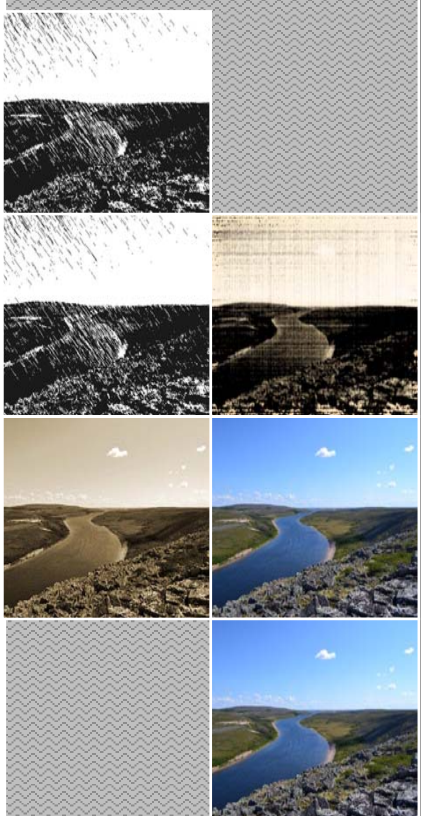
Report Two



Documented and Anticipated Stresses on the Aquatic Environment of the Baker Lake Watershed

Developing a framework for watershed-based cumulative effects monitoring in the Baker Lake Basin

Draft Final Report

Presented to Aboriginal Affairs And Northern Development Canada
Nunavut Regional Office
By Aarluk Consulting Inc. in Association with ESSA Technologies
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Introduction

Stressors are any physical, chemical, or biological entity that can induce an adverse effect on environmental systems (Cumberland Resources 2005a).

The Baker Lake watershed is subject to a range of documented, anticipated and potential stresses to water resources and the aquatic environment. These stresses include:

1. Mining activities which encompass:
   - Exploration
   - A range of development phases including mine development, operation, abandonment and reclamation
2. Hamlet of Baker Lake operations and development at the municipal level
3. Hydroelectric assessment and potential future development
4. Government activities which can include:
   - weather and communications stations
   - hydrometric stations, and
   - scientific programs (e.g., geological survey, physical and biological research)
5. Fish and wildlife harvesting and recreational activities
6. Linear developments which include:
   - Winter roads primarily in support of mining activities
   - Temporary or permanent all-weather roads associated with mine development and operations
   - Winter roads in support of smaller scale lodge operations
7. Transboundary aquatic stressors
8. Long range transport of Air Pollutants and Persistent Organic Pollutants
9. Climate change;
10. Natural cycles in the environment and natural events

In its analysis of regional water issues, Environment Canada (2010) pointed to the increase in mining and oil and gas projects, navigation and hydro power, fisheries, and tourism development as the main concerns for Nunavut’s water resources.

In Northern Canada in general, and due to the low levels of human activity and the large surface water supply produced by rivers, the supply-demand ratio is below 10%, meaning the threat to water availability is low (Environment Canada, 2011). However, the current and potential water uses pose a variety of potential impacts (Parsons, 2011), especially as activities like mining and oil and gas exploration spread. As of 2011, the Nunavut Water Board had issued 275 water licenses, distributed as shown in Figure 1. The Water Licences issued within the Baker Lake watershed are apparent in this figure.

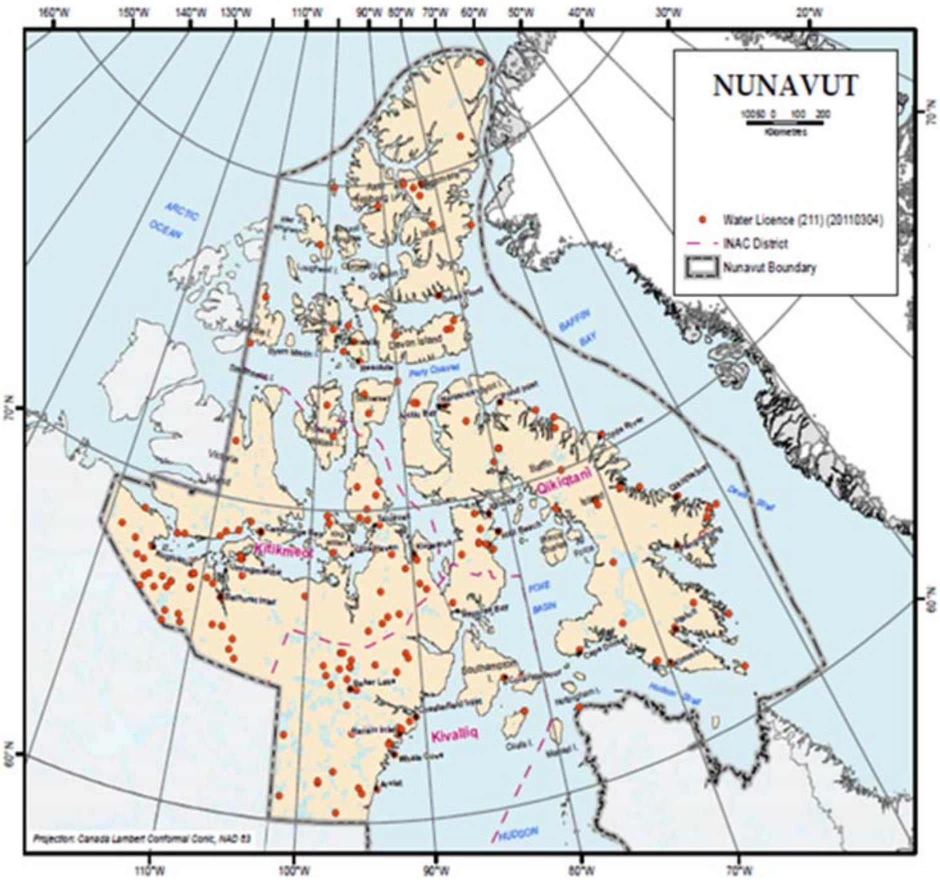

Figure 1. Distribution of Water Use Licenses in Nunavut
(Source: Parsons, 2011 - Cited in: Aarluk and ESSA 2012)

Geographically, stressors can be very sparsely distributed within the watershed; however, they may become somewhat spatially concentrated with biophysical resource hotspots. In a watershed setting, such stressors can have cumulative inputs and effects on the biophysical environment, and use of the environment by Nunavummiut. As such, the identified stressors become the key drivers for monitoring cumulative aquatic and related effects in the Baker Lake watershed.

The stressors discussed below focus to a large degree on development derived stressors, recognizing at the same time the importance of the more broad-scale and natural stressors in influencing cumulative effects, monitoring for cumulative effects and using knowledge of those cumulative effects to influence development related decision-making.

1. Mining Activities

Within the Baker Lake watershed there has been considerable activity in relation to mining exploration and development. Within the watershed to date, these activities have primarily focused on uranium, gold, rare earth and base metals. Figure 2 below provides a contextual overview of this mining related activity (AREVA 2011e). It is noteworthy that the diamond mines in the Northwest Territories (i.e., Ekati, Diavik, Snap Lake, Gahco Kué) are not located within the Baker Lake watershed.

Figure 2. Mining Exploration and Development in the Baker Lake Watershed (AREVA 2011e)

Mineral exploration in the area around Baker Lake has occurred since at least the 1970s. Despite this exploration and even the development of a few mining proposals, there had been no major mining developments in the area until 2003. After receiving approval from the Nunavut Impact Review Board (NIRB) in 2006, development of the Meadowbank project began and, by 2008, the all-weather road between Baker Lake and the mine was completed (Agnico-Eagle 2010).

Commercial production of gold began in March 2010 (Agnico-Eagle 2010). Meadowbank is projected to operate from 2010-2019 (Agnico-Eagle 2010 – cited in Peterson 2012; KIA website 2011 – cited in Peterson 2012).

Figure 3 and Table 1 below depict the 2011 and 2012 water licences issued for mining exploration and development within the Baker Lake watershed, based on records from the AANDC Minerals and Operations Directorate (November 2012). Mining and exploration activities are found throughout the watershed and the main mining and exploration activities are focused on uranium resources. There are 19 active water license sites within the greater Baker Lake watershed in 2012, and 11 of these water licenses are for companies active in uranium mining and exploration. The majority of mining and exploration activity within the greater Baker Lake watershed occurs within the Baker Lake subwatershed. Other licences are distributed among the Kazan, Thelon and Quoich subwatersheds. (Source information: Minerals Division and Operations Directorate AANDC, November 2012).

