A STUDY OF WATER AND SEDIMENT QUALITY AS RELATED TO PUBLIC HEALTH ISSUES, FORT CHIPEWYAN, ALBERTA

on behalf of the

Nunee Health Board Society
Fort Chipewyan, Alberta

by

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DEDICATION

This study is dedicated to:

the people of Fort Chipewyan, who have a right to a healthy future;

and to my mom, Doris, who gave me a shovel on my fifth birthday and taught me to dig until I reached the bottom.

Author's Note

Readers are invited to send relevant observations and to comment on points of fact or interpretation. I can be reached at *ktimoney@interbaun.com*.

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SUMMARY

This study examined water and sediment quality indicators in the area of Fort Chipewyan, Alberta. Data were analyzed and discussed in the contexts of water and sediment quality guidelines, wildlife contaminants, and ecosystem and public health.

Some of the findings of this study are:

(1) The people and biota of the Athabasca River Delta and western Lake Athabasca are exposed to higher levels of some contaminants than are those upstream. Because the ecosystem around Fort Chipewyan is dominated by deltaic and lacustrine processes, it is fundamentally different from the mainstem Athabasca and Peace Rivers. Fort Chipewyan lies within a depositional basin in which metals and other contaminants tend to accumulate in fine-textured sediments.

(2) Overall, the primary contaminants of concern may be arsenic, mercury, and polycyclic aromatic hydrocarbons (PAHs). Concentrations of these contaminants, already high, appear to be rising.

(3) People most at risk of adverse health effects are those who eat an abundance of country food and those who consume untreated surface water.

(4) In water, chemical constituents of concern include: arsenic, aluminum, chromium, cobalt, copper, iron, lead, phosphorus, selenium, titanium, and total phenols; the herbicides dicamba, mcpa, bromacil, and triallate; and the pesticide lindane. Other possible constituents of concern include: ammonia, antimony, manganese, molybdenum, and nickel.

(5) In sediment, constituents of concern include: arsenic, cadmium, PAHs, and resin acids.

(6) Mercury levels in fish used for human consumption present a serious concern. If US EPA standards are applied, all walleye (pickerel), all female whitefish, and ~ 90 % of male whitefish exceed subsistence fisher guidelines for mercury consumption. Another study (Golder 2003) observed similarly high levels of mercury in fillets of lake whitefish, sucker, goldeye, pike, walleye, burbot, and lake trout. Under US EPA subsistence fisher guidelines, all of those fishes would be considered unsafe to eat. Levels of arsenic in local fishes may also pose a health risk.

(7) An Alberta government sponsored report on the risk of cancer due to lifetime exposure to arsenic was reviewed. The report used questionable statistical methods and assumptions and underestimated levels of arsenic in water and sediment and the fish consumption rate of many Fort Chipewyan residents. Higher arsenic levels in the lower Athabasca River/western Lake Athabasca than found elsewhere, coupled with the clear link between arsenic exposure and various diseases, call for in-depth study.

(8) When scientific data and traditional knowledge on fish deformities are considered together, they indicate that rates of fish abnormalities may be: higher than expected,

increasing, and related to declines in water quality. PAH and other contamination, changes in water and sediment quality, and changes to the food web may underlie the fish deformities.

(9) A peer-reviewed toxicologic study of levels of exposure to environmental toxins in communities of the lower Athabasca River is needed. A well-designed study would allow for control of factors such as time of residence, location, occupation, diet, lifestyle, water supply, and demographic factors.

(10) For the seven parameters assessed in the fieldwork (arsenic, mercury and methylmercury, polycyclic aromatic hydrocarbons, dioxins and furans, naphthenic acids, nitrogen, and coliform bacteria), the local water treatment plant appears to do a good job of removing impurities. For safety's sake, a full chemical profile of the treated water should be conducted with low detection limits.

(11) Reports of increased algal growth, softer and watery fish flesh, and an apparent increase in total coliform levels lend support to the notion that increased water temperatures, perhaps coupled with adequate to high concentrations of nitrogen and phosphorus and changes in the aquatic food web, are bringing about aquatic changes.

(12) There is a paucity of data available from near Fort Chipewyan and from western Lake Athabasca. While there is a wealth of data available for river areas upstream of the Fort Chipewyan area, much of the Athabasca River data has become privately held in recent years.

(13) This study has likely underestimated the cumulative risk posed to the people and the ecosystem of the lower Athabasca River and western Lake Athabasca. More needs to be learned regarding the concentrations of many parameters in water, sediments, and wildlife, including mercury, arsenic, polycyclic aromatic hydrocarbons, and naphthenic acids.

(14) Concentrations of many parameters vary widely both in time and space, in some cases by factors of 10 to 100. This fact has three important implications. (a) a single measurement may mislead unless placed in context; (b) reliance on averages or medians as a means to interpret data may underestimate health risk; (c) short-term peaks in concentration (pollution events) may have a disproportionate effect on public and ecological health that is difficult to determine.

(15) An environmental monitoring program independent of control by vested interests is needed. The program should be affiliated with a university and report regularly in open public forum to the people of Fort Chipewyan.

INTRODUCTION

Background

Concern over the health of residents of Fort Chipewyan, Alberta has been rising in recent years. Health professionals and members of the general public have watched friends and family members grow sick with a variety of illnesses. At the same time, industrial developments on Lake Athabasca and upstream of the community on the Peace River, and, in particular, on the Athabasca River, have led many people to ask whether the illnesses in the community have an environmental cause. Environmental and public health concerns have been expressed in Fort Chipewyan and in other northern communities that industrial developments are leading to declines in the quality of air and water (NRBS 1999; MRBB 2004).

The need for a study of Ft. Chipewyan water and sediment quality is rooted in five facts: (1) The community is located in a depositional basin downstream of major industrial developments known to release contaminants into the Athabasca River. (2) Natural background levels of some riverborne contaminants may pose a risk to human health. (3) The Athabasca River is the primary source of the community's water supply. (4) There is a widespread perception among local people that rates of disease are above normal and are causally related to environmental contaminants. (5) The chief agency responsible for protection of public and environmental health, the Alberta Government, has a vested interest in oil sands development.

Dr. John O'Connor was the first medical professional to publicly call attention to the question of elevated disease rates in the community. In radio interviews he stated that he had found abnormally high incidences of bile duct cancers (cholangiocarcinomas), colon cancers, lymphomas, leukemia, autoimmune diseases such as lupus, thyroid cancers, overactive thyroid, and a host of skin rashes.

In response, the government of Alberta conducted a study of disease incidence (Alberta Health and Wellness 2006). The government reported statistical confidence intervals of expected disease rates and compared them to observed disease rates. It found elevated incidences of diabetes, hypertension, renal failure, and lupus in Fort Chipewyan. Injuries and poisoning accounted for 16.5% of deaths in Ft. Chipewyan compared to a provincial average of 3.8%. The overall Fort Chipewyan First Nations cancer rate was reportedly about 29% above the Alberta non-First Nations average. The government declined to conclude the cancer rate in Fort Chipewyan was elevated, perhaps due to the imprecise nature of its statistical estimates.

Study of the government report led Timoney (2007) to conclude that: (1) Due to the small population of Fort Chipewyan, statistics offered a blunt tool for detection of elevated rates of disease. Wide confidence intervals in a small population limit the power to detect elevated rates of disease. (2) Expected cancer rates are subject to variations related to statistical assumptions and methods. For example, the upper 95 percent confidence interval for the expected number of cases of prostate cancer in the community was 28 by the Indirect Standardized Incidence Ratio (ISIR) method, 16 by the binomial method, and 13 by the Monte Carlo method. The ISIR method produced the highest upper confidence intervals of the three methods (see Alberta Cancer Board 2007) and was the method used by Alberta Health and Wellness. The fact that estimates of the upper confidence limit for the number of prostate cancer cases differed by more than 100% demonstrates the approximate nature of the statistics of small populations. For the concerned citizen of Fort Chipewyan it might raise the question: how can the Alberta government be certain that cancer rates are not elevated?

This study seeks to provide timely answers to some of the questions that people have about water and sediment quality as it relates to public and environmental health. It is designed to be a short-term study focussed on water and sediment quality relevant to the community's health. It is a beginning that will answer some questions, raise others, and recommend directions for the future.

The Study Region

Fort Chipewyan is located at the west end of Lake Athabasca in northern Alberta near the junction of the Peace and Athabasca Rivers (Figure 1).

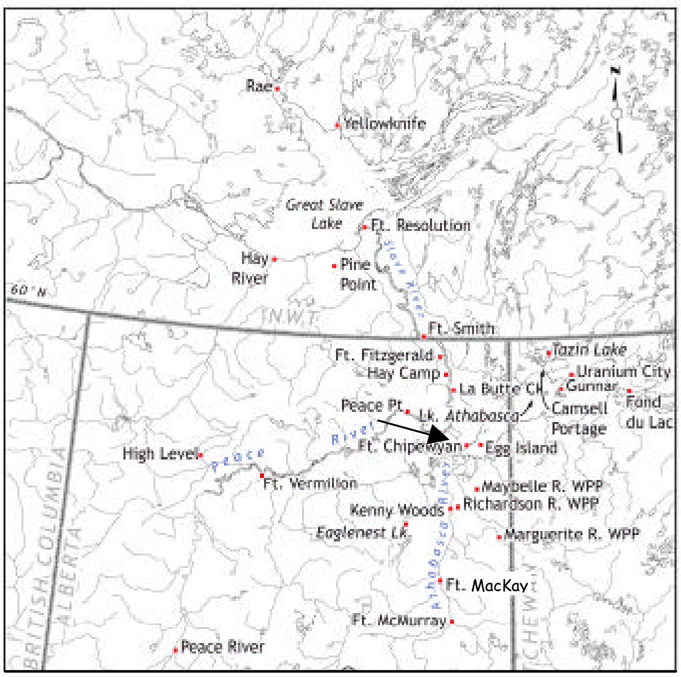

Figure 1. Fort Chipewyan (noted by arrow) and regional place names in northern Alberta and adjacent Saskatchewan and the Northwest Territories. WPP refers to Wildland Provincial Park. Map courtesy of Spatial Vision Group, Vancouver.

As of 2001, about 195,000 people lived in the Peace River watershed (MRBB 2004). The three largest cities are Grande Prairie in Alberta and Ft. St. John and Dawson Creek in British Columbia. About 12% of the population was aboriginal. Upstream of Fort Chipewyan, there are two hydroelectric dams, one coal mine, and one gold mine. Large-scale forestry operations supply wood to numerous sawmills and fiber to six pulp and paper mills, five of which discharge waste into the Peace River and its tributaries (there is a zero-effluent mill in Chetwynd, BC; MRBB 2004). Agricultural land covers about 23% of the basin.

More than 155,000 people lived in the Athabasca River watershed as of 2001. Within the Municipality of Wood Buffalo (the lower Athabasca River region), the population has more than doubled in the past 10 years to a 2006 total of 79,810 people, a growth of 114% (RMWB 2006). The largest cities in the watershed are Ft. McMurray, Hinton, and Whitecourt. About 13% of the population was aboriginal in 2001. Conventional oil and gas and oil sands industries cover much of the basin. There are three coal mines in the river's upper reaches and the forest industry operates several sawmills and panelboard factories, four pulp and paper mills and one newsprint mill. Agricultural land covers about 12% of the basin.

The primary environmental threat facing Fort Chipewyan's future is that it lies downstream of significant economic and industrial activity. Forest industry tenures have been granted to most public lands in northern Alberta. Oil and gas extraction and exploration and the forest industry have dissected and fragmented most of the landscape of northern Alberta. Seismic lines, pipelines, industrial service roads, and registered roads in northern Alberta extend for a total distance in excess of hundreds of thousands of kilometers.

Oil sands developments have impacted and will continue to impact the region (MRBB 2004). Impacts come from large-scale water consumption; land disturbance; cumulative impacts on wildlife, soil, and plant species, and contaminant effects on human and ecosystem health.

During the extraction of bitumen from oil sands, large volumes of water contaminated with polycyclic aromatic hydrocarbons, naphthenic acids, and salt are produced, stored in waste water ponds and reclaimed in aquatic systems (Dixon et al., undated). Key contaminants of concern associated with the oil sands industry are PAHs, naphthenic acids, trace metals, and salinity. Chronic environmental toxicity of lands subjected to bitumen extraction has been most strongly associated with salinity and naphthenic acids.

Contaminated dust, made airborne during oil sands mining operations, may have not only local and regional effects on air quality but also contribute to the contaminant burden of the Athabasca River. This hypothesis requires study.

Wastewater issues facing the lower Athabasca River include the continued accumulation of tailings waters; releases of sewage, refinery effluent, cooling water, dyke seepage, industrial site drainage projects (of wetlands, overburden, mine runoff), mine depressurization water, and tailings release water (McEachern 2004).

Water and Sediment Quality Parameters Assessed

Water and sediment concentrations were determined for seven parameters of concern: arsenic, total mercury and methylmercury, polycyclic aromatic hydrocarbons, dioxins and furans, naphthenic acids, total nitrogen and nitrate + nitrite, total coliform and fecal coliform bacteria. These data were placed in context by a review, and analysis where possible, of existing regional data for those parameters. Additionally, data on other parameters of concern or that have exceeded water or sediment quality guidelines were discussed. Data were discussed in the context of regional toxicological and exposure risk studies where possible.

Arsenic

Arsenic is a natural metallic element found in the Earth's crust. It can enter water systems when geological deposits and soils leach the element. Humans increase the level of available arsenic through the burning of fossil fuels, oil sands, gold, and base metal mining, in agricultural pesticides and additives, and through the burning of waste.

Across Canada, drinking water generally contains fewer than 5 μg/L of arsenic (Health Canada 2006a). For most Canadians, the primary exposure to arsenic is through food, followed by drinking water, soil, and air (Health Canada 2006a).

Arsenic is a known carcinogen and has been linked with bile duct, liver, urinary tract, and skin cancers, vascular diseases, and Type II diabetes (Guo 2003; Merck 2003). Long-term adverse health effects of high levels of arsenic in drinking water include thickening and discoloration of the skin; nausea and diarrhea; decreased production of blood cells; abnormal heart rhythm and blood vessel damage; and numbness in hands and feet (Health Canada 2006a). Short-term exposure may result in gastro-intestinal disorders; muscular cramping or pain; rashes and weakness or flushing of skin; numbness, burning, or tingling in hands and feet; thickening of the skin on palms and soles of feet; and loss of movement and sensory responses (Health Canada 2006a). Exposure to arsenic is becoming a national issue, and potentially, a national crisis.

