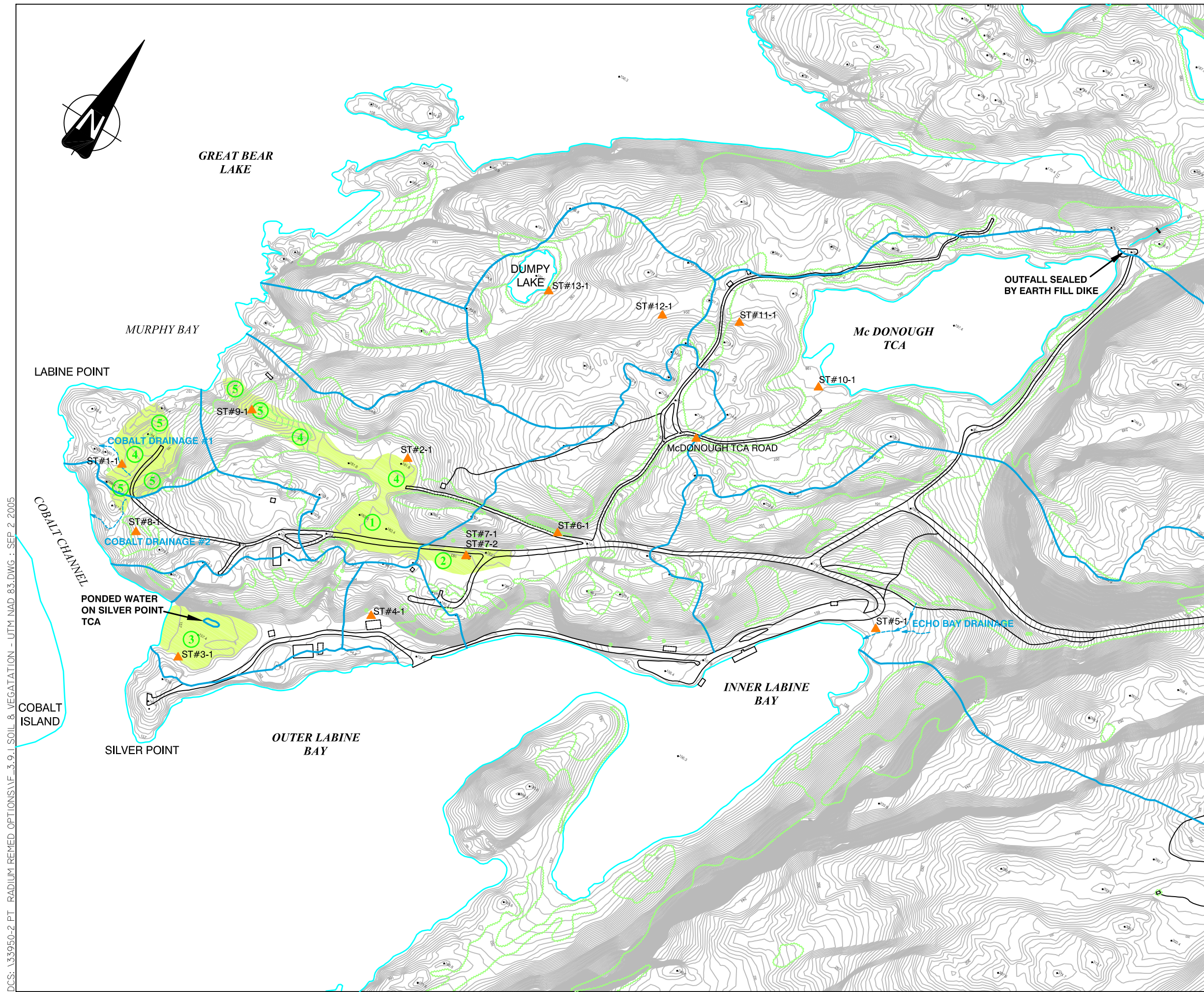
Location	Sampling Period	Depth	Mo µg/g	Ni µg/g	Pb µg/g	Sb µg/g	Se µg/g	Sn µg/g	Sr µg/g	Ti µg/g	U µg/g	V µg/g	Zn µg/g
Background #1	Oct2001		< 10	19.5	18	< 20	< 50	< 50	104.5	1500	< 60	65.5	225
Background #2	Sep2003	0-2 cm	3.72	50.3	121		0.83	<4	10.2	39.21	26.6	7.465	237
	Sep2003	5-10 cm	4.2	26.4	215		0.58	<4	9.5	33.9	19.7	6.2	159
Cobalt Drainage #1	Oct2001	Surface Tailings	44	278	645	87.5	<50	<50	34.5	835	2125	480	670
	Sep2003	0-2 cm	32.3	195	619		3.7	5	44.3	83.6	2317	146	366
	Sep2003	5-10 cm	32.6	245	407		5.0	15	14.1	186	912	277	458
Cobalt Drainage #2	Oct2001	Surface Tailings	56	41	500	150	< 50	< 50	41	730	960	370	560
	Sep2003	0-2 cm	19.5	548	487		5.3	<4	52.4	109	1873	228	999
	Sep2003	5-10 cm	30.4	408	690		6.9	<4	15.0	128	3040	281	1091
Murphy TCA	Oct2001	Surface Tailings	34.7	410	370	37.7	< 50	< 50	25.3	843	1303	417	290
	Sep2003	0-2 cm	15.5	409	391		2.6	<4	12.1	119	1009	221	335
	Sep2003	5-10 cm	18.2	645	490		3.6	<4	14.5	145	1109	273	492
CCME Soil Quality Guidelines	Res/Park		10	50	140	20	1	50				130	200
	Comm/Ind		40	50	260/600	40	3.9	300				130	360