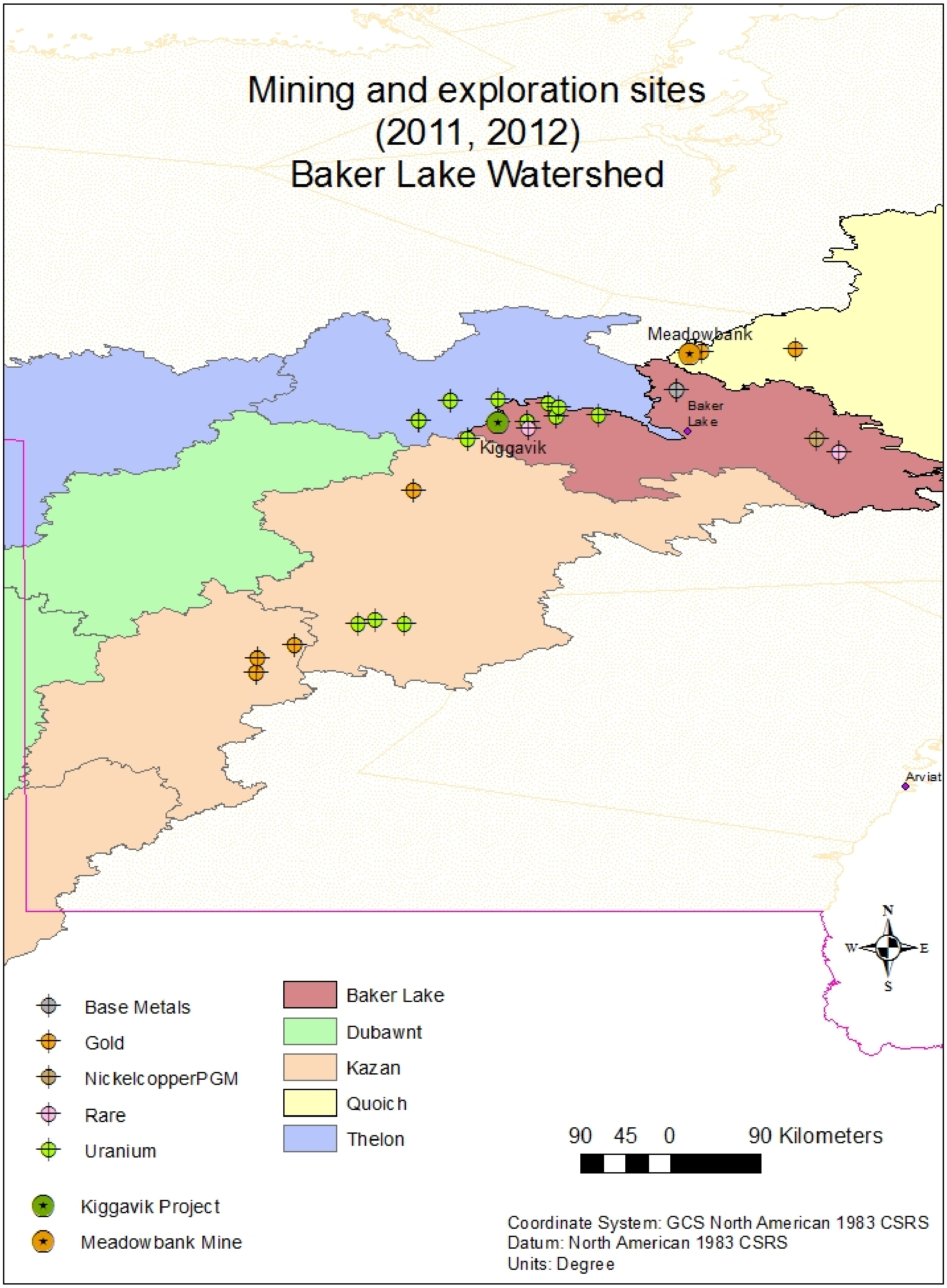

Figure 3. Map of 2011 and 2012 Water Licenses for Mining Exploration and Development Activity Based Upon Records from AANDC Minerals and Operations Directorate.

Table 1. Mining and Exploration Water Licences (Source Information: Minerals Division and Operations Directorate AANDC, November 2012).

Watershed	Project	Mineral Resource	Long	Lat	Status	License Issued	License Expires
Thelon	Aberdeen	Uranium	-98.4438	64.41612	Active	1-Jun-2012	31-May-2017
	Turqavik		-98.1647	64.59915	Active		
Thelon / Baker Lake/ Kazan	North Thelon (6)		-97.2104	64.44864	Active	19-Mar-2008	1-May-2010
			-97.7295	64.61084	Active		
			-98.0118	64.24724	Active		
			-97.471	64.41023	Active		
			-97.189	64.53763	Active		
			-96.8254	64.46449	Active		
Baker Lake	Kiggavik		-97.736	64.40004	Active	25-Apr-2008	31-Dec-2012
Kazan	Angilak (2)		-99	62.58188	Active	5-Aug-2008	31-Mar-2013
			-98.5796	62.58295			

Table 1 (cont'd). Mining and Exploration Water Licenses (Source information: Minerals Division and Operations Directorate AANDC, November 2012).

Kazan (cont'd)	Aura Consolidated Gold Project (3)	Gold	-99.9165	62.14486	Inactive	6-Jun-2011	30-May-2016
			-99.5649	62.39722			
			-99.8962	62.27793			
	Mallery Lake		-98.4926	63.78333	Active	17-Jul-2008	31-Jul-2012
Quoich	Meadowbank		-96.0103	65.02222	Active	9-Jun-2008	31-May-2015
	Muskox		-95.071	65.075	Inactive		
Baker Lake	Nutaaq	Rare Earth Metals	-97.467	64.34951	Inactive		
Baker Lake / Quoich	Nunavut Rare Earth Project		-94.6638	64.12656	Active		
Baker Lake	Greyhound Lake	Base Metals	-96.13	64.68422	Active	31-May-2010	13-Oct-2012
	ARNI	Nickel Copper Platinum Group Metals (PGM)	-94.8619	64.24402	Active		

The Kivalliq Inuit Association (KivIA) maintains a database with information on mining exploration and development. A GIS presentation of information from that database, showing claims, exploration and mining activity as of October 2012, is presented in Figure 4 below.

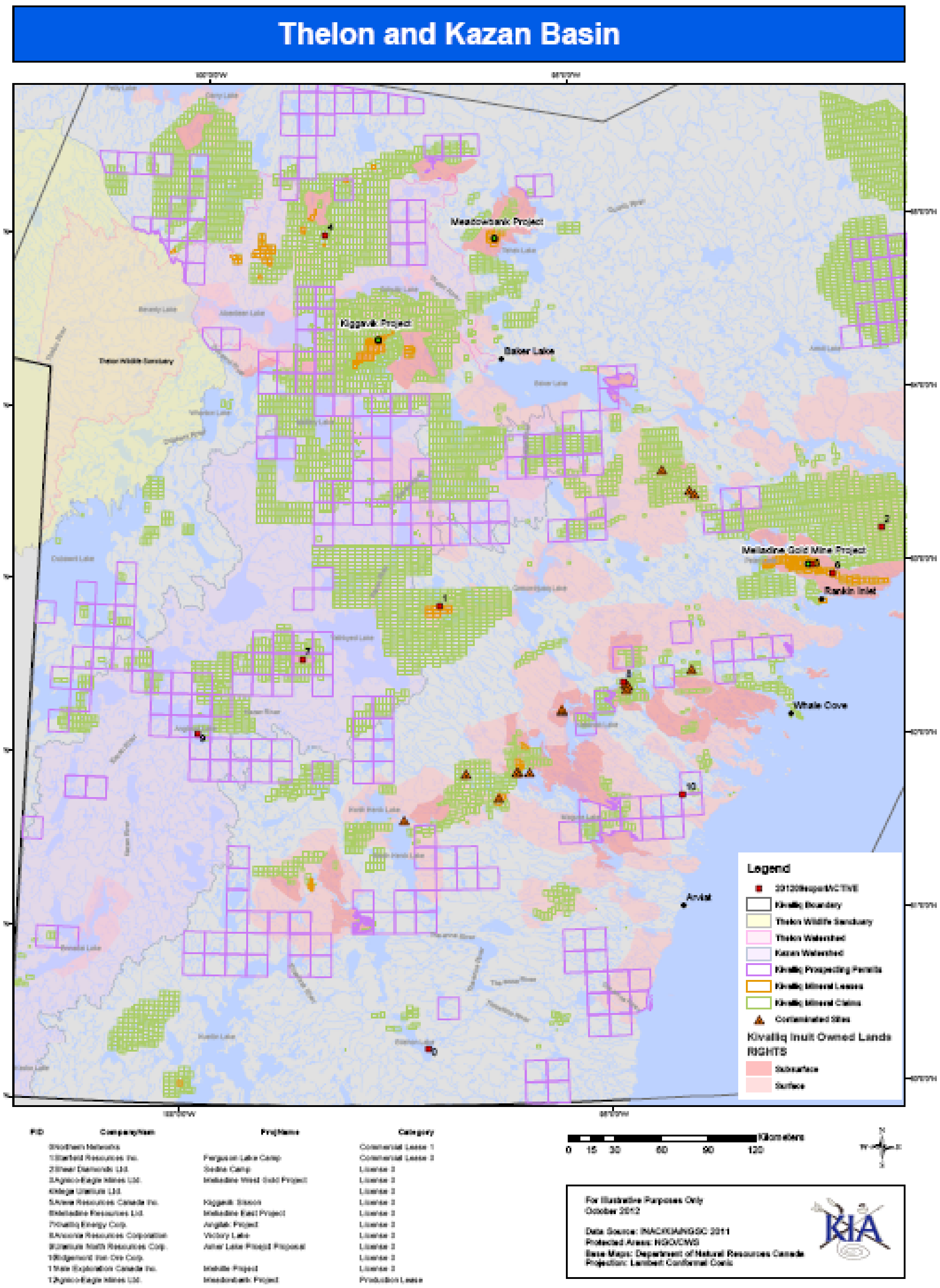

Figure 4. Claims, Exploration and Mining Activity Recorded on KivIA GIS and Database as of October 2012. (KivIA pers. comm. October 25, 2012)

There are reportedly hundreds of identified uranium occurrences in Nunavut, and two uranium deposits: Kiggavik near Baker Lake; and Mountain Lake south of Kugluktuk (Nunami Jacques Whitford Limited 2007). AREVA is currently in the environmental assessment review and regulatory phase for the Kiggavik project (Figure 5 below).