Mercury

Mercury is a natural metallic element that occurs in many forms. Natural sources of mercury include weathering of rocks and minerals, forest fires, volcanoes, undersea vents, and hot springs. It is also released from flooded soils, a fact of direct relevance to people living in or near a delta. Humans have increased the amount of mercury in the environment through metal smelting, the burning of coal and other fossil fuels, municipal and hospital waste incineration, sewage release, cement manufacturing, and leaching of mercury waste from landfills or storage (Environment Canada 2005). Dental amalgam, used to fill cavities, is an alloy of silver and mercury.

The chemistry of mercury is complex and is related to reduction-oxidation potential, pH, organic content, sulfur content, and other characteristics of the water and sediments (Ullrich et al. 2001). Once released into the environment, inorganic mercury is converted to toxic methylmercury, the primary form of mercury in shellfish and fish (US EPA 2001). The ability of methylmercury to accumulate in fatty tissue and to bind to proteins makes it readily biomagnified by aquatic biota and may pose a threat to humans and other fish-eating animals. Sediments can act as both a source and a sink of mercury and, once contaminated, can remain toxic to aquatic life for long periods (Ullrich et al. 2001).

Uncontaminated freshwater usually contains < 0.005 μg/L total mercury, of which up to about 30% may be methylmercury (Ullrich et al. 2001). The range in the methyl to total mercury ratio in Canadian freshwater is <1 to 73% (Environment Canada 2005). Uncontaminated freshwater sediments may contain up to 200 to 400 μg/kg, with about 1 to 1.5% as methylmercury.

Fish at the top of the food chain bioaccumulate methylmercury to levels 1-10 million times greater than the concentration of methylmercury in the surrounding waters (US EPA 2001).

Mammals with toxic levels of mercury exhibit abnormal behavior, eating disorders, loss of balance, lack of coordination, and paralysis of legs (Environment Canada 2005). Human exposure to mercury is associated with a variety of serious neurological and organic disorders whose nature depends on the species of mercury and the route and severity of the exposure.

Children and pregnant women, those with impaired kidney function, and people who consume large amounts of fish and wild meat are most at risk of adverse health effects.

Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs are a large group of organic ring compounds that are found or formed in some geologic deposits (petrogenic, e.g., oil sands) and can be created during combustion (pyrogenic) or via microbial degradation. They are hydrophobic and tend to bind to organic matter and small particles in the water column and in sediments. PAHs can bioaccumulate in the food chain; they do not biomagnify.

Pyrogenic PAHs are diverse but generally have a high concentration of unsubstituted parent compounds and/or molecular weights greater than C3 dibenzothiophene (Page et al. 1993). They are released during bitumen production and wildfires, in cigarette smoke, in vehicle exhaust, from asphalt roads, from burning of coal and from residential wood burning, agricultural burning, municipal and industrial waste incineration, and from hazardous waste sites (ATSDR 1995). Around the home, PAHs are found in tobacco smoke, smoke from wood fires, creosote-treated wood, some foods, and contaminated milk. Cooking meat at high temperatures, such as during grilling or charring, increases the PAH content (ATSDR 1995). PAHs of pyrogenic origin in animal tissue and fecal samples in Alaska were dominated by unsubstituted phenanthrene, fluoranthene, and pyrene whereas those of petrogenic origin (fresh oil spill) were dominated by naphthalenes and alkylated naphthalenes (Murphy et al. 2003). Weathering of fresh petroleum usually results in losses of naphthalenes such that alkyl-substituted 3-ring PAHs become dominant in older or weathered petroleum (J. Short, pers. comm., October 2007)

Generally, petrogenic PAHs are characterized by alkylated forms of their parent homologues. The chemistry of oil sands geological deposits near the Athabasca River is variable. In one study, alkylated forms of phenanthrene and anthracene (217,000 μg/kg), dibenzothiophenes (158,500 μg/kg), fluoranthene and pyrene (32,400 μg/kg), fluorene (26,400 μg/kg), naphthalene (19,100 μg/kg), and benzo(a)anthracene and chrysene (9,300 μg/kg) were dominant (Evans et al. 2002). In deposits with visible oil and bitumen, the PAH content can reach 7.7 to 216 million μg/kg (Akre et al. 2004). Sediment PAH concentrations in the lower Athabasca River and its delta are generally about 1/100 the concentration found in oil sands deposits (Evans et al. 2002, their Figure 3). PAH concentrations of some sediments in Lake Athabasca and Richardson Lake ranged from 1259-1867 μg/kg (Evans et al. 2002). Oil sands mixtures eroding into the Athabasca River can be rich in 3- and 4-ring alkylated PAHs, a fact of considerable toxicologic importance.

Because PAHs can come from geologic and combustion sources, identification of the source can influence decisions regarding the liability for cleanup and remedial options. Geologic deposits may differ in their ages, degree of weathering, and geologic source. Techniques are being developed that attempt to differentiate petrogenic sources of PAHs (e.g., Akre et al. 2004). Once released, PAHs may be subject to losses from evaporation, dissolution, microbial degradation and photo-oxidation, and hence the ‘signature’ of a PAH source is subject to change over time.

Shell Canada (2006) maintained that PAHs originating from industrial ‘oil sands developments’ can be differentiated from ‘natural petroleum sources’ through PAH ratios—viz., a phenanthrene:anthracene ratio > 5 and a fluoranthene:pyrene ratio < 1 indicated a ‘natural’ source. This view seems unlikely given the complex and dynamic nature of PAH assemblages. Liu et al. (2005) stated that a phenanthrene:anthracene ratio < 10 and a fluoranthene:pyrene ratio > 1 indicated a pyrogenic rather than a petrogenic source and did not mention differentiation of ‘oil sands’ from natural petroleum sources. Benzothiophene, dibenzothiophene, and naphthobenzothiophene, which contain a sulfur atom, are important for discriminating among petroleum sources (J. Short, pers. comm., October 2007). ‘Fingerprinting’ of PAH assemblages may prove of immense importance in the future if it can differentiate between natural and industrial sources in the lower Athabasca River oil sands region.

In an attempt to set water quality objectives for the lower Athabasca River, Golder (2007) defined PAH groups with similar structures based on their toxic equivalency to benzo(a)pyrene. Toxic equivalents were based on data in US EPA (1993) and OMEE (1997). PAH groups 1-3 are carcinogenic. PAH Group 1 includes types with a toxicity equivalent to that of benzo(a)pyrene; PAH Group 2 includes types with a toxicity equivalent to one-tenth, and PAH Group 3 includes types with a toxicity equivalent to one-hundredth that of benzo(a)pyrene.

Laboratory studies on animals have demonstrated that PAH exposure can lead to reproductive and birth defects and decreased body weight and harmful effects on skin, body fluids, and the immune system. Many PAHs are known or expected human carcinogens (ATSDR 1995). Fishes exposed to Athabasca River PAHs can have elevated liver EROD, an indicator of interference with estrogen metabolism (Sherry et al. 2006). Fish hatching alterations, increases in mortality, spinal malformations, reduced size, cardiac dysfunction, edema, and reduction in the size of the jaw and other craniofacial structures have been observed in fishes exposed to PAHs (Tetreault et al. 2003a; Colavecchia et al. 2004, 2006, 2007; Incardona et al. 2004).

Dioxins and Furans

Adsorbable organic halides, which include toxic chemicals such as dioxins, furans, and chlorinated phenolics, are produced as industrial contaminants (often from pulp mills) and can be introduced via treated sewage and atmospheric deposition (MRBB 2004). Incineration of municipal and medical waste is the largest source of dioxins and furans in Canada (Health Canada 2001). Other sources include the backyard burning of garbage, especially plastics; the production of iron and steel; combustion of fuel and wood; and electrical power generation (Health Canada 2001).

Dioxins and furans can travel long distances in the atmosphere and can bioaccumulate in the food chain. The major route of exposure for humans is ingestion of food such as meat, milk products, and fish, and smoking of tobacco (Health Canada 2001).

High levels of dioxins and furans have been documented in some fish species of the Athabasca River (MRBB 2004). Dioxins and furans have been detected in Lake Athabasca sediments (Evans 2000).

There is strong evidence that dioxin exposure is linked to non-Hodgkin's lymphoma and soft tissue sarcoma and good evidence that associates dioxin exposure with Hodgkin's disease, stomach cancer, altered sex ratio, hormonal changes, menstrual disorders, and thyroid disorders (Janssen et al. 2004). Skin, liver, and immune system effects have been observed (Health Canada 2001).

Naphthenic Acids

Naphthenic acids are natural constituents of bitumen that have a relatively high solubility in water, a low affinity for soil particles, are found in oil sands deposits, and tend to persist in the water column (McMartin 2003). During bitumen extraction from oil sands, naphthenic acids are concentrated in tailings. Under natural conditions, naphthenic acids may enter surface waters through groundwater mixing and through erosion of oil sands deposits. In oil sand extraction areas, naphthenic acids may enter surface waters through tailings pond and pipeline leaks. Typically, naphthenic acid concentrations in industrial tailings ponds are about 100 to 3000 times greater than they are in the Athabasca River.

Since oil sand deposits can contain hundreds of kinds of naphthenic acids, it is not known at present which naphthenic acids are the most toxic. Toxicity is more a function of the content and complexity of the naphthenic acid mixture rather than one of concentration. Adverse health effects may result from repeated exposure of mammals to naphthenic acids (Rogers et al. 2002). Much more needs to be learned about the effects of long-term human exposure to naphthenic acids.

Nitrogen

Nitrogen is a naturally occurring essential element that exists in a variety of organic and inorganic forms in water. Assimilation of ammonia and nitrate by plants and microorganisms forms organic nitrogen. Nitrates and nitrites are formed in many ways, both natural and industrial. Among the natural pathways are nitrification of ammonia and precipitation of nitric and nitrous oxides. Fertilizer use, release of industrial and municipal wastes, and leaching of farm animal wastes and septic tanks are major sources of nitrates. Nitrites can be formed from nitrates by denitrification in sediments that lack oxygen.

When total nitrogen is in excess it can contribute to eutrophication, odors, and harmful algal blooms. Nitrate in drinking water may affect human health in the general population at levels of 100-200 mg/L (McCasland et al., undated). Newborn babies are more susceptible to nitrite, which can bind to infant hemoglobin and cause an oxygen transport deficit. Studies linking nitrate in drinking water with cancer have involved high nitrate levels (>/= 100-200 mg/L), much higher than observed in all but extremely polluted waters.

Coliform Bacteria

Coliform bacteria are common and widespread within both ecosystems and organisms. They are usually harmless. Fecal coliforms and *Escherichia coli* are coliforms whose presence indicate that water may be contaminated with human or animal wastes.

Coliform bacteria are useful indicators for the presence of pathogenic microorganisms associated with fecal contamination and waterborne illnesses (Ayebo et al. 2006).

The location of the sewage disposal and domestic water supply intake at Fort Chipewyan may be unique in Alberta. While the domestic water intake is normally 'upstream' of the sewage outfall, this is not always the case. When water levels on the Peace River are higher than those at Lake Athabasca, the Rochers River and other outlet channels cease to flow north. Instead a 'flow reversal' occurs and waters from the Peace River flow south. At that time, municipal sewage entering the Rochers River from Mission Creek flows south to Lake Athabasca and may contaminate the waters around Fort Chipewyan. There is also concern that the town sewage treatment plant may be under-capacity for the size of the population. Another potential source of future contamination is sewage emptied into Lake Athabasca from the Allison Bay settlement northeast of Fort Chipewyan.

METHODS

Field Methods

Water and Sediment Samples

The field crew was composed of Vanessa Phillips (University of Alberta), local guide Robert Grandjambe, and Kevin Timoney (Treeline Ecological Research).

Water samples were gathered from four sites and sediment samples from three sites during the period 31 May to 1 June 2007 (Tables 1, 2 and Figures 2-6). Water samples were gathered from below the water surface after triple rinsing the appropriate container with the water to be sampled.

Due to unacceptably high detection limits for total mercury in water, a second set of total mercury samples was taken from the four sites on 28 August 2007.

Sediments were gathered with an Ekman grab sampler. The contents of the sampler were emptied into a clean glass tray and homogenized with a spatula prior to placing into containers. Sediments gathered for metal analyses were homogenized with a plastic spatula while those gathered for organic analyses were homogenized with a metal spatula.

Samples were stored overnight (31 May) in a cooler stored in a basement, then shipped by air to Edmonton and covered with bagged ice (1 June) for delivery to the ALS lab on the morning of 2 June.

PAH and naphthenic acid sampling protocols did not call for field preservation of water and sediment samples. Microbes may have used the PAHs and naphthenic acids as carbon sources, or both compounds may have adhered to sample container surfaces. Microbial degradation or adhesion to containers may have decreased the levels of PAHs and naphthenic acids below detection limits.

Traditional Knowledge Interviews

Elders with extensive knowledge of water were interviewed with a set of questions. Their responses were recorded digitally for later study. Each interview lasted from one-half hour to two hours.

Interview questions

1. Do you drink untreated water from the Athabasca River and other rivers and lakes? If not, did you drink it in the past?
    2. If so, do you think the water tastes or smells differently than it used to?
        3. How does it taste differently? Saltier? Oily smell?
        4. When did you notice the change?
5. Have you noticed oil slicks in the Athabasca River? If so, when and where?
    5a. Do you have any photographs of oil spills or oiled animals?
6. Have you noticed fish kills? If so, when and where?
7. Have you noticed oiled birds? If so, when and where?
8. Have you noticed oiled muskrats? Bloody noses? Die-offs? If so, when and where?
    8a. What happens to muskrats when they contact contaminants/oil?
    8b. What happens to waterfowl when they contact contaminants/oil?
9. Have you noticed changes in the taste of meat, fish, waterfowl? If so, when, where, what changes?
10. Have you noticed any changes in the abundance of waterfowl, rats, beavers, otters, mink, walleye, jackfish, whitefish, lake trout, burbot that might be related to water quality?
11. Have you noticed any human diseases that did not occur in the past?