FIGURE 3.9-1

PORT RADIUM SITE ASSESSMENT

2003 ENVIRONMENTAL STUDY  
SOIL AND VEGETATION REPORT

SITE PLAN



- LEGEND**
- ① BURIED TAILINGS, COVERED WITH WASTE ROCK AND GRAVEL FILL
  - ② BURIED TAILINGS COVERED WITH GRAVEL AND SOIL FILL
  - ③ BURIED TAILINGS COVERED WITH WASTE ROCK
  - ④ SPILLED TAILINGS, MOSTLY COVERED WITH WASTE ROCK BUT SOME AREAS TOTALLY EXPOSED
  - ⑤ EXPOSED SPILLED TAILINGS
  - SUB WATER SHED BOUNDARIES (REVISED 24/9/03)
  - OBSERVED SEEPAGE
  - ST#10-1 2003 ENVIRONMENTAL STUDY - SOIL AND VEGETATION SAMPLING STATION

DCS:\33950-2 PT. RADIUM REMED OPTIONS\VF\_3.9.1 SOIL & VEGETATION - UTM NAD 83.DWG : SEP. 2. 2005

**TABLE 3.9-2  
SUMMARY OF ANALYTICAL RESULTS FOR RADIONUCLIDES FOR THE 2003 and  
2001 SAMPLING CAMPAIGNS – SOIL SAMPLES**

Location	Depth	Sampling Period	K-40 Bq/g	Tl-208 Bq/g	Pb-210 Bq/g	Tl-210 Bq/g	Bi-211 Bq/g	Pb-211 Bq/g	Pb-212 Bq/g	Bi-214 Bq/g	Pb-214 Bq/g	Rn-219 Bq/g	Fr-223 Bq/g
Background #1	0-2 cm	Sep2003	< 0.90	0.05	< 0.8	< 0.06	0.35	< 2.0	< 0.080	< 0.20	0.2	< 0.4	< 0.09
	5-10 cm	Sep2003	<1.40	0.06	<0.9	<0.07	0.49	<2.0	<0.14	0.15	0.2	<0.5	<0.14
Cobalt Drainage #1	Surface Tailings	Oct2001			44.1								
	0-2 cm	Sep2003	< 0.90	< 0.07	16	< 0.07	28.7	1.9	0.06	8.82	9.4	1.3	0.32
	5-10 cm	Sep2003	< 1.00	< 0.08	27	< 0.07	46.4	< 3.0	< 0.20	14.3	15.2	1.7	< 0.2
Cobalt Drainage #2	Surface Tailings	Oct2001			29.2								
	0-2 cm	Sep2003	< 0.70	< 0.05	12	< 0.05	34.5	1.3	0.04	11	11.3	0.71	0.16
	5-10 cm	Sep2003	< 0.80	0.06	21	< 0.06	43	1.5	< 0.200	13.9	14.1	1.1	0.2
Murphy TCA	Surface Tailings	Oct2001			19.9								
	0-2 cm	Sep2003	0.5	0.05	19	< 0.05	47.6	1.6	0.05	15.2	15.6	1.9	0.16
	5-10 cm	Sep2003	0.7	0.05	15	< 0.05	38.2	< 2.0	< 0.200	12.2	12.5	1.4	0.1

Location	Depth	Sampling Period	Ra-223 Bq/g	Ra-226 Bq/g	Th-227 Bq/g	Ac-228 Bq/g	Ra-228 Bq/g	Th-228 Bq/g	Th-230 Bq/g	Pa-234 Bq/g	Pa-234m Bq/g	Th-234 Bq/g	U-235 Bq/g
Background #1	0-2 cm	Sep2003	< 0.10	<1.5	< 0.3	< 0.30			< 6	< 0.30	< 20	< 0.6	< 0.06
	5-10 cm	Sep2003	<0.15	<1.5	<0.4	<0.30			<7	<0.35	<20	<0.7	<0.07
Cobalt Drainage #1	Surface Tailings	Oct2001	2.1	40	2.7		< 0.20	0.06	45			47.5	2.1
	0-2 cm	Sep2003	0.57	36.5	1.4	< 0.3			17	0.109	44	21.4	2.08
	5-10 cm	Sep2003	0.53	35.2	0.76	< 0.4			28	0.4	30	13.6	2.01
Cobalt Drainage #2	Surface Tailings	Oct2001	1.2	47.2	1.3		< 0.20	0.07	26			< 2.0	0.6
	0-2 cm	Sep2003	0.692	24	0.8	0.26			7.4	0.036	19	7.6	1.37
	5-10 cm	Sep2003	0.992	37.1	1.1	< 0.3			15	0.186	35	14.7	2.12
Murphy TCA	Surface Tailings	Oct2001	0.8	21.9	1		< 0.20	0.06	18			13.5	0.6
	0-2 cm	Sep2003	0.622	35.2	0.88	0.21			19	0.022	32	12.9	2.01
	5-10 cm	Sep2003	0.682	27.3	0.64	< 0.30			10	0.039	21	9.3	1.56

The radionuclide levels measured on the vegetation samples are summarized on Table 3.9-4. Radium-226 was detected in all plant samples in which it was analysed, except one mushroom sample, and reached a maximum in Labrador tea leaves of 0.78 Bq/g (780 Bq/kg). Lead-210 was detected in several plant samples, with the highest levels in three lichen samples from contaminated areas.