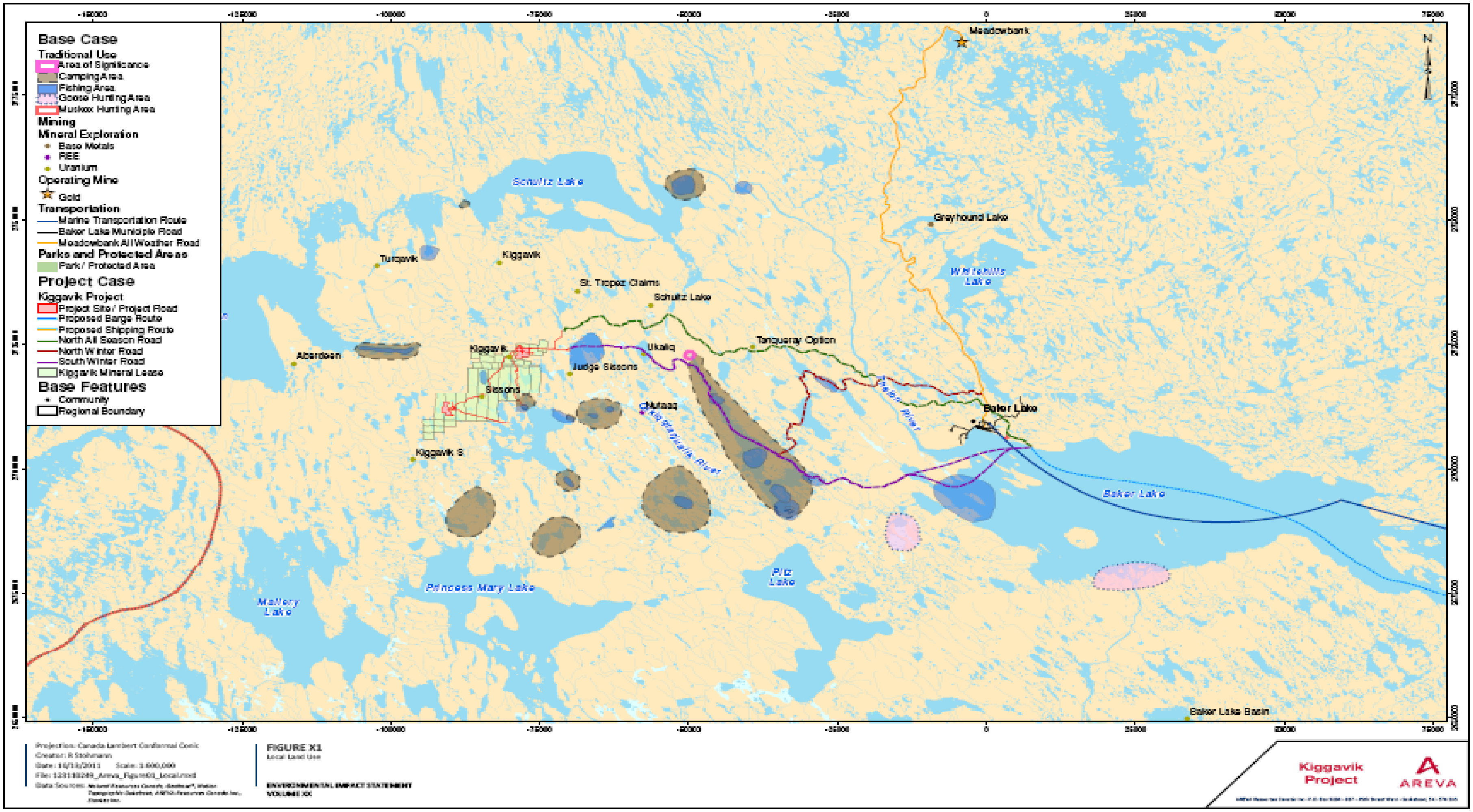

Figure 5. Local Land Use in the Vicinity of the Kiggavik Project (AREVA 2011e)

Cameco is engaged in exploration on the Aberdeen-Turqavik project (Figure 6 below). Aberdeen-Turqavik is an exploration project located approximately 85 km west of Baker Lake, with the exploration camp situated at the south end of Qamanaarjuk Lake along the Thelon River. Current exploration is focused in the southern portion of the two claims (http://www.cameco.com/exploration / major_projects/nunavut/ - accessed December 3, 2012).

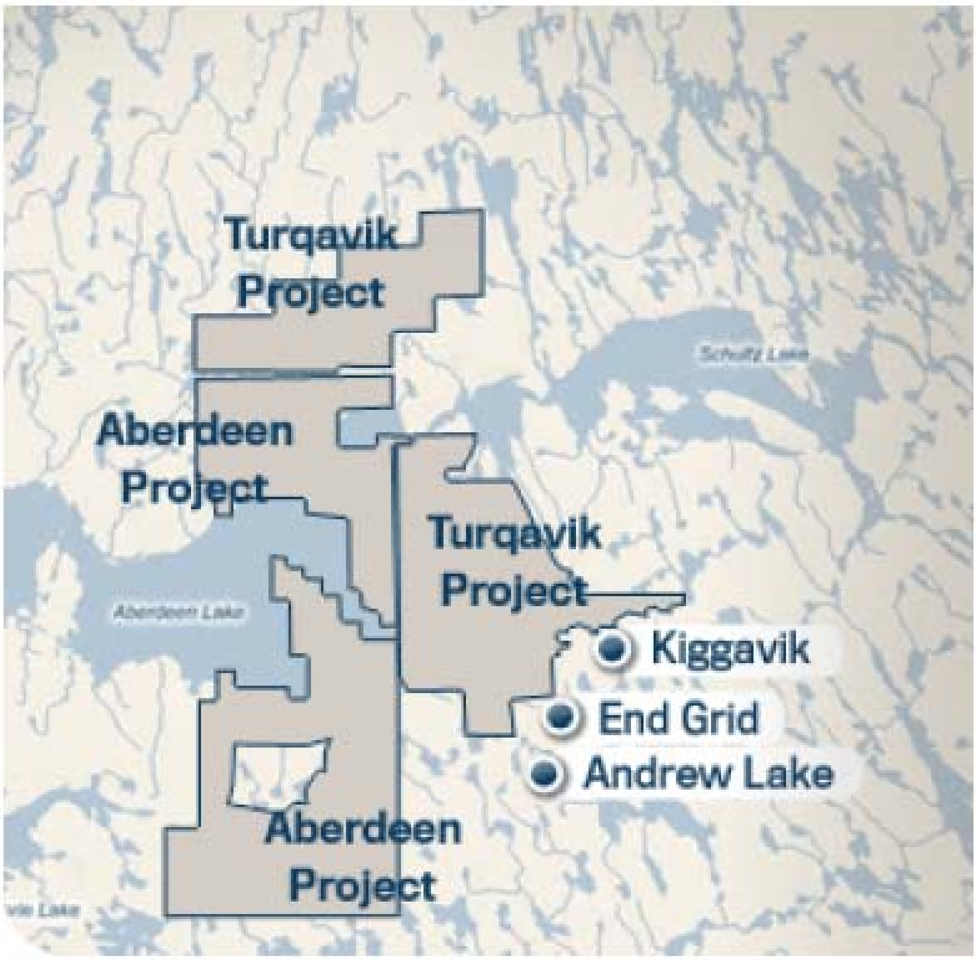

Figure 6: Aberdeen-Turqavik Project

1.1 Mining Exploration

Mining exploration entails a series of activities that have occurred in the past, are presently occurring, and are expected to occur in the future within the Baker Lake Watershed. The degree and intensity of activity are highly subject to fluctuations in mineral prices and capital markets. As an indicator of the scale of exploration activity, in 2006, an estimated $5.3 million was spent on uranium exploration in the Kivalliq (Nunami Jacques Whitford Limited 2007).

There are localized stressors associated with these activities, as discussed below. Vulnerabilities in the aquatic environment are related to the specifics of the activity and the characteristics of the aquatic environment within the zone of influence.

Mining exploration typically involves a number of activities that include airborne geophysical surveys, ground surveys, mapping, prospecting, sampling and drilling (Nunami Jacques Whitford Limited 2007). Applications in the Nunavut Impact Review Board (NIRB) registry provide details on each mining exploration initiative requiring a review. Frequently mining exploration operations require activities that relate to the aquatic environment, including helicopter and fixed wing aircraft overflights; fuel transportation, storage and handling (e.g., diesel, aviation fuel); aircraft landings and takeoffs on water; construction and use of ice landing strips on lakes; material handling on ice; winter roads and transport of fuel and materials; water withdrawal for diamond drilling and camp use; disposal of water from diamond drilling which normally contains suspended solids; disposal of waste water from camps; spills of fuel; etc.

While these activities do interact with the aquatic environment, the activities and their effects are normally quite small and localized. Noteworthy potential effects can include effects from spills of diesel and aviation fuel, particularly if they occur in winter, under ice. Even so, the quantities involved and zones of influence are normally quite small and localized. Vulnerabilities are generally related to the site/area specific characteristics of the aquatic environment. In general, smaller waterbodies tend to be more vulnerable due to the relative scale of a stressor, and areas that support human activities (e.g., potable water supply) and/or key life-cycle functions particularly of fish (e.g., spawning, migration).

As an indicator of activity scale, in 2006, an estimated $5.3 million was spent on uranium exploration in the Kivalliq (Nunami Jacques Whitford Limited 2007).

1.2 Mining Project Development

Within the Baker Lake watershed there is currently one mining project, the Meadowbank Gold Mine. One project is currently in the environmental assessment and regulatory review phase – the proposed Kiggavik Uranium Mine. A third project proposal is emerging and is expected to proceed to the environmental assessment and regulatory review phase within the foreseeable future – the proposed Aberdeen-Turqavik project. Mining projects can be stressors on the aquatic environment in a number of ways, as discussed below. The general stressors associated with mining projects are listed below. More specific stressors related to gold and uranium mines are detailed in subsequent sections 1.2.1 and 1.2.2 below.

General stressors associated with mining project include the following:

1. Aquatic habitat impacts and loss:
   - Aquatic habitat impacts and loss can be caused directly by mine infrastructure (camps, offices, mill, mine, waste rock piles, tailings impoundments, effluent discharge structure, sewage lagoons, dump, roads, etc.), or by hydrological alterations such as water drawdown or withdrawal, mine roads crossing streams, or reductions/ or increases in stream flow.

   - A harmful alteration, disruption, or destruction (HADD) of fish habitat is defined as "any change in fish habitat that reduces its capacity to support one or more life processes of fish"; mining projects are expected to design their facilities and implement mitigation measures to reduce HADDs to the extent possible.

2. Changes to water and sediment quality due to contaminant sources:
   - Besides direct loss of aquatic environments, the largest potential stressor from most mines is the water and sediment quality downstream of treated effluent release and the impacts this may have on aquatic biota. The constituents of potential concern (COPCs) vary depending on the type of mine and the milling process. Treated sewage is frequently released through the same effluent stream and also needs to be considered as a potential stressor.
   - Other potential contributors to impacts on water or sediment quality include run-off and seepage from waste rock piles, site facilities, vehicle wash facilities, and other similar potential contamination sources.
   - Water and sediment quality in potentially impacted aquatic environments is documented pre-development, and then is monitored throughout and after the life of the mine. Parameter concentrations released to the environment through the mine effluent are highly regulated; for instance metal mines must adhere to authorized levels prescribed in Schedule 4 of the Government of Canada Metal Mining Effluent Regulations.

3. Changes to water quality due to sedimentation:
   - As explained further in Section 1.2.1.1, increases in suspended solids and sedimentation can alter aquatic habitat and impact aquatic biota residing there.
   - Each project needs to identify potential sources of sediment loadings and mitigate against these during each project phase (construction, operations, and decommissioning).
   - Monitoring of parameters such as total dissolved solids, total suspended solids, turbidity, and Secchi depth are ways of measuring if changes are occurring.