Analytical Methods

Water and sediment analyses were conducted by the ALS Laboratory Group, Edmonton, Alberta with the exception of total mercury in water which were analyzed by Flett Research Ltd., Winnipeg, Manitoba. Details are provided in Appendix 1.

Data gathered during this study were compared to pre-existing water and sediment quality data and to toxicological and pathological data from the region and placed in the context of existing water and sediment quality guidelines.

Table 1. Water quality parameters and collection containers.

Parameter	Medium	Container
Total Coliforms	(in water)	250 mL sterilized plastic bottle with sodium thiosulfate preservative
Fecal Coliforms	(in water)	250 mL sterilized plastic bottle with sodium thiosulfate preservative
Total Coliforms	(in sediment)	whirlpack
Fecal Coliforms	(in sediment)	whirlpack
Mercury (total)	(in water)	125 mL teflon bottle (with 0.4% HCl); bottle is rinsed repeatedly with sample water, then filled)
Mercury (total)	(in sediment)	ziploc bag
Methylmercury	(in sediment)	125 mL jar
Methylmercury	(in water)	1 L amber jar
Arsenic (total)	(in water)	250 mL plastic bottle (with 5 mL of 20% nitric acid, from vial)
Arsenic (total)	(in sediment)	ziploc bag
PAHs	(in water)	2x1 L amber glass bottles
PAHs	(in sediment)	125 mL amber jar
Dioxins and Furans	(in water)	2x1 L amber glass bottles
Dioxins and Furans	(in sediment)	500 mL amber jar
Naphthenic Acids	(in water)	1 L amber glass bottle
Naphthenic Acids	(in sediment)	125 mL amber glass jar
Total Kjeldhahl N	(in water)	500 mL plastic bottle (with 2 mL of 1:1 sulfuric acid, in vial)
Total N by combustion	(in sediment)	whirlpack
Nitrate-Nitrite	(in water)	500 mL routine bottle

Table 2. Location of the sample sites (UTM zone 12, NAD 27). See Figures 2-6.

Site	Easting	Northing	Comments
Fletcher Channel	496635	6491684	site about 200 m south of the Canoe Portage – Fletcher Channel divergence; east side of thalweg; water depth 2.8 m
Rochers River at Mission Creek	488649	6506892	site about 10 m north and 15 m west of the mouth of Mission Creek; water depth 1.9 m
Water Intake for Fort Chipewyan, Lake Athabasca	491666	6507606	site about 300 m south of Fort Chipewyan Lodge; water depth 6.0 m
Water Treatment Plant in Fort Chipewyan	491139	6508410	treated water sample taken from tap inside of plant

Figure 2. Overview of the study area with location of the water and sediment samples. a. Fletcher Channel. b. Rochers River at Mission Creek. c. Water intake in Lake Athabasca. d. Water treatment plant. The bidirectional red arrow signifies that the Rochers River can flow either north (the typical direction) or south. Note the apparent sharp transition between Lake Athabasca-origin water (light turquoise) and Athabasca River-origin water (grayish brown) in this false colour image. Landsat 7 image, 10 September 2002, courtesy of Spatial Vision Group, Vancouver. Image: crop of rgb_321_L7_p43r19s00_2002sep10.tif.

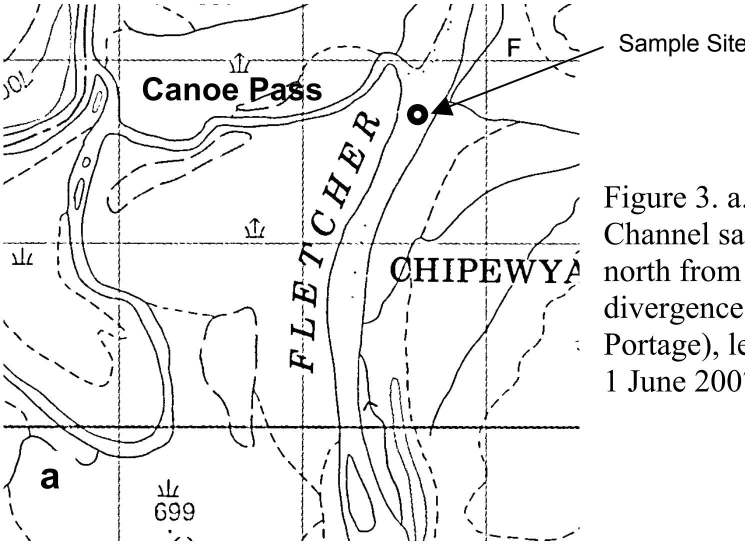

Figure 3. a. Location of the Fletcher Channel sample, UTM NAD 27. b. View north from the sample site towards the divergence of Canoe Pass (Canoe Portage), left, and Fletcher Channel, right, 1 June 2007.

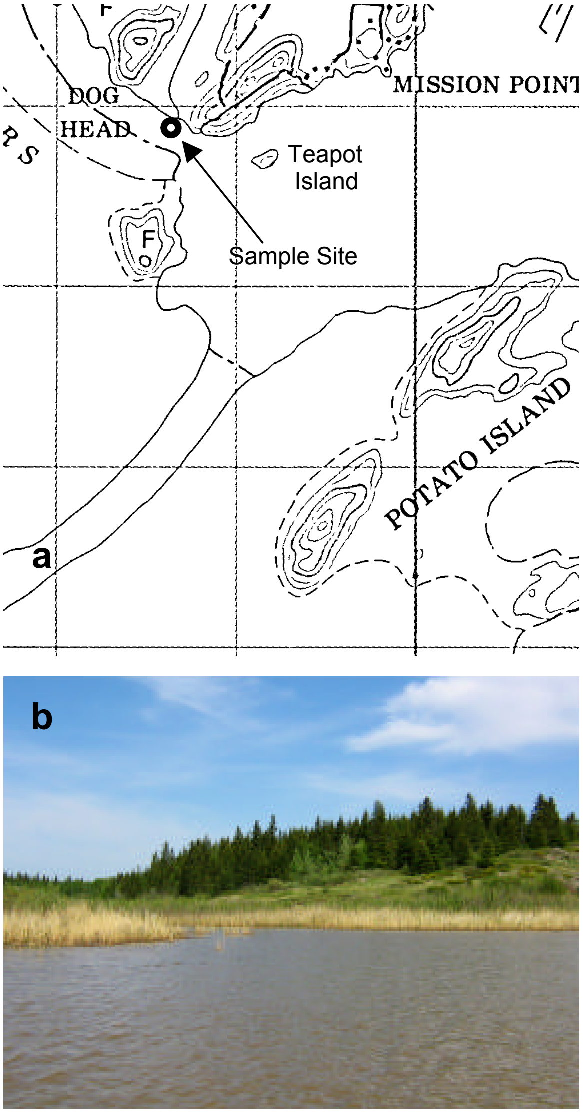

Figure 4. a. Location of the Rochers River / Mission Creek sample, UTM NAD 27. b. View northeast from the sample site in the Rochers River towards the mouth of Mission Creek, 31 May 2007.

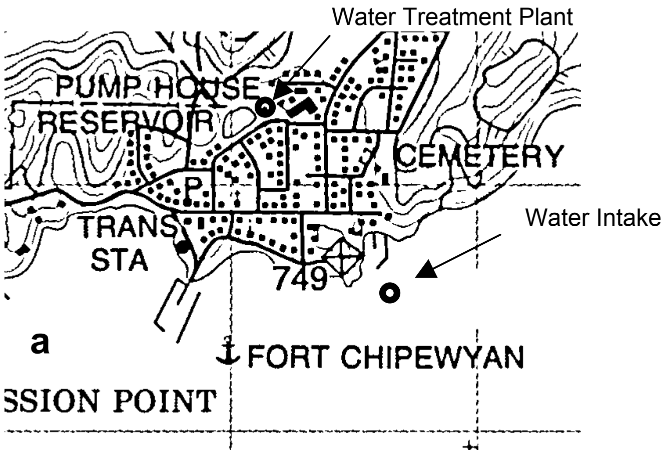

Figure 5. a. Location of the Fort Chipewyan Lake Athabasca water intake sample and the raw water sample from the water treatment plant, UTM NAD 27. b. View north from the sample site near the water intake pipe in Lake Athabasca towards the Environment Dock and the Fort Chipewyan Lodge, 31 May 2007.

Figure 6. Location of the water treatment plant and ponds, 12 August 2006.
a. The water treatment plant. b. Two reservoir ponds. c. Backwash pond. d. Two sewage ponds.

RESULTS and DISCUSSION

1. Regulatory Guidelines and Pre-existing Regional Data

Guidelines are prepared by government agencies as a means of summarizing information about water, sediment, air, food, or other natural or manufactured products. A guideline may be developed by a government agency as a regulatory limit used in enforcement of laws. A guideline may be developed to provide information to consumers as to what is safe to eat or drink. Alternatively, guidelines may be developed to inform the public about the levels of contaminants that would be expected to produce a given effect on an organism or a system.

In any case, a guideline is subject to change over time and to differ among jurisdictions. As a general rule, the guideline for a particular water or sediment quality parameter tends to decrease over time as more information comes to light. For example, in 1978, the Canadian maximum acceptable concentration for arsenic in drinking water was 50 μg/L. By 2002, the Canadian environmental quality arsenic drinking guideline had fallen to 25 μg/L. Presently, Health Canada (2006b) proposes a maximum acceptable concentration of 5 μg/L arsenic.

Similarly, if we compare a guideline across categories or jurisdictions, wide variation may be found. In the case of human consumption of fish containing mercury, the present Canadian mercury guideline is 0.5 mg/kg for general consumers, 0.2 mg/kg for subsistence fishers, while the US EPA mercury consumption guideline is 0.40 mg/kg for recreational fishers and 0.049 mg/kg for subsistence fishers.

Guidelines then, are simply that— they are meant to guide discussion and to structure knowledge. Whether the value for a chemical, biological, or physical parameter is acceptable or not is subject to change over time and to vary between jurisdictions or between individual risk profiles.

Nor should failure to exceed a guideline be interpreted as a ‘safe’ condition. Some people, e.g., babies and people with weakened immune systems, are more susceptible to contaminants than other people. The human body does not face a single contaminant or stressor in the course of a lifetime. Instead, we are immersed in a milieu of stressors that changes over time and differs among people. One person might face a contaminant burden of stored, fat soluble organochlorine pesticides, PCBs, and dioxins. Another person might face a contaminant burden of arsenic, mercury, and PAHs. It could well be that neither person has concentrations of these toxins that exceed individual guidelines. Yet due to synergistic effects, the combined contaminant burden in either person might result in an adverse health effect.

Precautionary common sense dictates that responsible agencies should seek to minimize the overall contaminant burden faced by each person.

Tables 3 and 4 list relevant current water and sediment quality guidelines.

Table 5 provides a summary of some regional observations of relevant water and sediment quality data. These data, and others not included in Table 5, provide a context for discussion of the results. I apologize for the difficulty in reading Table 5 but I have tried to collate a large amount of data into one table.

The primary challenge to making comparisons of regional water and sediment quality is the absence of standardized statistical reporting. Many data are presented in reports in summary form without supporting raw data or information on the form of the statistical distributions, means, medians, quartiles, percentiles, and other measures.

Without raw data it can be difficult or impossible to generate or to compare homologous statistics. In one case, a study might report a 90th percentile while another study might report a 95th percentile. One study might report numeric values for observations while another study might report for the same parameter the number of sites in exceedence of a guideline, but not the actual values. Some studies report the number of observations, some studies do not. In some cases it is unclear whether the datum reported is a median or a mean.

Some studies present novel statistical measures that, while not without merit, may not be comparable to other studies. (Golder 2007, their Table 4.1) reported a maximum long-term average of the median background concentration [meaning unclear] of 0.034 mg/L for naphthenic acids in the lower Athabasca River (without site locations and number of samples). In comparison, Imperial Oil (2006, volume 6, their Table 5-23) reported a mean naphthenic acid concentration of 0.74 mg/L for the Athabasca River (without site locations and number of samples). These summary values differ by a factor of 22. When it is realized that both these reports drew upon a host of other reports for their data, few of which received normal scientific peer review, it is difficult not to suspect that the message contained in the raw data has been muddled.

In short, conducting a meta-analysis or even making meaningful comparisons is a challenge.

Table 3. Canadian water and sediment quality guidelines as a context for the selected parameters.

Guidelines	Water		Sediment
	Drinking Water	Aquatic Life	
Total Coliforms	0 colonies/100 mL	no guidelines	no guidelines
Fecal Coliforms	0 colonies/100 mL	no guidelines	no guidelines
Mercury Total	1 µg/L MAC	0.013 µg/L acute 0.005 µg/L chronic	170 µg/kg ISQG
Methylmercury	no guidelines	0.001 µg/L chronic exposure	no guidelines
Arsenic Total	5 µg/L proposed MAC	5 µg/L	5.9 mg/kg ISQG
PAHs	see Table 4	see Table 4	see Table 4
Dioxins and Furans (PCDD/Fs)	no guidelines	no guidelines	0.85 ng TEQ/kg ISQG
Naphthenic Acids	no guidelines	no guidelines	no guidelines
Nitrogen Total	10.0 mg/L	1.0 mg/L chronic (total inorganic and organic)	no guidelines
Nitrate+Nitrite	3.2 mg/L for nitrite; no guideline for nitrate	0.06 mg/L for nitrite; no guideline for nitrate	no guideline

items in red are from CCME (2002)
MAC = max acceptable concentration
IMAC = interim MAC
ISQG = interim sediment quality guideline
items in green are from Health Canada (2006b)
items in blue are from Alberta Environment (1999)

Table 4. Canadian water and sediment quality guidelines for selected PAHs.*

Guidelines	Water (µg/L)	
PAH	Drinking Water	Aquatic Life
Acenaphthene		5.8
Acridine		4.4
Anthracene		0.012
Benzo(a)anthracene		0.018
Benzo(a)pyrene	0.01	0.015
Benzo(b)fluoranthene		5.8
Fluoranthene		0.04
Fluorene		3.0
Naphthalene		1.1
Phenanthrene		0.4
Pyrene		0.025
Quinoline		3.4
	Sediment (µg/kg, ISQG)	
Benzo(a)anthracene		31.7
Benzo(a)pyrene		31.9
Chrysene		57.1
Dibenzo(a,h)anthracene		6.22
Fluoranthene		111.0
Fluorene		21.2
2-Methylnaphthalene		20.2
Naphthalene		34.6
Phenanthrene		41.9
Pyrene		53.0

* CCME (2002)

Table 5. A summary of some water and sediment quality observations from the region.