The results of both these sampling campaigns were used in ecological and human health risk assessments. The assessment suggested that some small species in the areas of highest metal levels in soil and vegetation were at risk of adverse effects.

**TABLE 3.9-3**  
**SUMMARY OF ANALYTICAL RESULTS FOR NON-RADIONUCLIDES FOR THE 2003 and 2001 SAMPLING**  
**CAMPAIGNS – VEGETATION SAMPLES**

Location Collected	NOTE:	DRY WEIGHT (DW) BASIS		Al	As	Sb	Be	B	Cd	Cr	Co	Cu	Cs	Pb	Mn
	Sampling Period	Sample Type	No. of Samples	mg/kg DW	mg/kg DW	mg/kg DW	mg/kg DW	mg/kg DW	mg/kg DW	mg/kg DW	mg/kg DW	mg/kg DW	mg/kg DW	mg/kg DW	Mg/kg DW
Near west Adit	Oct2001	Grasses	6	745.83	224.52	4.13	0.16	27.48	0.33	1.52	112.30	495.78	0.20	38.52	102.90
St #1	Sep2003	Dwarf Birch/Rush	6	28.00	3.92	0.16	<0.05	52.33	0.19	0.17	7.26	13.45	0.05	2.29	182.65
Near west Adit	Oct2001	Willow (branch with seed)	1	64	11.5	0.23	<0.05	12.4	0.24	<0.1	4.1	51.3	<0.02	3.67	36.7
St #1	Sep2003	Willow	3	22.00	2.05	0.10	<0.05	60.03	3.05	0.20	37.57	8.83	0.05	1.08	192.00
Near west Adit	Oct2001	Juniper leaves	1	122	0.76	0.16	<0.05	35.6	0.23	7.6	1.25	257	<0.02	12.9	48.6
St #1	Sep2003	Mushrooms	2	34.00	54.35	0.17	<0.05	5.30	1.70	0.10	11.46	163.75	0.53	4.81	14.60
St #1	Sep2003	LabTea	3	33.33	3.02	0.12	<0.05	31.17	0.03	0.17	1.69	12.43	0.07	1.54	118.60
St #1	Sep2003	RoseHips	3	9.00	1.57	0.15	<0.05	17.57	0.04	0.13	1.65	4.47	0.10	0.28	53.43
St #1	Sep2003	Lichen	3	192.00	11.11	0.47	<0.05	2.87	0.54	0.73	9.41	40.40	0.08	29.07	105.37
Radium North TCA	Oct2001	Lichen	1	6330	246	14.3	0.52	5.8	0.51	12.8	331	1990	0.48	375	462
St #2	Sep2003	Lichen	3	181.67	3.69	0.19	<0.05	1.17	0.13	0.73	6.23	31.60	0.06	14.96	120.63
Radium North TCA	Oct2001	Berries	2	12.50	0.34	<0.06	<0.05	5.50	0.05	0.30	0.64	1.30	0.04	0.17	37.90
St #2	Sep2003	Berries	3	5.33	0.39	<0.06	<0.05	18.20	0.08	0.17	0.20	3.83	0.05	0.11	44.17
Radium North TCA	Oct2001	Rose Hips	2	24.50	2.60	0.16	<0.05	17.30	0.05	<0.1	1.39	6.00	0.14	0.69	40.65
St #2	Sep2003	RoseHips	3	4.67	0.59	0.06	<0.05	17.27	<0.02	0.10	1.27	4.40	0.42	0.21	34.83
St #7	Sep2003	RoseHips	1	3	0.29	<0.06	<0.05	14.3	<0.02	<0.1	0.56	2.5	0.05	0.04	44.2
St #7	Sep2003	Mushrooms	1	14	5.93	<0.06	<0.05	2.9	0.3	0.3	0.42	15.1	0.16	0.44	5.7

Units: mg/kg dry weight.