4. Changes in groundwater quantity and quality:
   - Groundwater may not be a large concern in the Baker Lake watershed because of the extensive permafrost layer; however, as noted in the historical monitoring report, climate change could alter groundwater volumes, flow, and chemistry.
   - Mining projects could potentially cause groundwater drawdown which would affect the hydrological regime of the study area. The degree of impact depends on the cone of depression causing water drawdown.
   - Other potential impacts include contaminant seepage into groundwater through open pit mines or other sources.

5. Air emissions
   - The potential for airborne mine-related contaminants to have an impact on the aquatic environment needs to be considered as a potential stressor.

6. Ancillary developments
   - When considering cumulative effects, all developments occurring to support mine projects need to also be considered when evaluating stressors to the aquatic environment. Some examples of these include roads, power lines, and sewage treatment facilities.

7. Changes to lake water levels and lake ice:
   - Activities associated with mining projects in general can have implications for lake ice. For example, in the case of the Mary River project, the focus is ensuring the availability of water under the ice in lakes. In terms of vulnerabilities, volume reduction of lakes is of particular importance during the winter months when lake surfaces are frozen and water levels are below the lake outlet elevation. During this period water withdrawal in association with mining exploration and development activities can lower the water surface elevation within a lake, potentially causing dewatering and stranding of fish. In lakes used by Arctic Char for spawning, there is a potential for ice contact freezing or smothering of eggs in shallow spawning beds. Once water begins flowing again in the spring, outflow from the drawn down waterbody will not occur until the lake has refilled to a level where the water surface elevation is above the outlet elevation. This refilling delays outflows from the lake with consequent effects on fish and the aquatic environment downstream. (Knight Piésold 2010).

Specific stressors associated with the active Meadowbank Gold Project and the proposed Kiggavik Uranium Mine are outlined below. It should be noted that such stressors can be generally, but perhaps not exclusively, extended to mining related exploration and development for other metals and minerals.

1.2.1 Stressors Associated with a Gold Mine

With respect to the Meadowbank Gold Project, Cumberland Resources (2005a) identified three groups of project-related stressors of potential concern (SOPC) that might affect valued components of the aquatic environment. These are:

- Suspended solids and sedimentation;
- Contaminants (chemicals, ions, nutrients, petroleum hydrocarbons, etc.) ; and
- Direct habitat impacts.

1.2.1.1 Suspended Solids and Sedimentation

Suspended sediments and sedimentation are stressors on the aquatic environment since they can result in a wide range of environmental effects, including: disruption of important biological systems in fish (e.g., gills, mouth); degradation of spawning and nursery habitat; suffocation of eggs and alevins; degradation of periphyton and benthic habitat (which has secondary impacts on fish via food sources); and reduction in light penetration (secondary effects include reduced photosynthesis). Biological systems have a natural resilience to suspended solids and sedimentation, however. Any given monitoring program should be designed to identify when tolerance levels are being exceeded (Cumberland Resources 2005a).

Mine construction and operation activities can be expected to release suspended solids and cause sedimentation. There are mitigation techniques that will reduce the exposure of receptors to this stressor and minimize adverse effects. Total suspended solids (TSS) concentrations in the Meadowbank project lakes are very low, typical of oligotrophic Arctic lakes (Cumberland Resources 2005a).

With respect to the Meadowbank Gold Project, it was noted that caribou and muskox can be susceptible to indirect effects related to contaminated water. These effects were primarily related to the potential for caribou and muskox to drink contaminated water from tailings impoundments or possibly runoff from waste rock piles. These were identified as site specific effects to be mitigated using methods to discourage use of the area by caribou and muskox (Cumberland Resources 2006a). With effective mitigation and project specific confirmation through monitoring, it is not expected that effects on caribou and muskox from drinking such water would contribute to widespread cumulative effects.

Water quality measurements related to this stressor group include: TSS, turbidity (NTU), Secchi depth (m), and total dissolved solids (TDS) (Cumberland Resources 2006a).

1.2.1.2 Contaminants

Contaminants are defined as potentially deleterious substances that are present either where they are not normally found, or at concentrations above those usually measured (i.e. above background levels) (Cumberland Resources 2005a). From a regulatory perspective, contaminants can be deleterious in certain situations. The federal *Fisheries Act*, (Section 36) has stated that "…no person shall deposit or permit the deposit of a deleterious substance of any type in water frequented by fish."

For the Meadowbank Gold Project, metals comprise one of the contaminant groups of greatest potential concern. The concentrations of total and dissolved metals in project lakes are consistently measured at low values, often below detection limits and almost never exceeding CCME guidelines. Dissolved metal concentrations comprise the vast majority of total metals concentrations in water, where results exceeded detection limits, indicating that nearly all metals are dissolved and not associated with particulates. Water quality modeling of the impacts of effluent discharge and metal leaching from dikes determined that there is a risk that a small group of metals may exceed CCME guideline concentrations in the aquatic receiving environment over the life of the mine (Cumberland Resources 2006a).

Mine construction and operation activities have the potential to cause increases in a range of contaminants including suspended solids, metals, petroleum hydrocarbons, nutrients, and sewage constituents (including bacteria). These inputs may also influence such conventional measures as hardness, ion concentrations, dissolved oxygen, and pH. The study design of the Meadowbank Gold Project Aquatic Effects Management Program (AEMP) takes into consideration likely sources of these contaminants and aims to detect any changes before they can cause harm (Cumberland Resources 2005a).

Aquatic environment vulnerabilities related to contaminants can include drinking water for people and wildlife, toxicity to fish and other aquatic biota, and bioaccumulation of contaminants.

1.2.1.3 Direct Habitat Impacts

Habitat impacts, including habitat loss (as defined by Fisheries and Oceans Canada (DFO)), modification, and degradation, can be seen for example in lake dewatering, hydrological alteration, and stream crossings. These types of habitat impacts may affect all aquatic organisms and in the specific case of fish, spawning grounds, rearing areas, adult feeding areas, overwintering areas, and migration routes (Cumberland Resources 2005a). Impacts to and/or loss of fish habitat may be compensated or offset pursuant to regulatory requirements on a case by case basis.

With respect to waterfowl habitat impacts related to the Meadowbank Gold Project, while the aquatic habitats at the lake used for tailings impoundment would be permanently lost to waterfowl, flooding of the Portage and Vault pits at closure would result in new aquatic habitats for waterfowl. Management of slopes and eventual water depths in the nearshore zone for fish would also ensure that additional near-shore emergent vegetation and fish foraging opportunities for waterfowl are provided (Cumberland Resources 2006a).

Flooded portions of the tailings impoundment areas may be used briefly by waterfowl for resting or roosting purposes during the summer and the migratory period; however, residence times were not expected to be long due to the lack of emergent and littoral vegetation, and the absence of fish (removed during the dewatering phase) in the tailings impoundment areas. It was also noted that there is a possibility that waterfowl may forage on contaminated vegetation (e.g., vegetation that has been contaminated by fugitive dust fall from the processing plant, tailings impoundment, waste rock storage facilities, or vehicles) (Cumberland Resources 2006a).

With respect to the Meadowbank Gold Project, people in the community responding to a survey reported issues with hazardous waste disposal and the inappropriate use of the municipal dump, along with fuel spills near Baker Lake, along the road and at the mine site. Others spoke of the overwintering of a barge in the lake, which potentially could have caused issues with drinking water contamination and fish health (Peterson 2012).

Many other respondents expressed concern about the amount of dust originating from traffic on the road, especially during the spring and summer. The heavy trucks travelling back and forth on the road reportedly kick up significant amounts of dust during their multiple trips each day. This dust settles on the snow or lands to the sides of the road causing concern for the health of the tundra and bodies of water near the road. Whitehills Lake, a major fishing location, is close enough to the mine to be considered by respondents to be potentially be affected by this dust (Peterson 2012).

Vulnerabilities include all aquatic species, with greatest concern focused on harvested species, particularly Arctic char, lake trout, Arctic grayling, whitefish, northern pike and burbot.

1.2.2 Stressors Associated with a Uranium Mine

Development of a uranium mine has the potential to result in stressors on the aquatic environment as discussed below, using the proposed Kiggavik Uranium Mine as an example.

1.2.2.1 Stressors – Radionuclides, Tailings, Acid Runoff

Uranium mining methods are highly mechanized, using remotely controlled equipment. Ore from the mine is ground in the mill to a fine sand size and mixed with water. Uranium is dissolved from the rock using chemicals, including sulphuric acid. The uranium is separated to produce Yellowcake and the tailings are sent to a tailings management area (Nunami Jacques Whitford Limited 2007).

Radionuclides:

- Direct Aquatic Effects: The largest potential impacts associated with uranium projects are on the aquatic environment due to the release of treated effluent or leaching of mine tailings into surface or ground water (see below for more on mine tailings). Release of treated effluent into the aquatic environment has the potential to affect water quality. As a result, all operational uranium projects are required to complete extensive monitoring downstream of treated effluent release, including Environmental Effects Monitoring programs administered by Environment Canada.

- Indirect Aquatic Effects from Radon Gas and Airborne Emissions: when uranium breaks down in the ground, it releases radon gas. Radon forms lead-210 in the air which falls with rain onto lichens and changes into polonium-210. Polonium-210 naturally increases the radiation dose to humans, since caribou eat the polonium-201 and transfer it to people and wolves. People eating caribou already receive a high radiation dose from polonium-210, and increased mining and milling dust has the potential to get into lichens eaten by caribou and increase this dose. Drinking LARGE amounts of uranium in water can hurt kidneys, while drinking water with radium-226 can give a radium dose to bones (Nunami Jacques Whitford Limited 2007).

Mine Tailings: The ore is ground up finely and chemicals are added to float out the uranium, leaving perhaps 99% of the ore behind as tailings, depending on the ore grade. The tailings are very toxic and remain radioactive for a very long time. Since for example radium-226 may enter water supplies from tailings, it has been recommended that tailings be put into the mined out pit (Nunami Jacques Whitford Limited 2007).