Guidelines	Water	Sediment	Location, Date, N	Reference
Total Coliforms	Mean 31 colonies / 100 mL, median 12, range 4-384		Fort Chipewyan water intake, n=103, all but three values between June 2001 and July 2007	this study, Table 9
Fecal Coliforms	Mean 5.1 colonies / 100 mL, median 4, range 4-44		Fort Chipewyan water intake, n=101, all but three values between June 2001 and July 2007	this study, Table 9
Mercury	Total: mean 0.0093 µg/L, median 0.0050 µg/L, 90th tile 0.0200 µg/L, max 0.0510 µg/L		AR above Embarras Portage (07DD0001), Aug 1989 – Sep 2001, 98	Donald et al. (2004)
	Total: mean 0.0126 µg/L, median 0.0050 µg/L, 90th tile 0.0300 µg/L, max 0.1300 µg/L (**many values above aquatic life acute guideline of 0.013 µg/L**)		PR at Peace Point (07KC0001), Aug 1989 – Sep 2001, 99	Donald et al. (2004)
	Total: 0.036 µg/L@; 0.10 µg/L@@ (**above aquatic life acute guideline of 0.013 µg/L**)		lower AR	Golder (2007, Table 4.1)
	Total: maxima, **winter 1.3 µg/L, spring 0.05 µg/L, summer 0.11 µg/L, fall 0.4 µg/L**[&] (**above aquatic life acute guideline of 0.013 µg/L**)		AR between Fort Creek and Embarras, winter 1968-2003, n=90; spring, summer, fall, 1976-2003, n=30, n=56, n=56	Imperial Oil (2006, Table 5-25)
	Mean (?) <0.1 µg/L, "modelled background median" 0.027 µg/L, range <0.0006-3.6 µg/L (**above aquatic life acute guideline of 0.013 µg/L; upper values exceed human drinking guideline of 1 µg/L**)		AR downstream of Steepbank R., years undefined, n = 122; the 'mean' statistic was not defined	Suncor (2005, Volume 3, Table 60)
	Mean (?) <0.05 µg/L, "modelled background median" 0.030 µg/L, range <0.005-0.8 µg/L (**above aquatic life acute guideline of 0.013 µg/L**)		AR upstream of Embarras R., years undefined, n = 171; the 'mean' statistic was not defined	Suncor (2005, Volume 3, Table 61)
		see Table 10	western Lake Athabasca	this study
Methylmercury ^		see Table 10	western Lake Athabasca	this study
Arsenic *^	Dissolved: mean 0.3 µg/L, median 0.3 µg/L, 90th tile 0.4 µg/L, max 1.0 µg/L		AR above Embarras Portage (07DD0001), Aug 1989 – Sep 2001, 102	Donald et al. (2004)
	Dissolved: mean 0.3 µg/L, median 0.3 µg/L, 90th tile 0.5 µg/L, max 1.2 µg/L		PR at Peace Point (07KC0001), Aug 1989 – Sep 2001, 92	Donald et al. (2004)
	Total: mean 0.526 µg/L, median 0.416 µg/L, 95th tile 1.229 µg/L, max 2.9 µg/L		RAMP acid-sensitive lakes, 2001, 2003, 2004, 2005, n?	RAMP (2006)
	Dissolved: mean 0.6 µg/L, median 0.4 µg/L, 95th tile 1.4 µg/L, max 4.6 µg/L		AR at Old Fort (07DD0010), 1987-2002, n = 74 values >/= 0.2 µg/L	Timoney data file: old fort arsenic.syd, from Alberta Environment data
	Total: 0.79 µg/L@; 29.0 µg/L@@ (**above MAC for drinking water of 5.0 µg/L**)		lower AR	Golder (2007)

	Mean (?) 1 µg/L, "modelled background median" 0.9 µg/L, range 0.2-10 µg/L (upper values in range **above MAC for drinking water of 5.0 µg/L**)		AR downstream of Steepbank R., years undefined, n = 35; the 'mean' statistic was not defined	Suncor (2005, Volume 3, Table 60)
	Mean (?) 0.5 µg/L, "modelled background median" 0.9 µg/L, range <0.1-18 µg/L (upper values in range **above MAC for drinking water of 5.0 µg/L**)		AR upstream of Embarras R., years undefined, n = 57; the 'mean' statistic was not defined	Suncor (2005, Volume 3, Table 61)
		8.2 mg/kg (**above ISQG**)	RAMP site EMR-2, Sep 2005	RAMP (2006)
		6.6 mg/kg (**above ISQG**)	RAMP site GIC, Sep 2005	RAMP (2006)
		median 4.7 mg/kg, max 4.8 mg/kg	RAMP site GIC, 1997-2004, fall, n = 3	RAMP (2006)
		median 4.5 mg/kg, **max 6.6 mg/kg**	AR "between Fort Creek and Embarras", 1997-2003; n =21	Imperial Oil (2006, Table 5-29)
PAHs	"PAH Group 2": 0.034 µg/L@@ #		lower AR (site locations not specified)	Golder (2007)
	"PAH Group 3": 0.016 µg/L@@ ##		lower AR (site locations not specified)	Golder (2007)
		of six PAHs from LA sediments near Fort Chipewyan for which there are sediment guidelines, **phenanthrene levels (assayed by GCMS) approached guidelines, with one exceedence at Site D (42 µg/kg**, see Table 11); If results of their fluorescence assays are used, **there were exceedences at all five study sites for both 2-methylnaphthalene and for phenanthrene**	see Figure 9	Bourbonniere et al. (1996, Table 5)
		of 8 PAHs for which guidelines exist, only exceedence for phenanthrene (48 µg/kg), AR below Alpac mill	AR below Alpac, 5 December 1995; six sediments at the single site; AR near Fort Mackay, two sediments at single site, 11 Oct 1994	Crosley (1996, Appendix B)
		maximum concentrations of seven of nine PAHs exceeded sediment quality guidelines (see Table 12)	AR "between Fort Creek and Embarras", 1997-2003; n for each pah varied from 20 to 22	Imperial Oil (2006, Table 5-29)
Dioxins and Furans (PCDD/Fs)	see Table 8, this study			
		see Table 14, this study		
Naphthenic Acids	0.034 mg/L@; 0.63 mg/L@@		lower AR (site locations and n not specified)	Golder (2007, Table 4.1)
	80-110 mg/L typical concentration in tailings ponds		Syncrude and Suncor tailings ponds	Rogers et al. (2002)
	mean 66.6 mg/L +/- 19.6 s.d., 95th tile 98.8 mg/L		AR tailings pond water	McEachern (2004)
	maximum 2 mg/L; median <1 mg/L		AR upstream of the Muskeg River, fall 1968-2003, n = 28	Imperial Oil (2006, volume 3, Table 5-23)

	maximum 5 mg/L; median 1 mg/L	AR between Muskeg River and Fort Creek, fall 1972-2003, n = 13	Imperial Oil (2006, volume 3, Table 5-24)
	maximum < 1, 1, <1, <1 mg/L	AR between Fort Creek and Embarras; winter (1968-2003), n=6; spring, summer, fall (1976-2003), n = 3,3,10	Imperial Oil (2006, volume 3, Table 5-25)
	"average" 0.74 mg/L	AR, summarized from several reports, location and n not specified; it is unclear whether the value refers is a median or a mean; nor is the value easily reconciled with the value from Golder (2007, above in table)	Imperial Oil (2006, volume 6, Table 5-23)
Total Nitrogen	mean 0.54 mg/L, median 0.52, 90th tile 0.86 mg/L, max 1.70 mg/L (**max above chronic exposure guideline of 1.0 mg/L for protection of aquatic life from Alberta Environment 1999**)	AR above Embarras Portage (07DD0001), Aug 1989 – Sep 2001, n = 101	Donald et al. (2004)
	mean 0.54 mg/L, median 0.26, 90th tile 1.27 mg/L, max 4.04 mg/L (**max above chronic exposure guideline of 1.0 mg/L for protection of aquatic life from Alberta Environment 1999**)	PR at Peace Point (07KC0001), Aug 1989 – Sep 2001, n = 92	Donald et al. (2004)
	0.77 mg/L@; 4.4 mg/L@@ (**above chronic exposure guideline of 1.0 mg/L for protection of aquatic life from Alberta Environment 1999**)	lower AR	Golder (2007)
Nitrate+Nitrite	Dissolved: mean 0.078 mg/L, median 0.040, 90th tile 0.201 mg/L, max 0.292 mg/L	AR above Embarras Portage (07DD0001), Aug 1989 – Sep 2001, 102	Donald et al. (2004)
	Dissolved: mean 0.071 mg/L, median 0.069, 90th tile 0.115 mg/L, max 0.394 mg/L	PR at Peace Point (07KC0001), Aug 1989 – Sep 2001, 96	Donald et al. (2004)

* the ratio of dissolved arsenic to total arsenic in RAMP (2006) acid-sensitive lakes for the years 2001, 2003, 2004, 2005 was: 0.84 for means and 0.84 for medians and 0.79 for the 95th tile. To estimate mean and median total arsenic from dissolved arsenic, multiply the latter by 1.19; to estimate the 95th tile of total arsenic, multiply the dissolved value by 1.27. This empirical dissolved to total arsenic factor is the same used by EPA (2003).

^ see Figure 7.

& the medians were reported as "<" values, despite the fact that the medians exceeded the reported minimum values; this likely arose due to the improved detection limits over time (1968 or 1976 to 2003); this rendered the medians virtually meaningless

@ "maximum... long-term average" of the median background concentration, from Golder (2007, their Table 4.1)

@@ "maximum... peak background concentration" (value of the 99.91 percentile), from Golder (2007, their Table 4.1)

PAH Group 2 includes benzo(a)anthracene and other types with a toxic equivalency factor of one-tenth that of benzo(a)pyrene, from Golder (2007)

PAH Group 3 includes chrysene and other types with a toxic equivalency factor of one-hundredth that of benzo(a)pyrene, from Golder (2007)

2. Water and Sediment Quality

Water Quality

Arsenic

Arsenic levels near Fort Chipewyan were 2.6 µg/L at the Lake Athabasca water intake; 3.4 µg/L in the Rochers River near Mission Creek; and 1.6 µg/L in the Fletcher Channel. Arsenic was below the detection limit (0.4 µg/L) in treated tap water.

Arsenic concentrations for untreated Lake Athabasca water near Fort Chipewyan are relatively high in comparison to regional values. For the Peace River at Peace Point, the 90^{th} percentile for dissolved arsenic, 1989-2001, was 0.4 µg/L (Table 5).

Modelled median arsenic concentrations for the Athabasca River reaches "downstream of Steepbank River" and "upstream of Embarras River" were both 0.9 µg/L (ranges: 0.2-10 and <0.1-18 µg/L, Table 5).

For RAMP acid-sensitive lakes, 2001-2005, the 95^{th} percentile for total arsenic, was 1.229 µg/L (Table 5). The mean dissolved arsenic concentration along the Muskeg River was 1.144 µg/L (1976-2000, for 9 sites for which the mean was not affected by values below detection limits) (Alberta Environment 2001).

For the dataset (n=488)* of lower Athabasca River dissolved arsenic observations above the detection limit, the mean = 1.533 µg/L, median = 0.600 µg/L, 95^{th} percentile = 5.0 µg/L. For the same dataset but with values at the detection limit set to one-half the detection limit, (n = 539)*, the mean = 1.433 µg/L, median = 0.600 µg/L, 95^{th} percentile = 4.9 µg/L) (Figure 7).*

Figure 7 demonstrates the decline in publicly available water quality data over time, an unfortunate result of cutbacks in Alberta government-funded water quality monitoring. The apparent decline in number of exceedences since the early 1980s is difficult to explain. There were some large oil spills in the 1970s and perhaps these are reflected in the higher arsenic concentrations. It is also possible that decline in sampling effort made it less likely that exceedences were detected.

* Kolmogorov- Smirnov test of normality, probability of normal distribution = 0.0000 for both datasets; both datasets are positively-skewed and strongly kurtotic).

Comparison of the various datasets supports the view that levels of total arsenic in western Lake Athabasca (Table 6) and in the lower Athabasca River (Figure 7) are high relative to those in the region at large.

Table 6. Total arsenic concentrations in western Lake Athabasca over the period 1987-94 in µg/L. Data file courtesy of R. Tchir, Alberta Environment "data for 07ma_07md.csv". Site 0.5 km south of Fort Chipewyan water intake is Alberta Environment number AB07MD0010.

Lake Athabasca Arsenic Dataset	Mean	Median	95th percentile	n
Values > detection limit (D.L.)	0.9	0.7	2.7	51
All values (<detection limit set to ½ D.L.)	0.8	0.6	2.7	54
Values > D.L., at site 0.5 km south of LA water intake	1.2	0.7	2.8	8
All values (<detection limit set to ½ D.L), at site 0.5 km south of LA water intake	1.1	0.6	2.8	9

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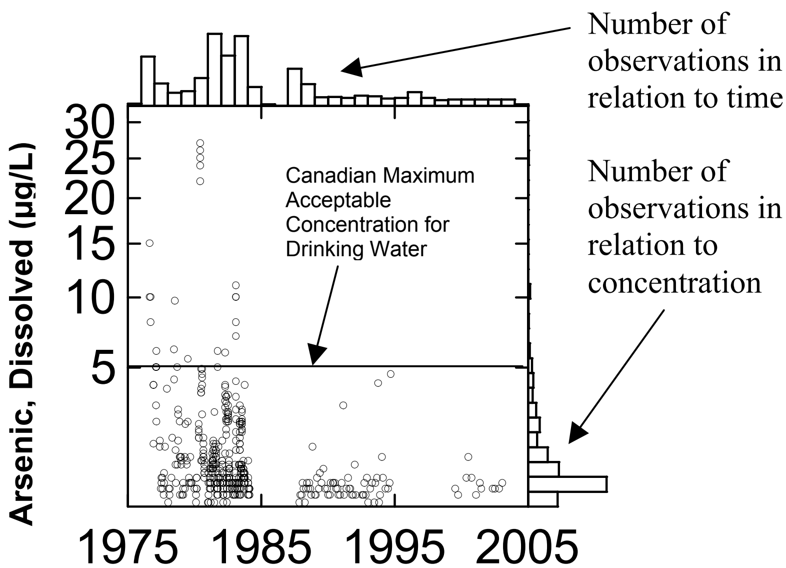

Figure 7. Concentration of dissolved arsenic in the lower Athabasca River, 1976 to 2003, n = 488 observations >/= 0.2 µg/L. In this graphs, stations* with values below detection limit were coded as missing. Y-axis is power-transformed 0.5. * Lower Athabasca River Stations (Downstream of Fort McMurray), 07DA: 0190, AT OLD AOSERP DOCK MILE 26.3; 0400, U/S OF THE CONFLUENCE WITH MUSKEG RIVER MILE 34.5; 0410, U/S FROM THE CONFLUENCE WITH MUSKEG RIVER - RIGHT BANK; 0970, ABOVE THE FIREBAG RIVER - MILE 82.4; 1500, SITE 4 - MILE 19 – AOSERP; 1520, SITE 6 - MILEAGE 29.8 – AOSERP; 1540, AT FORT MACKAY – AOSERP; 1550, BELOW CONFLUENCE WITH THE TAR RIVER - MILE 52.4 – AOSERP; 07DD: 0010, AT OLD FORT - RIGHT BANK; 0020, 13.0 MILES BELOW CONFLUENCE WITH THE FIREBAG RIVER; 0040, AT EMBARRAS AIRPORT - AT WSC GAUGE ARC KM 111.3; 0105, D/S OF DEVILS ELBOW AT WINTER ROAD CROSSING; 0150, EMBARRAS RIVER NEAR LAKE ATHABASCA; 0360, BIG POINT CHANNEL OUTLET - DELTA SITE – AOSERP.