**TABLE 3.9-3 (Cont'd)**  
**SUMMARY OF ANALYTICAL RESULTS FOR NON-RADIONUCLIDES FOR THE 2003 and 2001 SAMPLING**  
**CAMPAIGNS – VEGETATION SAMPLES**

Location Collected	Sampling Period	Sample Type	Hg	Mo	Ni	Rb	Se	Sr	Sn	Te	Ti	U	V	Ag	Zn
			mg/kg DW	mg/kg DW	mg/kg DW	mg/kg DW	mg/kg DW	mg/kg DW	mg/kg DW	mg/kg DW	mg/kg DW	mg/kg DW	mg/kg DW	mg/kg DW	mg/kg DW
Near west Adit	Oct2001	Grasses	0.04	1.86	106.73	8.92	0.55	39.75	<1.17	<0.09	7.65	126.44	7.07	1.83	257.25
St #1	Sep2003	Dwarf Birch/Rush		2.54	15.55	5.13	0.10	8.40		<0.08	0.61	5.81	0.23	<1	170.95
Near west Adit	Oct2001	Willow (branch with seed)	<0.008	0.59	14.8	8.6	0.2	7.57	<1	<0.08	0.98	5.4	0.32	<1	182
St #1	Sep2003	Willow		1.13	44.60	9.97	0.17	22.60		<0.08	0.39	1.28	0.15	<1	261.00
Near west Adit	Oct2001	Juniper leaves	0.012	0.08	182	8.2	<0.1	6.55	<1	<0.1	2.11	0.436	0.08	<1	45.3
St #1	Sep2003	Mushrooms		0.31	6.55	105.60	3.05	0.29		<0.08	0.30	1.86	0.13	106.50	126.65
St #1	Sep2003	LabTea		0.09	6.60	15.90	0.27	4.37		<0.08	0.77	2.95	0.28	<1	44.07
St #1	Sep2003	RoseHips		0.10	2.93	18.37	0.10	2.66		<0.08	0.17	0.42	0.12	<1	10.23
St #1	Sep2003	Lichen		0.16	9.80	2.80	0.30	5.57		<0.08	6.62	15.09	1.28	1.33	81.50
St															
Radium North TCA	Oct2001	Lichen	0.801	2.43	175	20	1.7	16.6	3	<0.08	95.6	284	50.5	28	249
St #2	Sep2003	Lichen		0.10	6.20	2.87	0.10	7.13		<0.08	4.57	4.54	1.39	1.33	39.20
Radium North TCA	Oct2001	Berries	<0.008	0.04	8.85	3.35	<0.1	1.43	<1	<0.08	0.12	0.09	0.06	<1	7.60
St #2	Sep2003	Berries		0.88	1.97	10.80	<0.1	1.63		<0.08	0.18	0.06	<0.06	1.33	18.33
Radium North TCA	Oct2001	Rose Hips	<0.008	0.16	2.95	34.20	0.10	2.14	1.00	<0.08	0.36	0.91	0.23	<1	10.55
St #2	Sep2003	RoseHips		0.13	1.67	36.40	0.10	2.38		<0.08	0.10	0.18	0.07	<1	12.63
St #7	Sep2003	RoseHips		0.11	0.5	11.4	<0.1	1.64		<0.08	0.1	0.041	<0.06	<1	6.6
St #7	Sep2003	Mushrooms		0.26	1.3	73.2	2	0.09		<0.08	0.42	0.228	0.09	<1	67.6

Units: mg/kg dry weight.

**TABLE 3.9-4  
SUMMARY OF ANALYTICAL RESULTS FOR RADIONUCLIDES FOR THE 2003 and 2001 SAMPLING CAMPAIGNS –  
VEGETATION SAMPLES**

Sampling Location	Sampling Period	Sample Type	Number of Samples	K-40 Bq/g	Cs-137 Bq/g	Pb-210 Bq/g	Po-210 Bq/g	Pb-212 Bq/g	Ra-226 Bq/g	Th-232 Bq/g	U-235 Bq/g	Am-241 Bq/g	Be-7 Bq/g
Near West Adit	Oct2001	Grass	6	0.105	<0.004	0.143	0.173		0.064	<0.0095	0.040	<0.0036	
St #1	Sep2003	Birch/Rush	2	0.187	0.010	0.106			0.075	0.025	0.045	0.008	0.418
Near West Adit	Oct2001	Willow/Seeds	1	0.013	<0.00017	0.006	0.007	0.0002	0.005	0.0002	<0.0022	<0.00014	0.241
St #1	Sep2003	Willow	1	0.254	0.007	0.069			0.067	0.020	0.024	0.006	0.162
St #1	Sep2003	Mushrooms	2	0.472	0.027	0.159			0.057	0.057	0.087	0.017	0.459
St #1	Sep2003	Labrador Tea	1	0.266	0.016	0.130			0.784	0.041	0.379	0.015	0.333
St #1	Sep2003	Wild Rose Hips	1	0.266	0.005	0.040			0.025	0.013	0.011	0.004	0.101
St #1	Sep2003	Snow Lichen	1	0.191	0.026	1.410			0.118	0.032	0.083	0.010	0.386
Radium Nort TCA	Oct2001	Lichen	2	0.749	0.199	6.391	9.255		4.706	<0.080	0.735	<0.024	
#2	Sep2003	Snow Lichen	1	0.130	0.021	0.886			0.056	0.020	0.027	0.006	0.227
Radium North TCA	Oct2001	Berries	2	0.056	0.001	<0.0057	0.005		0.002	<0.0017	<0.0021	<0.0005	
St #2	Sep2003	Wild Raspberry	1	0.254	0.005	0.036			0.024	0.013	0.018	0.004	0.113
Radium North TCA	Oct2001	Rose Hips	2	0.181	0.002	0.007	0.030	0.001	0.007	0.002	<0.0045	<0.00086	
St #2	Sep2003	Wild Rose Hips	1	0.317	0.005	0.036			0.022	0.012	0.019	0.004	0.115
St #7	Sep2003	Wild Rose Hips	1	0.247	0.010	0.088			0.058	0.026	0.035	0.008	0.316
St #7	Sep2003	Birch Bolete mushroom	1	0.555	0.024	0.176			0.143	0.064	0.097	0.019	0.701

Note: Analytical results are reported on a dry weight basis.