Waste Rock: If the waste rock contains sulphide minerals, the sulphides can oxidize to produce sulphuric acid. With precipitation, dilute sulphuric acid can drain from the waste rock piles and affect vegetation, and the aquatic environment including fish. As mitigation, the waste rock needs to be separated from oxygen to prevent acid generation. One method is to cover the waste rock with rocks and till; however, over time the waste rock will become re-exposed. The preferred method is to place the waste rock in a deep lake well under water so that oxygen exposure is very much reduced over the longterm. Waste rock also contains radionuclides and heavy metals (Nunami Jacques Whitford Limited 2007).

Water Quality Vulnerabilities: If the mined out pit leaks, water may travel outside the pits and eventually into aquifers. This can be monitored using monitoring wells. If such seepage does occur, the wells can be pumped dry to collect the seepage and prevent it from entering the environment. Ground water monitoring at Cluff Lake in Saskatchewan revealed highly elevated levels of heavy metals and radionuclides. Arsenic levels were 66 times background and nickel levels were 1,250 times background. Therefore total loadings over a mine life can have significant cumulative effects (Nunami Jacques Whitford Limited 2007).

Decommissioned Tailings Facilities: Perpetual monitoring of decommissioned tailings management facilities and potential acid-generating waste rock depositories is required (Nunami Jacques Whitford Limited 2007) in order to identify and track potential changes in the aquatic environment.

Cumulative Effects: Even if each uranium mine operates perfectly, the combined effect of all potential mines has the potential to overload the environment. The potential effects from all projects in an area need to be considered (Nunami Jacques Whitford Limited 2007), and monitored.

1.2.2.2 Stressors – Habitat Change

Transportation: Roads can cause environmental effects (Nunami Jacques Whitford Limited 2007) that need to be monitored. Stressors on the aquatic environment can include interference with fish passage, deposit of suspended solids from washouts and dust, and deposit of deleterious substances such as hydrocarbons from vehicle accidents. Vulnerabilities include aquatic species, particularly harvested fish species.

Climate Change: The impacts of climate change on permafrost and other conditions need to be considered (Nunami Jacques Whitford Limited 2007) in developing, operating and abandoning uranium mines.

Potential Cumulative Effects on Caribou from Uranium Exploration and Development:
The Thelon watershed is valuable to the Beverley and Qaminirjuaq caribou herds in providing key habitats, which include habitats that relate to the aquatic environment. The list of key caribou habitats provided includes: spring migration route between winter range and calving areas; traditional calving area; post-calving area; and undisturbed water crossings (BQCMB 2001 - Cited in: Aarluk and ESSA 2012).

It is clear that people are concerned about the stressors associated with mining on the Thelon River (Nunami Jacques Whitford Limited 2007). In responding to a survey in the community of Baker Lake, people indicated that there are more environmental concerns associated with uranium than there were with gold. Many people are afraid that radiation from a uranium mine will damage the land and water, affecting the caribou, fish and people living near Baker Lake. The Kiggavik site is located much closer to the Thelon River, which runs directly into Baker Lake, causing more concern for drinking water contamination (Peterson 2012).

2. Hamlet of Baker Lake

Baker Lake (Qamani'tuaq) is the only major permanent community within the Baker Lake watershed. The community is located on the shores of Baker Lake and is the only non-coastal Inuit settlement in Nunavut. It is located near the geographical centre of Canada at latitude 64'18'41" North and longitude 96'04'08" West.

The population of Baker Lake is 1,800 and is comprised of 91% Inuit and 9 % non-Inuit residents (Community of Baker Lake website www.bakerlake.ca – accessed November 21, 2012). Stressors on the aquatic environment arise from activities conducted by people living within the community (e.g., water use, waste water disposal, solid waste disposal, fuel storage, handling and use, etc.) as well as from activities of residents outside the community including fish harvesting and fishing and hunting related travel using boats, motors, ATVs, snowmobiles, etc.

The lakefront is lined with small sheds, used primarily by Inuit hunters and fishermen to store fishing gear, or winter equipment. There is a Northern Store and to the east of this is a landing area for floatplanes that transport mineral exploration teams, sport fisherman, or other visitors interested in the wildlife and culture of the barrenlands. The Akumalik Visitor Centre occupies the old Hudson Bay Trading Post. There is an arena, community centre, swimming pool, RCMP facility and a Health Centre, and also some of the first privately-owned homes in Baker Lake. To the east is the power plant, which uses fuel oil (delivered by barge in the summer) to generate electricity. To the north, beyond the community, on the hills above the houses, is a large snow fence, installed to control drifting in the community itself. Even with the fence, snow drifts often exceed 3 meters in some areas. The community cemetery is located beyond the snow fence, with graves constructed using mounds of rock above the permafrost. A new road extends north from the community (Community of Baker Lake website www.bakerlake.ca – accessed November 21, 2012).

The community is served by an all-weather 1,279 gravel runway (http://www.statcan.gc.ca/pub/51-210-x/ 2011001/t001-eng.htm - accessed November 21, 2012), which from 2007 through 2010 had a range of 5,582 to 7,840 local and itinerant aircraft movements (http://www.statcan.gc.ca/pub/51-210-x/2011001/t001-eng.htm – accessed November 21, 2012).

Baker Lake has a sewage lagoon which decants through two small lakes to Airplane Lake and subsequently via a small watercourse to Baker Lake (derived from Google Earth photos). People have been calling for improvements to the sewage system: in a report dated August 31, 2010, an INAC Inspector had recommended legal action against both the Government of Nunavut and the Hamlet of Baker Lake. The two small lakes reportedly had a sheen that was considered to be consistent with hydrocarbon pollution, and leaks and spills of waste oil were noted from hazardous materials and waste oils adjacent to the lagoon (Nunatsiaq News, February 25, 2012). In the past, people had complained of sickness from drinking Baker Lake water in the Hamlet, suspected to have been affected by overflow from the dump and sewage lagoon during spring runoff (June 13, 2008).

Agnico-Eagle stores large quantities of fuel at Baker Lake for shipment to and use at the Meadowbank Gold Project. In 2009, the company indicated that it required 65 million litres of diesel fuel per year and had a combined storage capacity of 45.6 million litres. Agnico-Eagle therefore proposed to expand its fuel tank farm at its Baker Lake marshalling facility from 40 million to 60 million litres (ML) of diesel fuel by the addition of two more tanks (each of 10 ML capacity) plus one 2 ML tank for bulk storage of Jet A fuel. A barge landing area, dry storage, fuel handling facilities and fuel storage tanks are located along the shore and adjacent upland east of the Hamlet of Baker Lake and between Airplane Lake and Baker Lake (Agnico-Eagle 2009).

Key aquatic environment vulnerabilities include ambient and drinking water quality, and fish species and population levels.

3. Hydroelectric Assessment and Future Potential for Development

While there is no hydroelectric development currently within the Baker Lake watershed, Qulliq Energy Corporation has been investigating the potential for hydro development throughout the Kivalliq Region of Nunavut. The hydro potential of the Central Interior and along the Kivalliq Coast has been considered to be enormous. Eight major rivers drain the Central Interior into the Arctic Ocean and Hudson's Bay. There is capacity for more than 3,600 megawatts (MW) in some 56 large sites. Potential sites within the Baker Lake watershed are listed in Table 2 below. (Qulliq Energy Corporation ttp://www.nunavutpower.com/home/index.php?option=com_docman&task= doc_view&gid=38 - accessed November 21, 2012).

Table 2. Large Hydro Sites with Potential for Development in Baker Lake Watershed

River	Number of Potential Sites	Potential Capacity
Thelon River	4 sites	200 MW
Dubawnt River	5 sites	500 MW
Hanbury River	2 sites	300 MW
Kazan River	3 sites	150 MW

Source: Qulliq Energy Corporation

In addition to large hydro potential, there are numerous small hydro opportunities. Qulliq Energy Corporation has indicated that modern mini-hydro technology has developed to the point where virtually any river potential can be developed. In particular, there are some mini-hydro sites that have been identified and studied, including a site that could serve Baker Lake. This site could produce a potential capacity of 10.0 MW, at a construction cost of $70 million. While these sites are available for further review, the main obstacle to their development is the lack of load (Qulliq Energy Corporation http://www.nunavutpower.com/home/ index.php?option=com_docman &task=doc_view&gid=38 - accessed November 21, 2012).

If developed, hydroelectric projects have the potential to become stressors on the aquatic environment in ways that include the following:

- Alteration of the hydrologic regime:
  - Changes to caribou crossing timing and safety;
  - Changes to spring peak flow regimes and flooding potential;
- Interruption of fish passage with the potential to affect spawning migration and success, and resultant potential for effects on fish population numbers and distribution; and
- Changes in water quality due to interference with downstream sediment transport, erosion downstream from the tailrace, oxygen supersaturation downstream from the tailrace.

Vulnerabilities related to hydroelectric development include fish of all species, and potentially caribou populations that might be affected by flow alterations at caribou crossing locations.

While these effects would be assessed and mitigation measures applied through the environmental assessment and regulatory review processes, the potential for cumulative residual effects could exist. Since there are no existing or currently proposed projects, hydroelectric development does not currently constitute a stressor, but has the potential to become a stressor in the future.

4. Government Activities

Government activities within the Baker Lake watershed can to some degree create stressors on the aquatic environment.

The Department of Defence established an RC Signals station at Ennadai Lake in 1949 in an area that had been previously used seasonally by Inuit. The installation was comprised of radio transmitters and receivers, diesel power plants, two 150 foot transmission towers and three 48 foot receiving towers. RC Signals personnel manned the Ennadai Lake Radio Station for 5 years from 1949 through 1954. During this time, a the Kazan River Group of Inuit, numbering about 45 people, was present over a wide area within a radius of approximately 60 miles from the Ennadai Lake Radio Station, depending upon caribou. Much of the heavy construction material and other supplies were transported into Ennadai from Churchill by cat train over the frozen lakes and muskeg. One D-6 Caterpillar tractor was abandoned at Ennadai when the cat train returned to Churchill. The tractor was repaired and became an important asset for the station, used to maintain the ice runway by dragging rollers behind it, to haul supplies to the station from the runway and the dock in summer, and for various other tasks. Following this, Transport

Canada assumed ownership of the Ennadai Lake site, and constructed and operated a manned weather station there until 1979. It was subsequently transferred to Environment Canada (EC), which now operates an unmanned Weather Station to the east of the original station.