Total Mercury

Total mercury was 0.00139 µg/L at the Rochers River, 0.00161 µg/L at the Lake Athabasca water intake, 0.00325 µg/L at the Fletcher Channel, and 0.00083 µg/L for treated tap water (Table 7). The total mercury level in the Fletcher Channel approaches the chronic exposure guideline for protection of aquatic life (0.005 µg/L, Table 3).

Other data place the preceding mercury concentrations in context. Many observed mercury concentrations exceed aquatic life protection guidelines (Table 5).

For the Athabasca River above Embarras Portage the 90th percentile mercury concentration was 0.02 µg/L with a maximum of 0.05 µg/L; for the Peace River at Peace Point, the 90th percentile mercury concentration was 0.03 µg/L with a maximum of 0.13 µg/L (Table 5; Donald et al. 2004).

A lower Athabasca River maximum of the median background concentration of 0.036 µg/L was reported by Golder (2007). Maximum mercury concentrations for the Athabasca River between Fort Creek and Embarras were: 1.3, 0.05, 0.11, and 0.4 µg/L for winter, spring, summer, and fall (Table 5). Modelled median mercury concentrations for the Athabasca River reaches "downstream of Steepbank River" and "upstream of Embarras River" were 0.027 and 0.030 µg/L, respectively (ranges: <0.0006-3.6 and <0.005-0.8 µg/L, Table 5).

The mean mercury concentration along the Muskeg River was 0.128 µg/L (1976-2000, for 11 sites for which the mean was not affected by values below detection limits) (Alberta Environment 2001).

The maximum mercury concentration observed in five lakes in the Athabasca oil sands region was 0.006 µg/L and at Poplar Creek Reservoir was 0.0024 µg/L (Shell Canada 2006). The ratio of methylmercury to total mercury in these sample ranged from 4 to 21% with a mean of about 10%.

Of 64 observations of total mercury in Lake Athabasca (1977-1994), 60 were below the detection limit of 0.1 µg/L; the other values were: 0.1, 0.2, and 0.2 µg/L (due west of the tip of Sandy Point) and 0.2 µg/L (composite of main area of lake) (data courtesy of R. Tchir, Alberta Environment). Improved methods and detection limits since the mid-1990s mean that older mercury estimates and 'non-detects' may be unreliable.

Overall, the total mercury data are a cause for concern in that values sometimes exceed acute guidelines for protection of aquatic life (0.013 µg/L) and commonly exceed chronic guidelines for protection of aquatic life (0.005 µg/L). The fact that mercury bioaccumulates in the food chain makes the observed mercury levels directly relevant to public health.

Methylmercury

Methylmercury was present in small quantities in untreated water (0.000124 to 0.000134 µg/L, Table 7). Methylmercury concentrations in five lakes and one reservoir in the Athabasca oil sands region (0.00005 to 0.00039 µg/L; Shell 2006) were in the same range as those found near Fort Chipewyan. The chronic exposure guideline for protection of aquatic life is 0.001 µg/L (Table 3).

While these concentrations in water do not appear to be cause for concern, biomagnification of methylmercury in fishes poses a health risk to the people of Fort Chipewyan (see section 3 of Other Data and Observations for a discussion).

Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs in water were below the detection limit of 0.01 µg/L in the 2007 sample (Table 7).

For the lower Athabasca River, Golder (2007) reported a "maximum... peak background concentration" (99.91 percentile) for PAH Group 2 of 0.034 µg/L and for PAH Group 3 of 0.016 µg/L (Table 5). The human health guideline for PAH groups 2 and 3 is estimated at 0.0029 µg/L by Golder (2007). In the United States, concentrations of 0.004-0.024 µg /L of PAHs in drinking water have been observed (ATSDR 1995).

Maximum peak background concentrations for PAH groups 2 and 3 in the lower Athabasca River have exceeded human health guidelines. Unfortunately, because the data in Golder (2007) were presented in summary form without statistics, it is not possible to determine how often the human health guidelines have been exceeded.

Dioxins and Furans

Penta, hepta, and octachlorinated dibenzo-dioxins were detected in the surface waters (Table 8). No furans were detected in surface waters (detection limits 0.1 to 0.2 pg/L). Neither dioxins nor furans were detected in treated drinking water. The highest value observed was 7.9 pg/L for P5CDD at the Lake Athabasca water intake. Overall, the dioxin concentrations would be considered low or very low (see Carey et al. 2004).

Naphthenic Acids

No naphthenic acids were detected in the four water samples (detection limit of 0.01 mg/L). This result is surprising in that naphthenic acids are known to be present in the lower Athabasca River (Table 5), albeit at concentrations of < 1 mg/L.

Nitrogen

The treated water nitrogen concentration was 0.2 mg/L (Table 7). Total nitrogen concentrations in the surface waters ranged from 0.6 to 1.0 mg/L, perhaps higher than typical of total nitrogen concentrations in the lower Athabasca and Peace Rivers (Tables 5, 7). The possibility that total nitrogen levels are higher in the waters near Fort Chipewyan than in the rivers is supported by Hall et al. (2004) who found a mean total nitrogen concentration of 1.95 +/- 1.01 mg/L in lakes (n=57) as compared to 0.33 +/- 0.15 mg/L in flowing rivers (n=9) of the Peace-Athabasca Delta in October 2000.

Median and mean values for total nitrogen in RAMP acid sensitive lakes (2002-2005) were 0.96 and 1.27 mg/L respectively (RAMP 2006). Median total nitrogen concentrations for the Athabasca River between Fort Creek and Embarras(1968-2003) ranged from 0.4 to 0.6 mg/L (highest values in spring and summer) (Imperial Oil 2006).

Nitrate + nitrite concentrations were all below detection limit (0.1 mg/L), consistent with mean concentrations of 0.08 mg/L and 0.07 mg/L observed on the Athabasca and Peace Rivers (Table 5). Median and mean values for total nitrate + nitrite in RAMP acid sensitive lakes (2002-2005) were 0.003 and 0.024 mg/L respectively, while median and mean values in 348 regional lakes were 0.002 and 0.021 (RAMP 2006). Median nitrate + nitrite concentrations for the Athabasca River between Fort

Creek and Embarras (1968-2003) ranged from 0.003 to 0.2 mg/L (highest in winter) (Imperial Oil 2006).

The chronic exposure total nitrogen guideline for protection of aquatic life is 1.0 mg/L (Table 3). The water quality data indicate that total nitrogen guidelines are commonly exceeded in the lakes of the Peace-Athabasca Delta whereas nitrogen guidelines are not often exceeded in the region's flowing rivers. It is not possible to determine whether nitrite guidelines are exceeded in the region since nitrite and nitrate are reported as one number in the available data.

Levels of nitrogen in the water around Fort Chipewyan do not pose a direct concern for human health but may pose a concern for aquatic life and indirectly to humans who depend on wildlife. An abundance of nitrogen in warm and shallow water may affect humans through environmental nuisances such as odors, eutrophication, and algal blooms—which can in turn impact aquatic life and waterfowl used for human food.

Coliform Bacteria

Total coliforms were present in the three surface water samples (4-20 colonies/100 mL) but absent in the treated tap water (Table 7). Fecal coliforms were present in only the Rochers River sample (5 colonies/100 mL).

There are no CCME guidelines for total and fecal coliforms for protection of aquatic life. For direct contact recreation, the mean of >/= five samples over not more than a 30-day period should have a total coliform count < 1000 colonies/100 mL and a fecal coliform count of <200 colonies/100 mL (Alberta Environment 1999). The coliform counts for the three surface water samples are well within these guidelines.

Total coliform colonies in untreated surface ("raw") water ranged between 4 and 384 colonies / 100 mL over the period December 1996 to July 2007, with a median of 12 and a mean of 31 colonies / 100 mL (Table 9, Figure 8). Two maxima of 300 and 384 fecal colonies were observed on 14 August 2002. Fecal coliforms in raw water over the period were usually at or below the detection limit of 4 colonies / 100 mL in the data provided by Alberta Environment. Two maxima of 38 and 44 fecal colonies were observed on 14 August 2002. These counts are well-within the "direct contact recreation" guidelines of Alberta Environment.

The only public health concern evident in the raw water data is the increasing trend in total coliform counts over the period (Spearman rank correlation, $r = 0.303$, $n = 103$, $p = 0.002$). Highest bacterial counts are usually observed in the autumn. It is unclear why the abundance of total coliform colonies increased over the period.

Treated water samples contained no fecal coliforms and no total coliforms over the period for which data were made available (Table 9). Treatment at the plant is effectively removing coliform bacteria from the drinking water. Rising temperatures may underlie the increase in total coliforms in the surface water.

Miscellaneous Parameters of Concern

During 2005, exceedences of water quality guidelines for the Athabasca River mainstem "downstream of development", were recorded for: dissolved phosphorus and total concentrations of phosphorus, aluminum, iron, chromium, cobalt, copper, lead, titanium, and phenols (RAMP 2006, their Table 5.1-4). Most exceedences were observed in spring (9 parameters) and fewest exceedences were observed in winter (4 parameters).

The largest exceedences were for aluminum (2-60 times the guideline) and iron (3 to 59 times the guideline).

The pollution associated with uranium mining on Lake Athabasca requires study (Evans et al. 2002). The Lorado Mine (closed in 1960) left 0.6 million tonnes of tailings; and the Beaverlodge Mine (closed in 1982) left six million tonnes (Sierra Club 2001). The tailings contain about 85% of the radiation in the original ore in the form of radioactive uranium, thorium, radium, and polonium, as well as heavy metals such as arsenic, copper, lead, nickel, and zinc. Gunnar (which operated from 1955 to 1964) left five million tonnes of tailings (SE 2006). Large amounts of tailings entered Langley Bay. Levels of radioactive uranium, radon and lead are reportedly much higher in the bay's sediments and its whitefish than in 'control' areas also on Lake Athabasca (SE 2006). The tailings at Lorado and Gunnar leach acids and heavy metals. At Gunnar, tailings entered Lake Athabasca when the retainment dam was destroyed (SE 2006). At Beaverlodge, most of the tailings were dumped into Beaverlodge Lake (Sierra Club 2001).

Elevated levels of selenium and relatively high levels of growth deformities in fishes have been observed in Beaverlodge Lake (WUO 2005). Relatively high levels of uranium were observed in 2002 in Labrador tea (*Ledum groenlandicum*) and in lake whitefish from Lake Athabasca near Uranium City (AWG 2002). The former Alberta Premier, Ralph Klein, referred to the situation at Uranium City in 1993 as one of Canada's "worst environmental nightmares" (Sierra Club 2001). The cost of cleanup at Gunnar and surrounding satellite mines has been estimated at $23-24 million dollars over eight years (Saskatchewan Govt. 2004). Sierra Club (2001) stated that the actual cost may be nearer to $100-150 million dollars.

The effects of agriculture on the Fort Chipewyan area are not well documented. Upstream, pesticides and fertilizers are applied in varying amounts to crops such as canola, oats, peas, and barley (Evans 2000). Over the period 1995 to 2002, five pesticides were found to exceed water quality guidelines in the Peace and Athabasca River basins (Anderson 2005). The herbicides dicamba and mcpa exceeded irrigation water quality guidelines in 11% of samples in both rivers; bromacil exceeded guidelines in the Athabasca River basin. Guidelines for the protection of aquatic life were exceeded for the persistent insecticide lindane and for the herbicide triallate. Pesticide concentrations were generally < 1 μg/L, with maximum concentrations of 2 to >6 μg/L in the Athabasca River and 1 to 13.8 μg/L in the Peace River. Aquatic life protection guidelines were exceeded more often in the Peace River (3.8% of samples) than in the Athabasca River (0.5% of samples). Lindane is banned for all agricultural uses in the United States but is still used in Canada.

Table 7. Summary of water quality values for the four sites.

Parameter	Rochers River at Mission Creek	LA Water Intake	Fletcher Channel	Tap Water
Arsenic Total	3.4 µg/L	2.6 µg/L	1.6 µg/L	<0.4 µg/L (ND)*
Mercury Total	0.00139 µg/L	0.00161 µg/L	0.00325 µg/L	0.00083 µg/L
Methylmercury	0.000134 µg/L	0.000134 µg/L	0.000124 µg/L	<0.00005 µg/L (ND)
PAHs (CCME)	all <0.01 µg/L (ND); 58-84% recovery of surrogates	all <0.01 µg/L (ND)*; 58-80% recovery of surrogates	all <0.01 µg/L (ND)*; 65-74% recovery of surrogates	all <0.01 µg/L (ND)*; 61-77% recovery of surrogates
Dioxins and Furans	see Table 8			
Naphthenic Acids	<0.01 mg/L (ND)	<0.01 mg/L (ND)	<0.01 mg/L (ND)	<0.01 mg/L (ND)
Coliforms Total	20 CFU/100mL	4 CFU/100mL	7 CFU/100mL	<1 CFU/100mL (ND)
Coliforms Fecal	5 CFU/100 mL	<1 CFU/100 mL (ND)	<1 CFU/100 mL (ND)	<1 CFU/100 mL (ND)
Nitrogen Total	1.0 mg/L	0.7 mg/L	0.6 mg/L	0.2 mg/L
Nitrite+Nitrate	<0.1 mg/L (ND)	<0.1 mg/L (ND)	<0.1 mg/L (ND)	<0.1 mg/L (ND)

* ND = below the detection limit

Table 8. Concentrations of dioxins and furans from water at four sites near Fort Chipewyan. Values are in pg/L.