### **3.10 TERRESTRIAL WILDLIFE**

The current state of knowledge respecting wildlife in the Great Bear Lake watershed is summarized in the recent report by Macdonald (2004). A brief summary of the information contained in Macdonald is presented below.

#### **3.10.1 Wildlife Biodiversity**

The area around Great Bear Lake naturally provides a large variety of habitats and rich species diversity of vegetation, wildlife and birds including boreal and tundra species. No large scale inventories of terrestrial species present in the Great Bear Lake watershed have been undertaken to establish the current biodiversity however, the Environment and Natural Resources (ENR) (previously known as Resources, Wildlife and Economic Development (RWED)) branch of the Government of the Northwest Territories maintains a database on terrestrial plants and animals by ecozone. ENR evaluates the status of each species on their numbers, distribution and the extent of threats to their populations.

Of the 54 animal species potentially present in the Great Bear Lake watershed, 37 are considered to be secure, 6 species are considered to be “sensitive” meaning there are few individuals, they have a limited distribution or there are significant threats and 1 species “may be at risk”. Characteristic wildlife includes caribou, moose, black bear, wolf, red fox, snowshoe hare and beaver. Surveys of the caribou herds indicate that the Bluenose-East and Bluenose-West herds to the north appear to have stable numbers but the Bathurst herd appears to have undergone a significant decline.

Of the 190 bird species possibly present in the watershed, 101 species are “secure”, 30 are “sensitive”, 2 species “may be at risk” and 2 species are “at risk”. Common birds include spruce grouse, raven, osprey and waterfowl. Assessments of waterfowl indicate that populations of pintail and scoters are much lower than historic levels, although mallard and Canada goose numbers remain relatively stable.

#### **3.10.2 Port Radium Small Mammal Sampling Program**

During the fall September/October 2001, site assessment campaign animal samples were collected as opportunity allowed on, and in the vicinity, of the Port Radium site. The objective of the collection program was to collect samples that provide insights into the potential uptake pathways of site-specific species, as well as, actual tissue samples for analysis of some of the species that have been traditionally harvested by the Sahtu Dene. Terrestrial fauna collected directly on site included one arctic hare (*Lepus arcticus*), three red squirrels (*Tamiasciurus hudsonicus*) and one grouse (species unknown).

Summaries of the measured mean levels of selected metals and radionuclides on tissue samples of each of the biota collected at the Port Radium site are provided in Tables 3.10-1 and 3.10-2 respectively. Not surprisingly, the lowest metal levels were generally measured on the muscle samples of all three biota. With respect to the radionuclides, the highest levels were generally found in the bone of each of the biota. The measured metals and radionuclide levels in the arctic hare and grouse were used in the risk assessment of potential effects on these ecological species and on people who might consume these species.

**TABLE 3.10-1  
SELECTED METALS DATA ON TERRESTRIAL BIOTA  
FROM OCTOBER 2001 SURVEY**

Sample ID	Species	Tissue	Ag µg/g	As µg/g	Cd µg/g	Cu µg/g	Mo µg/g	Pb µg/g	U µg/g	Zn µg/g
<b>wet weight basis</b>										
GBL-SQ1	Red Squirrel	Muscle	< 1	0.27	< 0.02	2.1	< 0.02	0.05	< 0.006	16.1
GBL-SQ1	Red Squirrel	Liver	< 1	0.33	0.27	6.5	0.75	0.39	< 0.006	38.2
GBL-SQ1	Red Squirrel	Kidney	< 1	0.52	1.59	8.3	0.3	1.77	0.012	34.8
GBL-SQ1	Red Squirrel	Gut with contents	< 1	0.75	0.17	16.9	0.26	1.18	1.12	35.2
GBL-SQ1	Red Squirrel	Bone	< 2	0.34	0.65	4.3	< 0.04	15.6	0.14	147
<b>wet weight basis</b>										
GBL-H1	Arctic Hare	Muscle	< 1	0.23	< 0.02	2.3	< 0.02	< 0.04	0.018	21.9
GBL-H1	Arctic Hare	Liver	< 1	0.34	0.09	8.3	0.77	0.13	< 0.006	29.2
GBL-H1	Arctic Hare	Kidney	2	1.28	1.91	6.3	0.47	0.97	0.022	27.5
GBL-H1	Arctic Hare	Gut with contents	< 1	7.37	0.09	13.4	1.14	1.91	2.9	17.8
<b>wet weight basis</b>										
GBL-GR1	Grouse	Muscle	< 1	0.68	< 0.02	6.5	< 0.02	0.1	< 0.006	7.6
GBL-GR1	Grouse	Liver	< 1	9.04	0.44	6.5	1	0.93	< 0.006	21.3
GBL-GR1	Grouse	Crop contents (food)	< 1	4.98	0.03	6.8	0.93	1.1	1.89	5.1