As of 2008, abandoned buildings, fuel tanks, fuel pipelines, oil drums, knocked down radio towers with cables, etc. remained on the weather station site (http://www.nwtandy.rcsigs.ca/stations/ennadai.htm - accessed November 27, 2012). The AANDC Contaminated Sites Program conducted Phase 1 and Phase 2 Environmental Site Assessments of the Ennadai Lake Weather Station in July 2009. AANDC planned to conduct a detailed Environmental Site Assessment of the site and, based on the detailed assessment work, intended to develop a strategy to remediate the site (AANDC 2012).

Other weather stations operated by government in the Baker Lake watershed include one at the Baker Lake Airport (http://www.weatheroffice.gc.ca/forecast/canada/index_e.html?id=NU - accessed November 27, 2012).

Environment Canada operates hydrometric stations within the Baker Lake watershed, and has operated other stations in the past. Table 3 below lists the past and current hydrometric stations within the watershed (Water Survey of Canada Website, http://www.wsc.ec.gc.ca/applications/H2O/HydromatD-eng.cfm - accessed October 9, 2012).

Table 3: Past and Current Hydrometric Stations Within the Baker Lake Watershed (http://www.wsc.ec.gc.ca/applications/H2O/HydromatD-eng.cfm)

Thelon River

Data Years Data Type	Status / Record Length	Station ID	Station Name				
			Prov. Code	Latitude	Longitude	Gross Drainage Area (km^2)	Sediment Collected?
1970 – 2011 Flow and Level	Active / 42 years	06JC002	NU	Thelon River above Beverly Lake		65,600	Yes
				64°31'49" N	101°21'44" W		
1973 – 1982 Flow	Discontinued / 10 years	06MA 003	NU	Thelon River above Baker Lake		154,000	No
				64°24'25" N	96°24'37" W		
1983 - 2011	Active / 28 years	06MA006	NU	Thelon River below outlet of Shultz Lake		152,000	No
				64°46'41" N	97°3'13" W		

Hanbury River

Data Years Data Type	Status / Record Length	Station ID	Station Name				
			Prov. Code	Latitude	Longitude	Gross Drainage Area (km^2)	Sediment Collected?
1971–2002 Flow & Level		06JB001	NT	Hanbury River above Hoare Lake		5,770	No
				63°35'28" N	105°9'16" W		

Kazan River

Data Years Data Type	Status / Record Length	Station ID	Station Name				
			Prov. Code	Latitude	Longitude	Gross Drainage Area (km^2)	Sediment Collected?
1962 – 2011 Flow and Level	Active / 50 years	06LA001	NU	Kazan River at outlet of Ennadai Lake		214,000	
				61°15'13" N	100°58'26" W		
1962-1995 Level	Discontinued 33 years	06LA002	NU	Ennadai Lake at Ennadai		N/A	No
				61°10'13"N	100°57'30" W		
1996-2011 Level	Active 16 years	06LA003	NU	Ennadai Lake near Ennadai		N/A	No
				61°6'50" N	101°1'44" W		
1965 – 2011 Flow and Level	Active / 46 years	06LC001	NU	Kazan River above Kazan Falls		70,000	Yes
				63°39'9" N	95°51'7" W		
1979 – 1990 Flow	Discontinued / 12 years	06LC003	NU	Siuraq Creek near outlet to Kazan River		1,480	No
				62°38'8" N	98°31'22" W		
1979 – 1996 Level	Discontinued / 18 years	06LC004	NU	Yathkyed Lake near Kazan River inlet		N/A	No
				62°41'50" N	98°18'20" W		

Dubawnt River

Data Years Data Type	Status / Record Length	Station ID	Station Name				
			Prov. Code	Latitude	Longitude	Gross Drainage Area (km^2)	Sediment Collected?
1960 – 1967 Flow	Discontinued / 8 years	06KC001	NU	Dubawnt River below Marjorie Lake		67,900	No
				64°20'40" N	99°47'22" W		
1966 – 1990 Level	Discontinued / 24 years	06KC002	NU	Marjorie Lake at outlet		N/A	No
				64°13'52" N	99°28'37" W		
1968 – 2001 Flow	Active / 43 years	06KC003	NU	Dubawnt River at outlet of Marjorie Lake		67,300	Yes
2002-2012 Flow and Level				64°13'56" N	99°28'33" W		
1969 – 1995 Level	Discontinued/ 26 years	06KC004	NU	Dubawnt Lake near Snow Island		N/A	No
				63°13'41" N	101°45'51" W		

Kamilukuak Lake

Data Years Data Type	Status / Record Length	Station ID	Station Name				
			Prov. Code	Latitude	Longitude	Gross Drainage Area (km^2)	Sediment Collected?
1978 – 1978 Level	Discontinued/ 1 season	06KB002	NU	Kamilukuak Lake at outlet		N/A	No
				62°29'40" N	101°51'10" W		

Baker Lake

Data Years Data Type	Status / Record Length	Station ID	Station Name				
			Prov. Code	Latitude	Longitude	Gross Drainage Area (km^2)	Sediment Collected?
1965-1994 Level	Discontinued / 30 years	06MA001	NU	Baker Lake at Baker Lake		N/A	No
				64°19'10" N	96°1'50" W		
1969-1994 Flow	Discontinued / 24 years	06MA002	NU	Qinguq Creek near Baker Lake		432.00	Yes
				64°15'42" N	96°18'53" W		
1978-1990 Flow	Discontinued / 12 years	06MA004	NU	Akkutuak Creek near Baker Lake		15	No
				64°18'57" N	95°58'23" W		
1979-1990 Flow	12 years	06MA005	NU	Prince River near Baker Lake		2,100	No
				64°18'8" N	95°45'31" W		

Anigaq River

Data Years Data Type	Status / Record Length	Station ID	Station Name				
			Prov. Code	Latitude	Longitude	Gross Drainage Area (km^2)	Sediment Collected?
1984-1994 Flow	Discontinued / 11 years	06MA007	NU	Anigaq River below Audra Lake		2,740	No
				64°12'48" N	96°35'14" W		

Quoich River

Data Years Data Type	Status / Record Length	Station ID	Station Name				
			Prov. Code	Latitude	Longitude	Gross Drainage Area (km^2)	Sediment Collected?
1972-1994 Flow	Discontinued / 23 years	06MB001	NU	Quoich River above St. Clair Falls		30,100	Yes
				64°18'51" N	93°54'35" W		

A government-owned lodge was built on Ennadai Lake in 2002; however this facility closed in 2005. (http://arcticwatch.ca/blog/exploring-the-ennadai-lake - accessed November 27, 2012).

Federal and territorial government departments undertake programs from time to time within the Baker Lake watershed, such as monitoring wildlife populations, or geological survey and research programs. Such programs may involve the establishment of temporary field camps with supporting infrastructure, water withdrawals/discharges, supplies and logistics, aircraft flights, fuel caches and handling, and other types of activities. Such programs are normally of short duration and leave little footprint on the local environment. The possible exception might be very localized fuel contamination in the event of a fuel spill from a drum or during fuel handling/transfer.

5. Fish and Wildlife Harvesting and Recreational Activities

Fish and wildlife harvesting is undertaken by Inuit throughout the Baker Lake watershed. In addition, other Nunavummiut and people from beyond Nunavut may hunt and fish as a recreational activity, frequently in association with Inuit guides and lodge facilities. Fish and wildlife harvesting activities and the operation of lodges can constitute stressors on fish and wildlife populations, and the activities of fisherman, hunters and lodge operators can be stressors on the aquatic environment via fuel spills, water withdrawal and solid waste disposal.

Hunting and fishing activities constitute a pressure on fish and wildlife populations. With respect to fishing pressure, a Sport Fishing Licence is required by anyone intending to sport fish in Nunavut other than a beneficiary of the NLCA. Licences are available from the GN Department of Environment or DFO, most sport fishing lodges, retail stores, and certain RCMP offices (Nunavut Sport Fishing Guide 2010-2011).

Hunting and fishing activities have the potential to result in fuel spills associated with boats and motors, snowmobiles and possibly associated with aircraft. Lodges also have the potential for fuel spills associated with fuel storage for generators, heating oil, outboard motors, and snowmobiles. Spills can also occur in association with fuel handling, including shipping fuel by winter road, or aircraft landing on an ice landing or on open water. In such cases, the volumes of fuel at risk of spilling are small and effects from a spill on the aquatic environment would be highly localized. Lodges also engage in water withdrawal/disposal and have requirements for solid waste incineration and disposal.

The potential also exists for small scale winter road construction and use for the re-supply of lodges. Stresses on the aquatic environment are similar to other winter road stresses; however, to a lesser degree, particularly in cases where a small scale winter road development is specific to a lodge only.

People engage in canoe trips and wildlife observation within the watershed. These are small scale activities which generally leave little or no footprint. Participants may catch fish on a small scale for consumption en route; these activities tend to result in little or no stress on the aquatic environment.

6. Linear Developments: Winter and All-Weather Roads

Linear developments have the potential to create stressors on the aquatic environment within the Baker Lake watershed. Linear developments of significance within the watershed include primarily winter ice roads to mining exploration camps and the occasional lodge, along with one private all-weather road to the Meadowbank Gold Project. Roads for local use also exist within and in the immediate vicinity of the Hamlet of Baker Lake.

Since these linear developments relate primarily to mining activities, their role as stressors are discussed in those sections above. Any winter roads dedicated exclusively to lodges would create similar stresses but to a much lesser degree. Stresses on the aquatic environment associated with a winter road relate primarily to spills of hydrocarbons, and possibly spills of other project specific materials that might be associated with a specific type of mining exploration.

In the case of the Meadowbank Gold Project all-weather road, stresses on the aquatic environment include the deposit of suspended solids from erosion or dust, the deposit of deleterious substances, primarily hydrocarbons, from vehicular accidents, and interference with fish migration created by improperly installed/maintained culverts.

Roads have the potential to increase fishing pressure on fish populations, as a result of facilitated access for harvesting of fish for subsistence of recreational purposes. Such pressure may be modulated to a degree by the ready access to fishing opportunities afforded by the proximity to Baker Lake itself.

Vulnerabilities related to winter roads include fish populations and water quality.

7. Transboundary Aquatic Stressors

While the potential for transboundary stressors needs to be taken into account in developing a cumulative effects monitoring initiative for the Baker Lake watershed, the actual existence of transboundary stressors in the case of the Baker Lake watershed is limited. For example, the diamond mines that occur in the Northwest Territories (Ekati, Diavik, Snap Lake, Gacho Kué), are not located within the Baker Lake watershed and consequently do not constitute a transboundary stressor.