Site	T4CDD	P5CDD	H6CDD	H7CDD	O8CDD	T4CDF	P5CDF	H6CDF	H7CDF	O8CDF
Rochers R. at Mission Creek	^ ND (0.3)	2.2	ND (0.1)	1.1	3.7	ND (0.2)	ND (0.1)	ND (0.1)	ND (0.1)	ND (0.1)
LA water intake	ND (0.6)	7.9	ND (0.2)	ND (0.2)	3.4	ND (0.2)	ND (0.2)	ND (0.1)	ND (0.2)	ND (0.2)
Fletcher Channel	ND (0.2)	1.6	ND (0.2)	ND (0.2)	3.1	ND (0.1)	ND (0.1)	ND (0.1)	ND (0.2)	ND (0.2)
Tap water	ND (0.3)	ND (0.1)	ND (0.1)	ND (0.2)	ND (0.4)	ND (0.1)	ND (0.1)	ND (0.1)	ND (0.1)	ND (0.2)

^ ND = not detected. The value in parentheses is the sample detection limit.

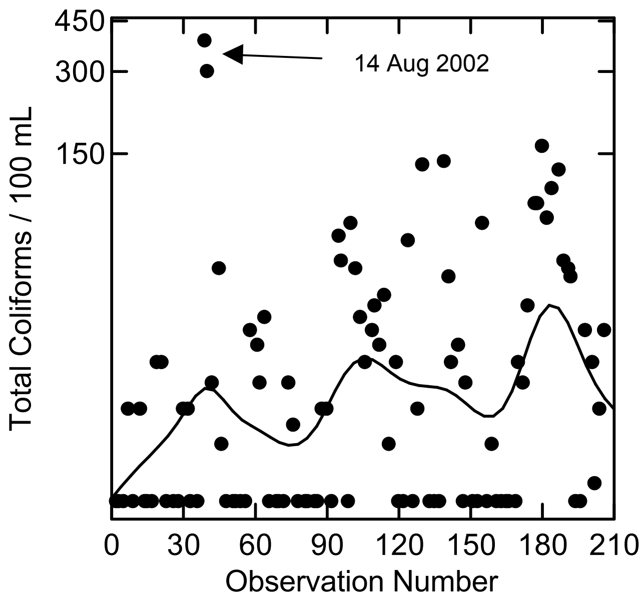

Figure 8. Total coliform colonies per 100 mL in “raw water” at Fort Chipewyan, with “less than” values included, 3 Dec 1996 to 3 July 2007, n = 103 (100 values between 6 June 2001 and 3 July 2007). Y-axis is power transformed (power = 0.1), line is a distance-weighted least squares regression, tension = 0.5. Data provided courtesy of Kathleen Pongar, Alberta Environment, 23 July 2007.

Table 9. Statistics for total and fecal coliform colonies per 100 mL in “raw water” at Fort Chipewyan (3 Dec 1996 to 3 July 2007, 100 values between 6 June 2001 and 3 July 2007) and statistics for total coliforms (presence/absence, 3 Mar 2003 to 8 May 2007) and fecal coliform colonies per 100 mL in treated water at Fort Chipewyan (3 Mar 2003 to 29 Apr 2003). Data provided courtesy of Kathleen Pongar, Alberta Environment, July and June 2007.

	Raw Water (coliforms / 100 mL)		Treated Water (P/A, coliforms / 100 mL)	
Statistic	Total	Fecal	Total	Fecal
Mean	31.0	5.1	0	0
Median	12.0	4.0	0	0
Minimum	4	4	0	0
Maximum	384	44	0	0
n	103	101	423	16

Sediment Quality

To facilitate placing the sediment observations in context, I have included relevant sediment quality data from a previous study in Lake Athabasca (Bourbonniere et al. 1996, Figure 9). In order to differentiate the data sources in this section, data from this study appear in italics.

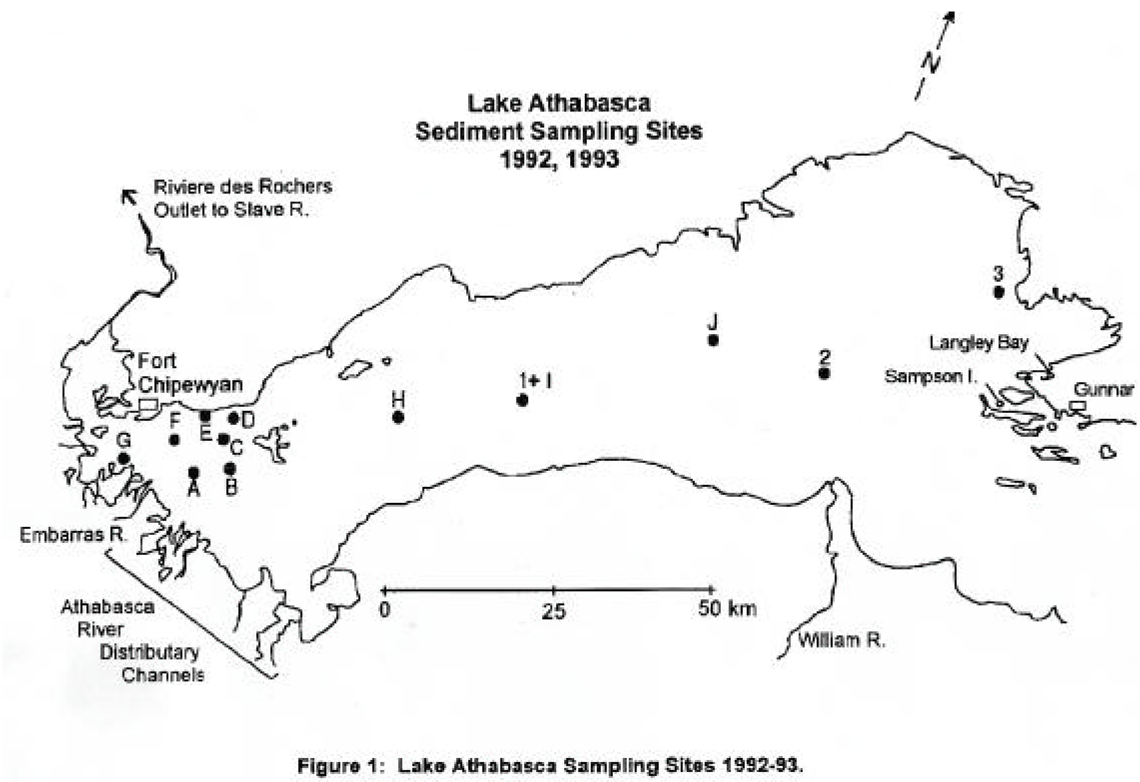

Figure 9. Sample site locations from the sediment study by Bourbonniere et al. (1996).

Arsenic, Mercury, and Other Heavy Metals

Arsenic

Lake Athabasca sediment arsenic concentrations observed by Bourbonniere et al. (1996) and in this study are in close agreement with mean of 9.04 mg/kg and a median of 8.80 mg/kg (n = 10, Table 10). The Fletcher Channel sediment arsenic concentration was 1.8 mg/kg. Seven of the ten Lake Athabasca arsenic concentrations exceeded the interim sediment quality guideline of 5.9 mg/kg. Imperial Oil (2006) reported a median sediment arsenic concentration 4.5 mg/kg (maximum 6.6 mg/kg, n = 21) for the lower Athabasca River between Fort Creek and Embarras.

Bourbonniere et al. (1996) noted that arsenic concentrations showed an increasing trend over time from 1970, starting at 2 mg/kg and increasing to 10 mg/kg by 1990. They noted that Allan (1979) had found a similar profile for arsenic in the central-west basin of Great Slave Lake, who suggested that surface enrichment may be related to processing at gold mines. The sediment arsenic concentration was high at one Langley Bay, Lake Athabasca coring location near uranium mining activities (Joshi et al. 1989). Uranium mining might partly explain some of the elevated arsenic values in Lake Athabasca, but Bourbonniere et al. (1996) thought that the arsenic more likely originated from western Lake Athabasca. They concluded that an east to west transport of arsenic in Lake Athabasca was unlikely and another source must be invoked to explain higher recent values for arsenic.

Mercury and Methylmercury

The available data for total mercury and methylmercury in sediment near Fort Chipewyan are enigmatic (Table 10). In the Bourbonniere et al. data, most of the total mercury was in the form of methylmercury. In the sites near Fort Chipewyan (sites B, D, F, and G), total mercury ranged from 85.0 to 89.0 µg/kg while methylmercury ranged from 73.0 to 89.0 µg/kg. By comparison, total mercury was 60 µg/kg at the Rochers River site of this study but below detection limits at the other two sites (< 50 µg/kg). Methylmercury was found at two of the three sites, but at concentrations more than 100 times lower than found by Bourbonniere et al.

These differences may be due in part to laboratory methods. Recent sedimentation may be another factor that may help to explain the low methylmercury concentrations in this study. In the spring of 2007, a large amount of fresh sediment was deposited as a result of high discharge on the region's rivers. There may have been too little time for methylation of the mercury in the sediment to proceed. Conversely, sediment methylmercury concentrations in excess of 1% total mercury may be unrealistic (Ullrich et al. 2001), which calls into question the accuracy of the methylmercury values reported by Bourbonniere et al. (1996) which accounted for most of the total mercury.

Total mercury ranged from 42.5 to 200 µg/kg in the sediment of five lakes of the Athabasca oil sands region; no data were provided for methylmercury (Shell Canada 2006).

Total mercury ranged from 11.1 to 33.0 µg/kg in the sediment of five lakes in Wyoming, while methylmercury ranged from 0.53 to 3.05 µg/kg, with methylmercury accounting for 1.8 to 11.0% of total mercury (Peterson and Boughton 2000).

Further analyses of mercury contained in the sediments near Fort Chipewyan are needed.

Other Heavy Metals

Lead, chromium, copper, vanadium, and zinc, assessed by Bourbonniere et al. (1996) exhibited a nearly constant concentration with depth. Zinc and copper concentrations were relatively high over western Lake Athabasca. Those authors noted that their concentrations for copper, zinc, arsenic, and total mercury agreed well with the results of Allan and Jackson (1978) from Lake Athabasca. They concluded "that many of these metals have sources in the western part of the lake and probably move offshore according to grain size. An increasing trend from river to delta to lake for many of the same metals studied was reported by Allan and Jackson (1978)."

Cadmium levels in all of the surface sediments (sites G, F, B, D, and I) exceeded the interim sediment quality guideline of 0.6 mg/kg by a factor to 3 to 4 times the guideline.

Imperial Oil (2006, their Table 5-29) noted an exceedence for a maximum concentration of chromium (ISQG 37.3 mg/kg) of 61.3 mg/kg (Athabasca River, between Fort Creek and Embarras, fall 1997-2003, n=21; and two of three observations during summer 1976-95 were also in excess of guideline: 54 and 85 mg/kg).

Table 10. Heavy metal concentrations in 1992 surficial sediments in western Lake Athabasca (from Bourbonniere et al. 1996, their Tables 6 and 7) compared to arsenic and mercury concentrations at three sites near Fort Chipewyan (this study). Values are in mg/kg (with exception of mercury for which values are in µg/kg). Note that the sites of Bourbonniere et al. are arranged in a westmost (site G, top of table) to eastmost (site S3) pattern.

Site	Arsenic	Lead	Cadmium	Chromium	Copper	Vanadium	Zinc	Total Mercury	Methyl-mercury
G	8.5	8.8	1.8	26.5	23.1	36.2	98.2	86.0	86.0
F	8.5	8.2	2.1	27.8	26.6	36.5	102.0	89.0	89.0
B	3.1	7.4	2.2	28.8	24.3	32.6	98.5	83.0	73.0
D	5	8.5	2.1	27.8	25.3	36.4	106.0	85.0	78.0
I	22.9	10.9	2.5	30.6	23.2	40.4	100.0	74.0	63.0
S1CB (0-6)	5.5	9.1	ND*	31.7	25.6	46.0	110.0	126	ND (20)
S2CA (0-6)	9.5	7.2	ND*	35.5	22.7	46.4	87.1	83.3	21.3
S3CB (0-6)	9.1	5.9	ND*	24.4	14.7	30.3	54.2	25	ND (20)
Rochers R. at Mission Ck	*9.1*							*60*	*0.281*
LA Water Intake	*9.2*							*ND (50)*	*0.137*
Fletcher Channel	*1.8*							*ND (50)*	*ND (0.050)*

* detection level of 0.3 mg/kg

Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs were assessed by the GC/MS method. In order to place those values in context, PAH concentrations determined by the same method by Bourbonniere et al. (1996) are provided in Table 11. Those data indicate only one exceedence (for phenanthrene, 42 µg/kg at Bourbonniere's site D). It is difficult to compare the data from this study with those of Bourbonniere et al. due to differences in detection limits. For those types of PAHs for which a comparison can be made, it appears that the levels of phenanthrene, pyrene, benzo(b)fluoranthene, and perhaps benzo(a)pyrene observed in this study were lower than those observed in 1992.

Bourbonniere et al. (1996) detected 11 types of PAHs.

Data from the lower Athabasca River (reported by Imperial Oil 2006) indicate exceedences of sediment quality guidelines for naphthalene, acenaphthene, dibenzo(a,h)anthracene, benzo(a)pyrene, chrysene, phenanthrene, and pyrene (Table 12).