**TABLE 3.10-2  
SELECTED RADIOLOGICAL DATA ON BIOTA  
FROM OCTOBER 2001 SURVEY**

Sample ID	Species	Tissue	U µg/g	Ra-226 Bq/kg	Pb-210 Bq/kg	Po-210 Bq/kg	U-235 Bq/kg
<b>wet weight basis</b>							
GBL-SQ1	Red Squirrel	Muscle	< 0.006	0.51	3.0	3.5	< 1.4
GBL-SQ1	Red Squirrel	Bone	0.14	38	65	31.5	< 6.5
<b>wet weight basis</b>							
GBL-H1	Arctic Hare	Muscle	0.018	< 1.6	< 3.1	1.2	< 1.39
GBL-H1	Arctic Hare	Liver	< 0.006	< 0.5	3.0	11.0	< 0.68
GBL-H1	Arctic Hare	Kidney	0.022	< 4.2	< 17	23.1	< 7.5
GBL-H1	Arctic Hare	Bone	-	64	46	22.6	< 20
GBL-H1	Arctic Hare	Gut with contents	2.9	19	58.8	200	1.9
<b>wet weight basis</b>							
GBL-GR1	Grouse	Muscle	< 0.006	< 1.1	< 5.13	2.7	< 2.4
GBL-GR1	Grouse	Liver	< 0.006	< 3.4	< 15	19.1	< 6.6
GBL-GR1	Grouse	Bone	-	6.3	48	19.4	< 10
GBL-GR1	Grouse	Crop contents (food)	1.89	27	77	36.0	< 16

### **3.11 HYDROLOGY AND HYDROGEOLOGY**

A recent review of the state of aquatic knowledge of the Great Bear Watershed (MacDonald *et al.* 2004) provides a comprehensive overview of limnological, hydrological and environmental conditions and of the structure and function of the aquatic ecosystem of Great Bear Lake. Hydrologic and water quality information specific to the Port Radium site has been gathered in conjunction with ongoing investigations of site conditions (SENES 2002, 2004). A brief summary of the most relevant information is presented below.

#### **3.11.1 Great Bear Lake - Physical Limnology**

The Port Radium site is situated on the eastern arm of the largest fresh water lake within Canada's borders. The statistical attributes of the lake include it being the ninth largest lake in the world by volume, the 19th deepest lake in the world, and holding the largest mass of cold fresh water in the world. It is characterized by its clear waters, maximum recorded Secchi depth 30 m, and simple food web. Total water volume is approximately 2.24 billion m<sup>3</sup> with a drainage area to water surface area ratio of 4.7 to 1 which is smaller than most lakes.

Precipitation is in the order of 300 mm/yr (250 to 350 mm/yr), half of which falls as rain in the summer months. The evaporation rate in the area is about half that of precipitation, therefore in general, surface water flow into lakes in the area is small. The lake has a slow turnover rate and a 124 years residence time.

Great Bear Lake is an isothermal, un-stratified lake, and this lack of temperature variance means it is well mixed. During summer storms, water from shallow areas circulates and mixes with deeper water, and on average Great Bear Lake turns over once every 3 years (Johnson 1975a). Great Bear Lake is ice covered from December to May, but sheltered bays and shallow water can be frozen by November. Ice formation can continue to April, and ice is not off the lake until July.

#### **3.11.2 Great Bear Lake - Hydrology**

As noted above, the drainage area of Great Bear Lake is very small compared to the total area of the lake, which limits the influence of inflows from contributing basins. Great Bear Lake receives inflow from six major sub-watersheds: Johnny Hoe, Camsell, Sloan, Dease, Haldane and Whitefish. The Camsell River is the largest tributary contributing 21% of total drainage at 3.083 billion m<sup>3</sup>/yr. Johnny Hoe is the next largest contributor with 12% drainage of the total drainage at 1.287 billion m<sup>3</sup>/yr. Response of the river system and the timing of peak flow is typical of peak flows that are the direct result of snow melt and runoff. Peak flow usually occurs in mid- to late-May. Soon after the peak, flow begins to subside to low levels for the rest of the year.

Great Bear Lake water levels have been recorded since 1938, with continuous measurements starting in 1963. Data from Port Radium and Hornby Bay indicate that the extreme range in the lake level elevation is one meter. The lowest mean daily water elevation was 155.57 m a.s.l. in April 1948 and the highest was 156.59 m a.s.l. in August 1961. The majority of water levels range from between 155.8 and 156.4 m a.s.l.. Water levels can also be affected by “seiche” wind effects and barometric changes.

### **3.11.3 Port Radium Site - Hydrology**

The mine site is located to the north of the Camsell River in an area that hosts no major streams or rivers in its immediate vicinity. Rainfall and snowmelt pond and accumulate in localized depressions to the point where they reach steady state conditions. Runoff from the area reflects its rugged surface profiles and shallow soil cover, similar to other areas around the northern part of Great Bear Lake.