With respect to uranium mines in northern Saskatchewan, these are also not located within the Baker Lake watershed and consequently do not constitute a transboundary stressor.

There is a need to monitor on an ongoing basis the potential for transboundary stressors that occur within the watershed and a affect the aquatic environment.

8. Long Range Transport of Air Pollutants and Persistent Organic Pollutants

Long Range Transport of Air Pollutants (LRTAP) and Persistent Organic Pollutants (POPs) have the potential to be aquatic environment stressors within the Baker Lake watershed. However, the extent to which these pollutants actually are stressors does not appear to have been extensively studied to date. Vulnerabilities of concern could include harvested fish species, particularly the longer lived species such as Arctic char, lake trout, burbot and northern pike that have a greater potential to concentrate contaminants.

AANDC (2011b) has provided evidence that the transport of pollutants into the Canadian Arctic in general is a cause for concern, as reported through the research activities of the AANDC Northern Contaminants Program. While much of the concern and consequent program activity is focussed on pollutant concentrations in top predators in the marine environment that are harvested and consumed by northerners as country food, the potential presumably exists for pollutants to affect the general aquatic environment in the Baker Lake watershed.

INAC (2003b) indicates that new insights had emerged into atmospheric pathways, processes and environmental behaviour of mercury, suggesting its potential as a stressor. Canadian scientists discovered a phenomenon known as mercury depletion events (MDE) wherein atmospheric mercury is converted from the gaseous elemental state to the particulate phase and is rapidly deposited on Arctic surfaces during springtime polar sunrise. Enhanced mercury deposition through MDEs could be significantly contributing to the high levels of mercury observed in Arctic biota.

INAC (2003b) indicated decreasing atmospheric trends in most “legacy” persistent organic pollutants (POPs) over the previous 5–10 years, which suggest a decreasing role as stressors. However, “new chemicals” were reportedly observed in the Arctic abiotic environment, which potentially constitute new stressors. A new generation of POPs had been measured in Arctic air, seawater, and freshwater sediments that includes brominated flame retardants (in particular polybrominated diphenyl ethers, PBDEs), perfluorinated alkane compounds (PFA), short chain chlorinated paraffins (SCCPs) and polychlorinated naphthalenes (PCNs). Some pesticides currently used in the circumpolar countries were also identified: endosulfan, trifluralin and methoxychlor. PBDEs have concentrations that are rising. Unlike most other organochlorine pesticides, concentrations of endosulfan in Arctic air had not declined over the previous 7 years. These constitute potential stressors on the aquatic environment of the Baker Lake watershed that may warrant attention.

In Kivalliq, most of the mercury consumed by people comes from consuming caribou meat, beluga muktuk and lake trout muscle (INAC 2003a). Mercury in lake trout muscle would be the stressor of concern in the case of the Baker Lake watershed aquatic environment.

9. Climate Change

Climate change is a major stressor on the water resources and aquatic environment of the Baker Lake watershed. It has the potential to create an overriding cumulative stress within the watershed that could synergistically augment the impacts of other stressors. Climate and permafrost play important roles in the hydrological regime that drives most of the environmental responses within the Baker Lake watershed.

Components of the environment that have the potential to be vulnerable to climate change as a stressor are discussed below. As a precursor to this discussion, it is relevant to note key components of the hydrological cycle within the Baker Lake watershed.

Peak stream discharges occur during the spring melt (late May - early June) and account for the majority of the total annual runoff (Cumberland Resources Ltd., 2005a-2). During the summer and fall, warm temperatures increase the active layer of permafrost, thereby increasing the amount of groundwater storage. Secondary peaks are common in the late summer or early fall periods, due to precipitation later in the season (AREVA, 2011). Primary streams may start to freeze in late September; medium channels start to freeze by November; and all channel bottoms are frozen over the winter. These begin to flow again overtop of the anchor ice as a result of spring melt (AREVA, 2011, Cumberland Resources, 2005a-2). Lake ice thickens over winter, reaching a depth of approximately 2 m. Within the Baker Lake watershed, many shallow lakes freeze completely and larger lakes are frozen over by late winter (AREVA, 2011, Cumberland Resources Ltd, 2005a-2).

9.1 Climate Change Effects on Permafrost as a Stressor

Permafrost is an important component of the Arctic environment of Nunavut and climate induced changes in the permafrost regime have the potential to create an important stressor on the Baker Lake watershed. Permafrost is very sensitive to climate change, and is dependent upon ambient temperatures for its existence and distinctive properties. Only the thin active (seasonally thawed) layer of permafrost responds immediately to temperature changes, making it both an indicator and a product of climate change, as its depth is dependent on temperature (McBean et al. 2007). Permafrost also has important implications for landscape processes (terrain, slope and coastal stability), hydrology (surface and ground water regimes), surface characteristics (vegetation, albedo), greenhouse gas sources and sinks (peatlands, soils, gas hydrates), as well as for ecosystems, engineering and infrastructure (CCIN No Date).

Permafrost slopes, along with organic horizons, are the principal controls on streamflow generation in subarctic catchments (McBean et al. 2007). Climate induced changes to the permafrost regime have the potential to alter such streamflows.

The permafrost regime affects Arctic groundwater supply, and permafrost is also essential to the existence and functioning of arctic wetlands. The effects of increased permafrost temperatures on groundwater could possibly include the development of large, unfrozen near-surface aquifers with groundwater flow throughout the year. More active recharge and discharge of aquifers and increased groundwater flow would affect the base flow volumes and chemistry of many rivers (McBean et al. 2007).

Global warming is expected to be greatest over high latitudes and permafrost areas will be among the regions most heavily affected. Predicted increases in mean annual air temperature of several degrees in northern latitudes will lead to thawing and destabilization of perennially frozen ground. This permafrost degradation has important implications for landscape processes (terrain, slope and coastal stability), hydrology (surface and ground water regimes), surface characteristics (vegetation, albedo), greenhouse gas sources and sinks (peatlands, soils, gas hydrates), as well as for ecosystems, engineering and infrastructure (http://www.socc.ca/cms/en/socc/lakeIce/socc/permafrost/currentPermafrost.aspx – Accessed January 17, 2012).

Climate change has been shown to be a stressor on the permafrost regime within the Baker Lake watershed. In the central southern portion of the Arctic Ecozone, permafrost temperatures to 3 m depth have been collected since 1997 at Baker Lake, Nunavut. Between 1997 and 2007, a general increase in thaw depth was observed although there is some inter-annual variability within the short record (Aarluk and ESSA 2012). The largest increase in thaw depth occurred between 1997 and 1998 and this was related to the longer thaw season in 1998 (Smith et al., 2001 Cited in: Smith 2011).

Studies indicate that the boundaries of discontinuous and continuous permafrost are expected to move northward due to global warming based on predictions of warming of 4°C to 5°C over the next 50 years. Based on these predictions, it was concluded that the Meadowbank property would remain within the zone of continuous permafrost, but the active layer thickness would increase and the total thickness of permafrost may slowly reduce in time. It was concluded that these changes would not compromise permafrost encapsulation strategies for the rock storage and tailings facilities (Cumberland Resources 2005a-3).

Permafrost encapsulation of the tailings is needed to avoid longterm effects on the aquatic environment. Thermal modelling predicts that permafrost will penetrate the Meadowbank tailings facility and underlying talik and will eventually encapsulate the facility. This will reduce the potential for the generation of acid rock drainage (ARD), and for pore water contaminants to migrate outside of the tailings disposal facility. Thermal modelling that incorporates climate change predictions indicates that the length of time required for the tailings to freeze will increase under climate warming trends, but the tailings will still tend to the frozen condition. The development of permafrost in the tailings dike core and tailings side of the tailings dike is a key aspect of the design concept. Both steady-state and transient thermal modelling for the post-closure indicate that the dike will become frozen during operation and remain frozen after closure under current climate conditions, and under climate warming trends. At waste rock disposal facilities, waste rock will be placed on thaw-sensitive ground during winter months to minimize ground disturbance and permafrost degradation. Potential permafrost degradation associated with the tailings discharge pipeline was to be avoided by using an insulated pipe with heat tracing, and by elevating the pipeline across thaw-sensitive terrain (Cumberland Resources 2005a-3).

9.2 Climate Change Effects on Precipitation as a Stressor

Snow is a defining component of the Arctic environment in Nunavut. Changes in the snow regime as a result of climate change represent another important stress on the aquatic environment. Snow affects transportation in that it both facilitates overland transportation by Nunavummiut utilizing snowmobiles or sled dogs and hampers transportation via all weather roads (Aarluk and ESSA 2012).

Snow melt contributes water to the hydrologic regime. Snow exerts a significant influence on climate and hydrology through modification of energy and moisture transfers and the storage of water. Snow cover is considered to be an effective climate integrator and a useful component to monitor since it responds to both temperature and precipitation (Brown et al. 2000).

Hanesiak and Wang (2005) provide an assessment of changes in the occurrence frequency of four types of adverse weather (freezing precipitation, blowing snow, fog, and low ceilings) and no-weather (i.e. no precipitation or visibility obscuration) events as observed at 15 Canadian Arctic stations of good hourly weather observations for 1953–2004. The results show that the frequency of freezing precipitation has increased almost everywhere across the Canadian Arctic since 1953. Rising air temperature in the region has probably resulted in more times that the temperature is suitable for freezing precipitation. The frequency of blowing snow occurrence has decreased significantly in the Canadian Arctic, most significantly in spring. Changes in fog and low ceiling (LC) occurrences have similar patterns and are most significant in summer and least significant in autumn. Decreases were identified for both types of events in the eastern region in all seasons. In the southwest, however, the fog frequency has increased significantly in all seasons, while the LC frequency has decreased significantly in spring and summer. The regional mean rate of change in the frequency of the four types of adverse weather was estimated to be 7%–13% per decade (Hanesiak and Wang 2005).

The frequency of no-weather events has also decreased significantly at most of the 15 sites. The decrease is most significant and extensive in autumn. Comparison with the adverse-weather trends above indicates that the decline in no-weather occurrence (i.e., increase in weather occurrence) is not the result of an increase in blowing snow or fog occurrence; it is largely the result of the increasing frequency of freezing precipitation and, most likely, other types of precipitation as well. This is consistent with the reported increases in precipitation amount and more frequent cyclone activity in the lower Canadian Arctic (Hanesiak and Wang 2005).