Sediment samples from the lower Athabasca River and major open-drainage lakes adjacent to Fort Chipewyan were studied for PAH concentrations by Evans et al. (2002) (Table 13). Evans et al. (2002) observed that PAH concentrations were variable in space and time. Overall, sediment quality guidelines were exceeded in 7 % of the samples. Concentrations of 2-methylnaphthalene exceeded guidelines in 35.6% of samples while those of naphthalene, benzo(a)anthracene, and chrysene exceeded guidelines in 6.8% of samples. Guidelines levels of fluoranthene and pyrene were exceeded only in "Fort Chipewyan Harbor". Lower molecular weight PAHs tended to increase in concentration from upstream sources to downstream depositional areas. Bioassay toxicity testing was done on some sediment samples using the midge *Chironomus tentans*, the amphipod *Hyalella azteca,* and the oligochaete worm *Lumbriculus variegatus*. In a 1999 Athabasca River Delta sample, survivorship was low for *C. tentans* (42%) and *H. azteca* (72%). Growth of *Lumbriculus* was low in both 1999 (62%) and 2000 (53-58% in two samples).

In the PERD lakes (exclusive of the RAMP river data), four of the PAHs exceeded guidelines: naphthalene (18.5% of samples), 2-methylnaphthalene (70.4% of samples), and fluoranthene and pyrene (both 3.7% of samples). Ratios of unsubstituted to alkylated PAHs in Athabasca River are on the order of 0.05 to 0.4, indicating that most PAHs in Athabasca River sediments are from oil sands deposits rather than from combustion sources (Shell Canada 2006).

Six PAHs exceeded guidelines in some sediment samples on the Peace and Athabasca Rivers (phenanthrene, benzo(a)anthracene, benzo(a)pyrene, chrysene, fluoranthene, and pyrene) (Crosley 1996). The frequencies of exceedences were not reported, but inspection of the raw data indicated that exceedences were uncommon.

Taken together, the data indicate that concentrations of PAHs in the lower Athabasca River and the adjacent delta and western Lake Athabasca can vary greatly in time and space and may at times exceed guidelines.

Table 11. Concentrations of PAHs from 1992 surficial sediments in western Lake Athabasca (from Bourbonniere et al. 1996, their Table 5, by GCMS method) compared to those observed at three sites near Fort Chipewyan (this study). Abbreviations: Naphthalene (Npth); Fluorene (Fl); Phenanthrene (Ph); Fluoranthene (Fth); Pyrene (Py); Benzo(b)fluoranthene (B(b)Fth); Benzo(k)fluoranthene (B(k)Fth); Benzo(a)pyrene (B(a)Py); Benzo(ghi)perylene (B(ghi)Per). See Figure 9 for site locations. Values are in micrograms / kg (= nanograms / g).

Site	Npth	Fl	Ph	Fth	Py	B(b)Fth	B(k)Fth	B(a)Py	B(ghi)Per
G	4.8	*ND (0.5)	22	11	18	24	ND (0.5)	ND (0.5)	ND (0.5)
B	^ tr (2.7)	ND (0.5)	26	11	18	29	ND (0.5)	8.9	22
D	8	ND (0.4)	42	12	21	35	ND (0.4)	15	30
H	tr (2.0)	ND (0.6)	25	11	13	36	ND (0.6)	ND (0.6)	29
I	tr (1.7)	ND (1.0)	29.5	15	13.5	40.5	ND (1.0)	17.5	35
Mission Creek	** *ND (10)*	^^ *NA*	*20*	*NA*	*10*	*10*	*ND (10)*	*ND (10)*	*NA*
LA water intake	*ND (10)*	*NA*	*10*	*NA*	*ND (10)*	*10*	*ND (10)*	*ND (10)*	*NA*
Fletcher Channel	*ND (10)*	*NA*	*ND (10)*	*NA*	*ND (10)*	*ND (10)*	*ND (10)*	*ND (10)*	*NA*

^ trace values are greater than the method detection but less than the quantitation limit
* ND values are less than the method detection limit (given in parentheses)
** ND values are less than the method detection limit (given in parentheses)
^^ NA = not assessed

Table 12. Maximum concentrations of nine PAHs in the Athabasca River between Fort Creek and Embarras, fall 1997 to 2003 (from Imperial Oil, 2006, volume 3, their Table 5-29). Exceedences of guidelines are bolded. PAH assay method was not specified.

PAH	Maximum Observed (µg/kg)	Interim Sediment Quality Guideline (CCME 2002, µg/kg)	N	Comments
Naphthalene	**37**	34.6	22	
Acenaphthene	**11.3**	?	21	no CCME standard, but Imperial (2006) listed the maximum concentration as an exceedence
Dibenzo(a,h) anthracene	**41.7**	6.22	22	
Benzo(a)anthracene	27	31.7	22	
Benzo(a)pyrene	**95**	31.9	22	
Chrysene	**1010**	57.1	20	
Fluoranthene	65.5	111	22	
Phenanthrene	**189**	41.9	22	
Pyrene	**435**	53.0	22	

Table 13. Exceedences of sediment quality guidelines for PAHs reported by Evans et al. (2002) from 73 study sites in Lake Athabasca and the lower Athabasca River. The 73 sites included 46 Regional Aquatics Monitoring Program (RAMP) samples from the Athabasca, Clearwater, Muskeg, and Mackay Rivers and McLean and Fort Creeks and 27 Petroleum and Energy Development (PERD) samples from western Lake Athabasca, the Athabasca Delta, Mamawi Lake, and Lake Claire. PAH assay method was not specified.

PAH	Exceedences (% of observations in exceedence, range in exceedence values in μg/kg)	Interim Sediment Quality Guideline (CCME 2002, μg/kg)	Comments
Naphthalene	6.8, 35-77	34.6	
2-Methylnaphthalene	35.6, 20-92	20.2	most common exceedence
Fluorene	0	21.2	
Phenanthrene	4.1, 45-58	41.9	
Benzo(a)anthracene	6.8, 48-300	31.7	highest values in Donald and McLean Cks and in the AR upstream of Fort Ck
Anthracene	0	46.9	
Chrysene	6.8, 142-900	57.1	highest values in Donald and McLean Cks and in the AR upstream of Fort Ck
Fluoranthene	1.4, 131	111	one exceedence in "Fort Chipewyan Harbor"
Pyrene	1.4, 118	53.0	one exceedence in "Fort Chipewyan Harbor"

Total PAHs in Sediments

Up to this point the results have focussed on concentrations of individual types of PAHs. What are the concentrations and trends for the total suite of PAHs in the sediments? Each of the four study sites, and the aggregate group, showed an apparent trend of increasing PAHs from 2001-2005 (Figure 10a, b). Mean concentrations for sediment PAHs in the Athabasca Delta assayed over the period 2001-2005 have varied from 1 to 1.4 mg/kg.

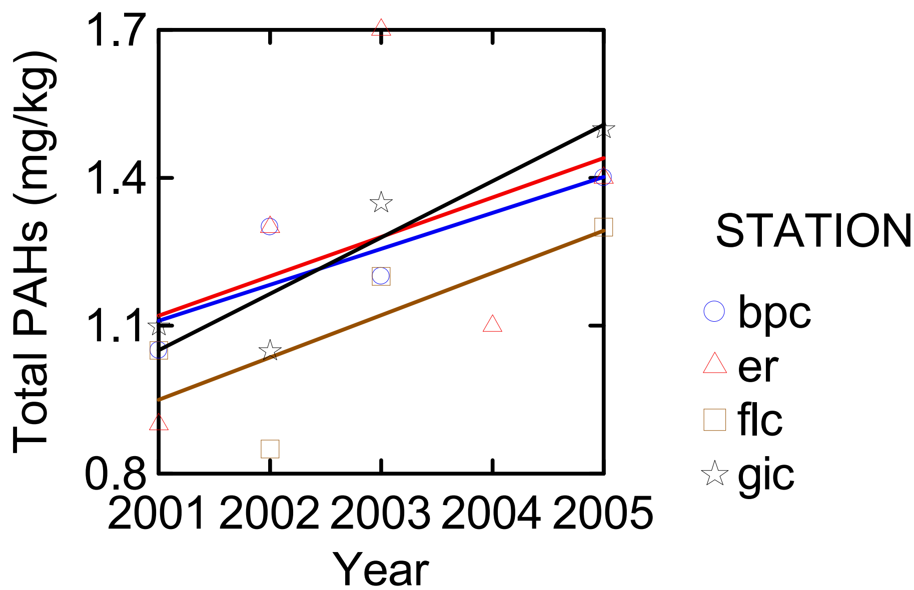

Figure 10a. PAH concentrations from four sites in the Athabasca River Delta (er = Embarras divergence; flc = Fletcher Channel, bpc = Big Point Channel, and gic = Goose Island Channel). Data re-analyzed from RAMP (2006). There are overlapping data points in four of five years. Lines are linear best fits.

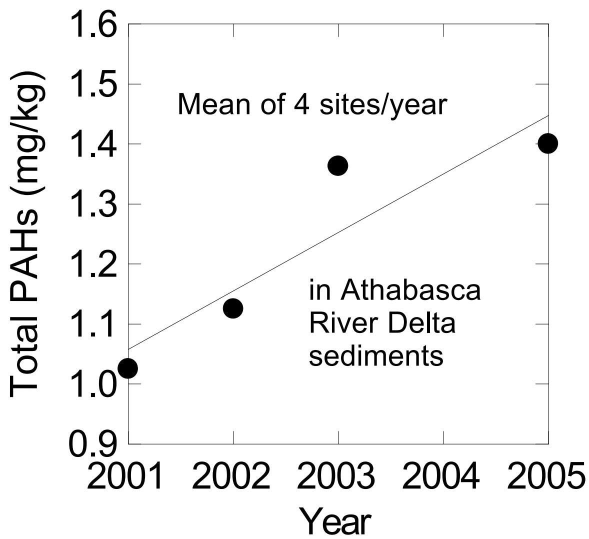

Figure 10b. Mean sediment PAH concentrations from four sites in the Athabasca River Delta (Embarras divergence; Fletcher Channel, Big Point Channel, and Goose Island Channel). Data re-analyzed from RAMP (2006).

Total PAHs in sediment of the Athabasca River along the reach from above Lesser Slave River to near Fort Mackay ranged from 0.637 to 2.233 mg/kg (mean 1.505 mg/kg) and that for the Peace River from above the Little Smoky River to below Fort Vermilion ranged from 2.363 to 4.115 mg/kg in October 1994 (mean 2.985 mg/kg; Crosley 1996).

RAMP (2001) reported total PAHs in sediment of 0.88, 1.59, 1.55 mg/kg for the Athabasca River upstream of Embarras River, Big Point Channel, and Flour Bay, respectively, as of the year 2000. In comparison, a 'historical median' (period 1976-99) total PAH concentration for the Athabasca River Delta of 1.22 mg/kg was reported. RAMP (2001) concluded: "Sediments from the lower Athabasca River, including Athabasca Delta, were found to be toxic to several species of invertebrates." It is unclear why those data were not included in the RAMP (2006) report.

Sediments in almost all of the Athabasca River Delta contained high levels of PAHs and metals (RAMP 2006). When the ARD observed values are normalized to 1% total organic carbon, the observed total PAH values approximate 100 mg/kg of sediment, which exceeds the mean probable effect concentration of 22.8 mg/kg suggested by Wisconsin DNR (2003).

Are the lower Athabasca River sediment PAH concentrations a cause for concern? There are presently no Canadian guidelines for total PAHs in sediment. A study conducted for the US National Oceanic and Atmospheric Administration (Johnson 2000) recommended a threshold of 1 mg/kg dry weight of total PAHs in marine sediment for protection of estuarine fish populations. Above 1 mg/kg total PAHs, there was a substantial increase in the risk of liver disease, reproductive impairment, and potential effects on growth. Levels of total PAHs in sediments of the lower Athabasca River exceed by a factor of about two the PAH threshold observed to induce liver cancers in fishes (Myers et al. 2003).

Levels of cytochrome P450 1A (CYP 1A) in fish livers collected from the Athabasca River or its tributaries show large increases near tar sands mining sites (Colavecchia et al. 2006, 2007; Sherry et al. 2006, Tetreault et al. 2003b), as do fish liver cells exposed to lipophilic contaminants concentrated from the Athabasca River (Parrott et al. 1996). These increases, indicative of contaminant stress, are not evident at sites affected by natural erosion of tar sands bitumen (Tetreault et al. 2003a).

Dioxins and Furans

Minute levels of dioxins were detected in the 2007 sample (Table 14). The highest level of dioxin detected in this study was for O8CDD group at the Lake Athabasca water intake (5.6 pg/g). Similarly, Bourbonniere et al. (1996) found that O8CDD group was the most abundant of the dioxins. Levels of dioxins and furans in sediments near Fort Chipewyan may have declined since 1992 (Table 14). No furans were detected in this study.

Carey et al. (2004) noted an apparent decline in sediment concentrations of pulp-mill related PCDDs and PCDFs in the Athabasca River near Hinton over the period 1988-1995. They concluded that the Lake Athabasca sediment dioxin and furan data indicated long-range atmospheric transport and combustion seemed to be the primary sources of the contaminants. The major dioxin and furan congeners found are related to the fungicide pentachlorophenol used in western North America during the 1970s and early 1980s.

Toxic equivalencies (TEQ), based on the assumption that a non-detection equals one-half the detection limit were: Mission Creek 0.17 ng/kg; LA water intake 0.30 ng/kg; Fletcher Channel 0.22 ng/kg. As the CCME (2002) TEQ interim sediment quality guideline is 0.85 ng/kg, there were no exceedences observed at the three sites.

Naphthenic Acids

Naphthenic acids were not detected in the sediments (Table 15), a result that may stem from the high detection limit of the laboratory (1 mg/L). No regional sediment data for naphthenic acids were found.

Nitrogen

Observed levels of total nitrogen (Table 15) in the three sediment samples (0.02, 0.12, 0.14 %) are low to average for levels of percent nitrogen in subsoils in six Alberta ecoregions (0.06 to 0.19%) (Alberta Agriculture 2002).

Table 14. Concentrations of dioxins and furans from 1992 surficial sediments in western Lake Athabasca (from Bourbonniere et al. 1996, their Table 2, by GC/MS method) compared to those observed at three sites near Fort Chipewyan (this study). Values are in nanograms / kg (= picograms / g).