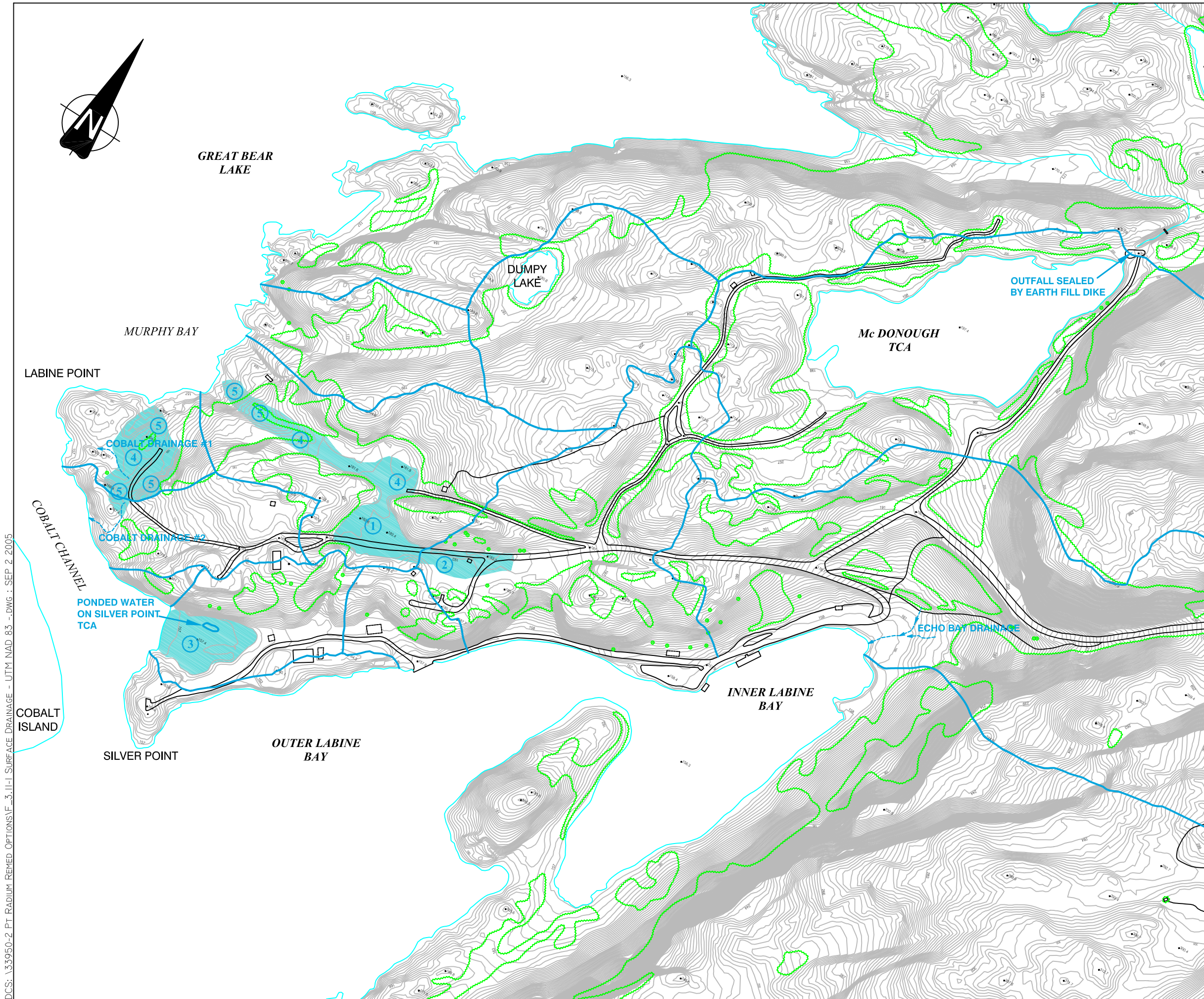
Figure 3.11-1 outlines the boundaries of the small surface drainage networks on the Port Radium site. The two small valleys that have the potential to drain contaminated water (water which is in contact with the tailings) into Great Bear Lake, were investigated. The first valley is where Murphy and Radium North TCA's are situated. Detailed investigations determined a gravel and boulder rise which crosses the valley (west of Murphy TCA). This rise likely prevents Murphy and Radium North TCA's draining into Murphy Bay. Instead water tends to pool in the Murphy TCA above the waste rock cover. Waste rock covering tailings has been spread over much of the area west of the gravel ridge to near Murphy Bay, which limits the amount of tailings that can be taken up by the draining surface water. A small area of exposed tailings is evident further west of the covered tailings. It is situated on bedrock near the Murphy Bay shoreline and the tailings have the potential to be taken up by drainage.

### **3.11.4 Port Radium Site - Hydrogeology**

The Port Radium site is characterized by extensive bedrock outcropping and shallow soil cover. During site visits, no direct evidence was found of surface water or shallow groundwater moving into the fractured bedrock. However, water was observed draining from the contact between waste rock and the bedrock surface at three separate locations, indicating that some near-surface water flow occurs at certain times of the year. Given the extensive bedrock outcropping at the site, groundwater flow across the site will be confined to fractures.