9.3 Climate Change Effects on Lake Ice as a Stressor

Climate change could affect the lake ice regime in the Baker Lake watershed, through delayed freeze-up and earlier breakup. This has the potential to be an important stressor to the aquatic environment of the Baker Lake watershed.

Ice on lakes is integral to the ecosystem of Nunavut. Freshwater ice plays an important role in physical, geochemical and biological processes in cold region lakes, and changes in the lake ice regime as a result of climate change represent an additional critical stress on the aquatic environment. Lake ice is important to the limnological processes of a lake during the winter (Mueller et al. 2009). It is generally present from October through late spring and is therefore a key driver in the limnological regime. Runoff peaks during the spring snowmelt, except where glacier melt water contributes significantly to the discharge. Permafrost prevents infiltration of water into the ground and this contributes to rapid runoff (Aarluk and ESSA 2012).

The formation and breakup of ice are important seasonal events in mid- to high-latitude cold regions. There is increasing concern regarding how climate change and variability will affect lake-water thermal structure and lake-ice characteristics, particularly ice formation, duration, breakup, thickness and composition (Dibike et al. 2010). Lake ice is an important indicator of climate change (Mueller et al. 2009, Dibike et al. 2010). Mueller et al. (2009) provide evidence of cascading regime shifts in climate, ice cover and mixing. Brown and Duguay (2010) demonstrate linkages between ice cover and climate change.

Ice on lakes is important to Nunavummiut and wildlife, since is facilitates mobility and transportation in the winter (Aarluk and ESSA 2012). Inuit in Nunavut depend on lake ice for travel, fishing and hunting and have consequently monitored ice conditions on an ongoing basis in the areas they frequent. GN DOE (2005) reports on a program to gather *Inuit Qaujimajatuqangit* concerning historical lake ice conditions in the areas surrounding Baker Lake and Arviat. The Beverly and Qamanirjuaq Caribou Management Board indicates that caribou hunters monitor and report on ice conditions (BQCMB 2001). Inuit have reported observing various changes in ice cover (GN DOE 2005). The slow rate of thickening in autumn and the overall reduction in ice thickness have produced more dangerous ice conditions early in the season resulting in a delay of some land-use activities (e.g., Inuit travel and caribou hunting) (GN DOE 2005).

Winter roads are developed for access to mine development projects, including the Kiggavik minesite near Baker Lake (AREVA 2011a). Winter roads depend on the presence of ice, of a suitable thickness/strength for transportation, and lake ice is monitored to ensure safety on winter roads. Mining interests also use lake ice for landing strips (Aarluk and ESSA 2012). Ice road and airstrip flooding may be employed to thicken ice if required (JVTC 2012).

Analysis of modelling results indicates that future warming associated with climate change will result in an overall increase in lake-water temperature, with summer stratification starting earlier and extending later into the year. The timing of freeze-up is projected to be delayed by 5 to 20 days and break-up advanced by approximately 10 to 30 days, thereby resulting in an overall decrease of lake-ice duration by about 15 to 50 days. Maximum lake-ice thickness will also be reduced by 10 to 50 cm. The change in maximum snow depth on the lake-ice ranges between -20 to +10 cm, while the change in white-ice thickness ranges between -20 to +5 cm depending on the geographic location and other climate parameters (Dibike et al. 2010).

9.4 Climate Change Effects on Hydrology as a Stressor

Climate change has the potential to significantly alter the hydrologic regime within the Baker Lake watershed, which would constitute one of the most significant stresses on the aquatic environment within the watershed. Some changes in hydrologic and water quantity variables have been observed throughout Nunavut. However, at this point in time the data records are for the most part rather short; and it has therefore often been difficult to distinguish statistically sound trends in the time series (Woo et al. 2008).

Spence (2002) analyzed the stream flow variability of selected rivers in Canada’s Northern region, including the Back and Kazan rivers of Nunavut. This study looked at hydrometric data for the period between 1965 and 1998 and concluded that warmer temperatures are causing earlier spring freshets in mainland Nunavut.

It has also been observed in the ten-year review reports of the Canadian Heritage Rivers System (CHRS) for the Kazan and Thelon Rivers (Nunavut Parks 2000a and 2000b) that water flows for these two main rivers within the Baker Lake watershed have shown a marked change during the preceding decade, with declining water levels reported by local data and the change in vegetation along the river banks. Whether or not this represents a cyclical change that will not be significant over the long term, or the effects of climate change, is presently not known.

As noted above, decreasing water levels were reported at a wildlife workshop in the West Kitikmeot (Dumond, 2007); participants referred to unusually low water levels (in some places 2 or 3 feet lower) due to permafrost melting, and to the drying up of some lakes from where they used to we used to get water. These observations support the findings by Whitfield and Cannon (2000), which looked at recent variations in climate and hydrology in Canada and determined that, for Northern Canada (boreal shield and plains), a hydrological shift towards year-round reductions in streamflows had taken place for the studied period (1976-1995).

The effects of climate change on Nunavut's water resources are also likely to add to the pressure of increased demand and regulation of rivers. In terms of water quantity, the main effect is the reduction in water flows predicted for Arctic Rivers (Whitfield and Cannon, 2000), which will inevitably add pressure on these resources.

Changes in the hydrologic regime as a result of climate change have the potential to affect all components of the aquatic environment of the Baker Lake watershed, which are therefore all vulnerable to such an overriding stressor.

10. Natural Cycles and Events

Natural cycles can constitute important stressors on the aquatic environment within the Baker Lake watershed. Such cycles can include cycles in precipitation and resulting hydrologic regime; ambient air temperature; etc. Natural occurrences such as seismic events; isostatic re-bound; floods; ice jams; etc. can also constitute stressors on the aquatic environment. Cycles may also occur within the biological system, such as population cycles in caribou and other game animals, as well as in fish. At this time, there is insufficient knowledge to reliably quantify and predict such natural cycles and events within the Baker Lake watershed. However, they can be important stressors to track in a cumulative effects monitoring initiative, since, if they do occur, they can become an overriding driver for changes that may be observed in the system.

11. *Inuit Qaujimajatuqangit* Information Relevant to Vulnerabilities

Inuit Qaujimajatuqangit (IQ) "means the traditional, current and evolving body of Inuit values, beliefs, experience, perceptions and knowledge regarding the environment, including land, water, wildlife and people, to the extent that people are part of the environment." (as defined by Qikiqtani Inuit Association). This definition of IQ is widely accepted by the Government of Nunavut and also used by the Nunavut Impact Review Board in its dealings with companies that are proposing resource development projects in the Nunavut Settlement Area.

There are a growing number of organizations and researchers encouraging government, regulatory agencies, and the private sector to integrate *Inuit Qaujimajatuqangit*, or Traditional Knowledge (TK), with "scientific" knowledge (Davis and Wagner 2003). Traditional Knowledge is a broad term that is meant to encompass both local and community-based knowledge, traditional ecological knowledge, and IQ. It has been gathered over many generations through personal observation, experience and transferred mainly through oral transmission. In the Baker Lake watershed numerous consultations and interviews have taken place to collect IQ, however, most of the information collected has focused on wildlife.

As described in the historical monitoring report, very little IQ information has been collected that is directly related to water quality parameters in the Baker Lake watershed. Traditional knowledge studies to date done for the Baker Lake watershed area have revolved around wildlife and climate change, while most of the information has been gathered by companies preparing Environmental Impact Statements. Most of IQ knowledge collected from residents of the Baker Lake area is from AREVA (Kiggavik Project) and Cumberland Resources (Meadowbank Project), which is now owned by Agnico-Eagle. These traditional knowledge studies were sound in methodology, but the questions asked of the people interviewed were more geared towards wildlife as opposed to specifics regarding the watershed area. There are indirect references to water and even though wildlife and water are directly related, people from the community will always speak of the wildlife because it has been sustenance and survival for them for generations. Local people do have IQ information on water as well, but they would need to be asked specific questions regarding water in order to share that knowledge.

Except for very general information provided in Nunavut Planning Commission Map data there are no specific data available on vulnerabilities of specific aquatic VECs. IQ information could be used as a proxy for vulnerability information as it identified local features (such as caribou crossing, fishing or waterfowl hunting areas) that local people use and care about. The features and locations identified by local residents – for hunting, fishing or travelling – are generally close to the Baker Lake community or camps used by local people. Although the current IQ information is not adequate for identifying vulnerable aquatic areas, relevant information could be obtained if IQ informants were asked more specific questions related to water parameters and to associated vulnerabilities in the Baker Lake watershed.

Summary

The Baker Lake watershed constitutes a very large area with extremely sparse population beyond the vicinity of the Hamlet of Baker Lake. The most apparent stressors on the aquatic environment within the watershed include those related to mining exploration and development, as well as the Hamlet of Baker Lake itself. For the most part the effects of these stresses are relatively localized.

Stresses related to mining are currently related to the operating Meadowbank Gold Project, with potential stresses associated with the proposed Kiggavik Uranium Mine and with a proposed Aberdeen-Turqavik Uranium Project. These stresses are situated in the lower reaches of the Baker Lake watershed, relatively close to Baker Lake itself. Mining exploration is, however, more widely distributed within the watershed. Stresses related to mining tend to be relatively localized, although there are concerns about more widespread stresses associated with radionuclides from mining and potentially cumulative effects across multiple uranium related projects and activities.

Stresses associated with the Hamlet of Baker Lake relate to potential hydrocarbon spills, sewage treatment and disposal and solid waste disposal. In addition, fish and wildlife harvesting by residents and people operating out of Baker Lake constitute the most meaningful stress on fish as well as wildlife populations that relate to the aquatic environment. Lodges also contribute to these stresses.

As an overriding stressor, climate change has the potential to induce important cumulative changes in the aquatic environment within the Baker Lake watershed. These potential changes that can have important implications for the hydrological regime in the watershed, include changes in precipitation; the permafrost regime with resultant changes in soil porosity, ice regime, water flows, and timing within the hydrologic cycle. These stresses can also affect the biological environment and can act cumulatively with stresses from development. These broader climate change stresses are not specifically project-related, but will need to be monitored and understood through broader climate change research initiatives in order to place cumulative effects from development in a proper context.

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