PORT RADIUM SITE ASSESSMENT

SURFACE DRAINAGE AREAS AND SURFACE SEEPAGE FLOWS AT SITE



**LEGEND**

- ① BURIED TAILINGS, COVERED WITH WASTE ROCK AND GRAVEL FILL
- ② BURIED TAILINGS COVERED WITH GRAVEL AND SOIL FILL
- ③ BURIED TAILINGS COVERED WITH WASTE ROCK
- ④ SPILLED TAILINGS, MOSTLY COVERED WITH WASTE ROCK BUT SOME AREAS TOTALLY EXPOSED
- ⑤ EXPOSED SPILLED TAILINGS
- SUB WATER SHED BOUNDARIES (REVISED 24/9/03)
- ← OBSERVED RUNOFF



DCS: \33950-2 PT RADIUM REVISED OPTIONS\F\_3\_11-1 SURFACE DRAINAGE - UTM NAD 83 -.DWG : SEP 2 2005

### 3.12 WATER AND SEDIMENT QUALITY

Ambient environmental monitoring has been carried out on Great Bear Lake for several decades including monitoring of contaminant levels in water, sediment and biota. Water quality monitoring has been carried out by Environment Canada as part of the routine surveillance network while a number of specific surveys have been conducted on portions of Great Bear Lake and/or its tributaries. Several of these surveys have been carried out in the vicinity of the Port Radium site. Recent surveys have also included sampling of surface ponds and drainage streams on the Port Radium site. A review of the much of the historic data has been summarized by MacDonald *et al.* (2004). Only a brief review of the results of the surveys is presented below.

#### 3.12.1 Great Bear Lake

##### *i) Water Quality*

Water sampling programs were carried out on Great Bear Lake between 2001 and 2003 in the near shore (range of distance from shore) and off shore waters (range of distance from shore) adjacent to the Port Radium site at the locations shown on Figure 3.12-1. Table 3.12-1 presents the general water chemistry data for Great Bear Lake in 2003 and also summarizes the results from the 2001 sampling campaigns. As seen from the table, the general water chemistry results are similar for all parameters at all locations sampled and independent of the distance from shore. Great Bear Lake water has moderately low alkalinity (typically 55 to 60 mg/L as CaCO<sub>3</sub>) and hardness (65 to 80 mg/L as CaCO<sub>3</sub>), slightly alkaline pH (near 8 pH units) and moderately low total dissolved solids (60 to 95 mg/L) content. The general chemistry values reported in Table 3.12-1 are very comparable to the values reported on Table 3.12-2, which summarizes water quality data on the Great Bear River at the outlet of Great Bear Lake. The summary statistics presented in Table 3.12-2, which cover the period from 1969 to 2001, are based on long-term monitoring data reported by Environment Canada. Comparison of the general chemistry data from Tables 3.12-1 and 3.12-2 suggest that there is no obvious effect of the Port Radium site on general water quality parameters for Great Bear Lake.

Table 3.12-3 presents selected water quality data for the near-shore locations in Great Bear Lake around the Port Radium site and Table 3.12-4 summarizes selected water quality data for the far-shore locations. No far-shore locations were sampled in 2001.

**TABLE 3.12-1**  
**SUMMARY OF GENERAL CHEMISTRY RESULTS FOR THE 2003 AND 2001 SAMPLING CAMPAIGNS**

Sample Location	Sample ID	Period	Alkalinity mg/L	Calcium mg/L	Sulphate mg/L	Conductivity µS/cm	Hardness as CaCO <sub>3</sub> mg/L	Dissolved Organic Carbon mg/L	Total Organic Carbon mg/L	pH	Total Dissolved Solids mg/L	Total Suspended Solids mg/L
Offshore – OS1 (South of Cobalt Island)	OS1D	Sep2003		19.5	22		75.8		1.9		66	
	OS1M	Sep2003		20.9	22		79.2		1.9		82	<3
	OS1S	Sep2003		20	20		77.4		2		86	<3
Offshore – OS2 (West of Cobalt Island)	OS2D	Sep2003		18.6	22		74		1.9		62	<3
	OS2M	Sep2003		18.9	22		74.7		1.8		90	<3
	OS2S	Sep2003		19.7	22		76.6		2		60	<3
Offshore – OS3 (North of Cobalt Island)	OS3D	Sep2003		19.4	25		75.7		2		78	<3
	OS3M	Sep2003		19.1	22		74.9		1.9		88	<3
	OS3S	Sep2003		19.9	25		76.8		1.9		86	<3
Inner Labine Bay – Top	1LB-T	Oct2001	55.9	15.4	16	157	69.1	1.9		7.95	65	<3
	(WS-1T)	Sep2003		19.5	24		77.2		1.9		82	
Inner Labine Bay - Bottom	1LB-B	Oct2001	84.1	15.2	16	158	69.6	1.8		7.69	77	<3
	(WS-1B)	Sep2003		20.8	23		80.1		1.9		84	
Outer Labine Bay – Top	OLB-T	Oct2001	55.7	14.7	15	153	68.4	1.6		7.98	78	<3
	(WS-2T)	Sep2003		20.3	21		78.3		2		82	
Outer Labine Bay - Bottom	OLB-B	Oct2001	55.9	14.8	15	155	67.9	1.6		7.93	69	5
	(WS-2B)	Sep2003		19.8	22		77.2		1.9		88	
Labine Bay near Silver Pt. – Top	LB-T	Oct2001	55.7	14.7	15	154	68.4	1.6		7.99	70	<3
Labine Bay near Silver Pt. – Bottom	LB-B	Oct2001	55.5	14.6	15	153	68.9	1.9		7.95	74	<3