	Dioxins					Furans				
Site	T4CDD	P5CDD	H6CDD	H7CDD	O8CDD	T4CDF	P5CDF	H6CDF	H7CDF	O8CDF
G	2.9	^ ND (0.5)	2.4	5.6	16	0.9	ND (0.3)	ND (0.6)	ND (0.5)	ND (0.7)
F	11	5.9	5.3	2.7	7.2	0.6	ND (0.1)	ND (0.2)	ND (0.3)	0.7
B	8.4	6.0	4.8	5.4	17	0.6	ND (0.2)	ND (0.3)	ND (0.3)	ND (0.3)
D	8.5	3.7	5.0	2.9	14	1.0	ND (0.1)	1.1	0.6	0.4
H	11	3.4	4.4	4.1	10	1.6	ND (0.2)	ND (0.2)	0.8	0.9
I	6.4	4.4	5.9	8.8	23	2.1	ND (0.7)	ND (1.1)	ND (1.5)	ND (1.9)
* 1	8.8	5.6	4.3	4.4	12.9	1.5	ND (0.2)	0.6	0.7	0.9
Rochers R. at Mission Creek	*^ ND (0.1)*	*ND (0.1)*	*1.4*	*ND (0.2)*	*3.9*	*ND (0.1)*	*ND (0.1)*	*ND (0.1)*	*ND (0.2)*	*ND (0.2)*
LA water intake	*ND (0.2)*	*ND (0.2)*	*1.6*	*ND (0.3)*	*5.6*	*ND (0.1)*	*ND (0.1)*	*ND (0.2)*	*ND (0.3)*	*ND (0.4)*
Fletcher Channel	*ND (0.2)*	*ND (0.1)*	*ND (0.1)*	*ND (0.2)*	*ND (0.5)*	*ND (0.1)*	*ND (0.1)*	*ND (0.1)*	*ND (0.2)*	*ND (0.2)*

^ ND = not detected. The value in parentheses is the sample detection limit, which for the Bourbonniere et al. (1996) data equaled three times the maximum peak detected on baseline runs.
* Site 1 (of the 'deep core' sites, the nearest to Ft. Chipewyan) values are the average of sections 0 to 1, 2 to 3, and 4 to 5 cm. For P5CDF, two-thirds of the values were below detection limits (ND), for H6CDF, H7CDF, and O8CDF, one-third of the values were ND.

Coliform Bacteria

Total coliforms were present in the three sediment samples at a level of four colonies per gram (Table 15). Fecal coliform colonies were not detected.

Coliform populations in sediment near the shore of southern Lake Michigan were observed to vary over four orders of magnitude (Whitman et al. 2006). Multiple samples are needed to describe sediment coliform population variations in space and time.

It is likely that the observed levels of coliform bacteria in the three sediment samples do not pose a risk to human health.

Table 15. Naphthenic acid and nitrogen concentrations and coliform bacteria counts in the sediments near Fort Chipewyan.^

Site	Naphthenic Acids (mg/kg)	Nitrogen Total (%)	Coliforms Total (MPN/g)	Coliforms Fecal (MPN/g)
Rochers R. at Mission Creek	*ND (1)*	*0.14*	*4*	*ND (3)*
LA water intake	*ND (1)*	*0.12*	*4*	*ND (3)*
Fletcher Channel	*ND (1)*	*0.02*	*4*	*ND (3)*

^ ND = not detected. The value in parentheses is the sample detection limit.

Other Pollutants

Resin acids and chlorinated resin acids were detected in sediments at all the sites studied by Bourbonniere et al. (1996). Chlorinated resin acids do not occur in nature and are produced by pulp bleaching with chlorine (Carey et al. 2004). The westernmost site (site G, south of Fort Chipewyan) had the highest resin acid concentrations. Their presence may indicate that bleached kraft mill contaminants are reaching Lake Athabasca from the Athabasca River. Levels of resin and chlorinated resin acids in sediment at sites on the Wapiti and upper Athabasca Rivers declined from the late 1980s to 1995 due to changes in pulping methods (Carey et al. 2004).

The elevated resin acid concentrations near Fort Chipewyan may be due to its sheltered location relative to other sites and/or to winter freezing of ice to the bottom that might block removal of resin acids from the site (Bourbonniere et al. 1996). Resin acids and retene (a breakdown product of resin acids) may prove to be useful time markers in future sediment core studies (P. Hodson, pers. comm., November 2007).

3. Traditional Ecological Knowledge

Four elders were interviewed in person and recorded digitally. In the following, some of their observations are provided. Other observations are provided in sections on fish deformities and oil spills.

The observations of the elders are remarkably consistent. They say that the river water tastes differently now—oily, sour, or salty. When the river water is boiled, it leaves a brown scum in the pot. Fish (and muskrat) flesh is softer now, and watery. Ducks, muskrats, and fishes taste differently now. There is now a slimy, sticky, or gummy material (algae?) in their fishing nets in winter; this started in perhaps the mid-1990s. There is inadequate information provided to the community by outside agencies about the state of the ecosystem and human health. They have noted increased rates of cancer, diabetes, and heart problems.

John Piche, interviewed 31 May 2007 at his fish camp on the Rochers River.

John Piche still drinks the river water, but it does not taste good. On the Athabasca River, the water has an oily taste. He has seen oil seeping from the banks of the Athabasca River. When tea or coffee is made, the local river and lake water leaves a coating in the pot and on cups. He has noted an oily film on top of the water.

While he continues to drink from the river, he noted: "I know now it's affecting me... I feel tired... Water from the tap tastes different, it's a lot smoother, tastes better... but this water [the river],... I lose all my strength."

Regarding the Athabasca River's water quality, he noted that "No information is ever given to the people here, nothing, [they just keep saying] the water's fine, the water's fine."

He has seen many fish kills, especially in the spring time. Summer fish kills happen when the weather is hot.

Ducks in the spring, beavers, and muskrats taste differently now. They have a watery taste and the meat is tougher after it's cooked. Whitefish meat is softer now in summer.

Muskrats that live along the rivers are smaller than they used to be. He has noticed that "frog water" along the shores of the rivers is more common in recent years. JP wondered if the "frog water" prevents the muskrats from reaching full size.

Algal blooms are more common than they used to be. Fishing nets when pulled are nowadays often coated with a blackish slimy material, even in winter. He thought it might be algae.

Ice is no longer blue in winter. It is slushy and weaker.

The sky is lighter blue than it used to be, not deep blue. Sunsets are more red than they used to be.

Regarding air pollution from the south he noted: "I've seen that in town... south wind... a black cloud... [you] see that in cities... been in San Francisco, I've seen smog. I know what it looks like, that's what it was."

Johnny Courtereille, interviewed 1 June 2007, at his home in Fort Chipewyan.

He does not drink unboiled water from the river anymore. "You have to boil the water now. Dip your cup into a pot of tea; the water coats the cup brown; it didn't used to be like that."

"The water doesn't tasted good anymore. It's not sweet; there's a sour taste to the water."

"There's a gummy stuff that sticks to the nets in winter. It started at least 10 years ago; it's worse now."

Some years ago John Weeks dug a well [near Jackfish village and the Richardson River, on the Athabasca River and had the [ground]water tested. The results said the water was not fit to drink.

"Muskrats taste different in the Otter Lake area [near the Embarras R]. They have an oily taste. The muskrats near Sweetgrass [north of Lake Claire] don't taste oily."

Muskrat die-offs might have something to do with the water.

Years ago his dad had a trapline. There was a nice slough off the Athabasca across from Kathy ? cInnes's. "The river flooded into the slough and we thought there'd be lots of rats after the flood; no rats came; still today, no rats on that slough."

"Whitefish don't taste as good as they used to; they taste 'mossy'".

"Last spring there was a big fish die-off in Lake Claire; that water was so damn low in the winter."

"They take samples of water; we never hear nothing. They took some water samples from the Prairie River (about 20 years ago); still today, I never heard anything."

"TB was the number one disease in the past. Now more are diabetic, heart problems. Cancer... never heard of it long ago-- maybe one or two. Now, somebody gets sick and you hear it's cancer; you never used to hear that."

"All the information never comes back to town; I think the government, they hide... they don't tell you."

"Dr. O'Connor... he's the first doctor that's not hiding anything behind a bush."

Regarding the cancer rates... "Last year [2006] 22 people died here, half of cancer. There's something wrong... There has to be something wrong...." [The Alberta

Government's view that Fort Chipewyan cancer rates are not statistically elevated (Alberta Health and Wellness 2006) is based on an incomplete set of cancer statistics that ends in 2004].

What to do? "The Athabasca River... There's not too much we can do once they [oil companies] get their licence... The government gives them the license... All these problems they're causing, they should compensate the people; there's lots of ways they can help..."

Big Ray Ladouceur, interviewed 2 June 2007, at his home in Fort Chipewyan.

He used to drink untreated water from the Athabasca River. For the last 10 years he hasn't. When he stopped drinking the water, he used to haul water from town to his cabin. Now he drinks from a little 'muskeg' creek near his cabin, or he digs a shallow well over an underground stream.

There is a different taste and color to the Athabasca River now. When you boil water, it leaves a scum on the pot; there is oily sheen on top. He has noticed an oily sheen on the surface of the river when the water is flowing smoothly and there is no wind.

"They are really destroying the water... right from the farmer's fields... we have things coming down, you know, after a rain...the highways, they have salt, that ends up here... the sewers, whatever they discharge... the pulp mills, the mines from the east... we're collecting, we're the dumping ground... It's very dangerous to live here... I call it a danger zone, a red zone in this area, we've lost so many people."

He talked about setting nets in the winter time. "Have a drink of that water, you can taste salt in there... dad said the same thing...This thing is salty, how come?" [Total dissolved solids, a measure of the 'saltiness' of the water varies seasonally. During the period 1997 to 2005 total dissolved solids in the Athabasca River at Old Fort varied from a low of ~ 100-150 mg/L in early summer to a high of ~ 220 to 320 mg/L in the winter (RAMP 2006, their Figure 5.1-12).]

Of setting a fishing net in winter in a side creek connected to the Athabasca River ... "After two nights or so in the river, the net is just brown... it's a scum or something...dirty... years back... thirty, forty years ago, it wasn't like that... sticky, slimy thing... brown."

"It's killing the fish too... [About five years ago] Right here at Goose Island, one spring, after breakup, there were... maybe 10,000 fish floating on [Goose Island] creek... they went in there and they all died... don't know what the cause was... they were rotten, must have happened in the winter... there was whitefish, northern pike in there."

He has noticed many big die-offs of muskrats over the years. In the past (more than 10-15 years ago), when they would die-off, next year they' be back. Now, when they come back, in the first winter they are dying again. "They just can't increase, they keep dying."

He used to eat burbot liver, but hasn't for some time since he heard the liver can make you sick.

Ducks taste different now. And they pluck differently. Years ago you could pluck them. Now, the skin tears.

Fish flesh is softer than it used to be; e.g, northern pike.. when you would cook it, it was hard in the past . Now it's mushy.

Air pollution. The other day, at Big Point, there was a south wind. The smell was really strong, like the smell at Suncor. He had to skidoo to Camsell Portage recently. A man there told him "they were getting the smell there too, from Suncor and all that, tar smell... damn strong".

Diseases: This new kind of cancer is killing the young people too. There's more heart problems, and Alzheimer's. He thought aluminum might be a factor in the Alzheimer's. Years ago, you never heard about diabetes. People used to die of 'old age.' Young people are getting diabetes now.

"I think our main killer here is our water. That's what I've been trying to tell these reporters... It's too much chemicals in our water, too much garbage in our water... The air and the water are very important, without that, we're not going to exist... And these people that's more interested in money than life in this Earth... I don't know, that's just a piece of paper... Sure it's nice to have money, but who are you destroying down below? See, McMurray's not as affected as we are... they're upstream... we're getting everything from the Rockies on down, and from Saskatchewan... "

"Auntie Elsie, my uncle's wife, has a list of the people who died here... from [the year] 2000, took the names of people who died... my mother was the 98th one... more than that now...Must be at least a hundred now. Take all the names on that list and determine which ones died of cancer... out of those 98, maybe 50 or 60 of them died of that [cancer]... We're losing people in way higher numbers [than in the cities to the south]... [the government's number of cancer cases for Fort Chipewyan] don't make sense..."

"The oil companies they come here, they destroy the land... they'll never put that land the way it was... just leave a heck of a mess... It's gonna be another Sahara Desert."

"They have to watch what they're discharging, that's my main concern... and what they're using out there in the fields, it's been going on for years... without the people knowing in this part of the country... one of the beautifullest places to live... nice and quiet,... but one of the deadliest now... scared... how many more's gonna die, when's my turn?"

A friend killed a moose. "It had an enlarged liver... white spots right through..."

"If they don't... reduce the pollution of this country... straight across North America... we're not gonna have anything to drink in the years to come."

Jumbo Fraser, interviewed 2 June 2007, at his home in Fort Chipewyan.

He does not drink untreated surface water; he drinks water from the treatment plant. He does not drink bottled water.

He oversaw the water treatment from about 1966. About then he stopped drinking the surface water (he saw that the water was dirty).

When they go hunting, they haul water from town. If he uses surface water, he "boils the tar out of it."

He has noticed that boiled water leaves a brown or black scum around the pot. It is hard to get off the pot when cleaning.

"The Alberta government is just as bad as the oil companies... all they're looking for is that dollar... that's not right... Think what this country is going to be like in 50 years from now; there's just going to be a desert... All these tailings are going to be sitting there... Reclamation, they'll never put nothing back..."

He noted places where thick tar has seeped through the sands to the river. He compared these to the abandoned tailings ponds, and asked how it can be said that tailings water won't seep through the ground to the river.

He has heard people talk about oiled birds that couldn't fly.

He noted that there were thousands of pickerel in the spring 2007 kill in Lake Claire. He questioned whether it was winter-kill. If it were a winter-kill, where's the rest of the fish, how come it was just pickerel? Thousands of them floating near Frog Creek.

He has not seen oiled rats, nor has he seen bloody-nosed rats.

His favorite meal used to be goose and duck. Now, it's not his favorite meal anymore. He wondered why. Is the taste different? He doesn't know why.

He was filleting a walleye the other day and it was difficult to do, the flesh was too soft. Burbot are not like they used to be-- they used to be bigger.

Diseases. "Seems like our biggest disease is cancer." And heart disease. He had colon cancer in 1995. Not too many just die of old age. That doesn't happen anymore.

"Their [Alberta government's] numbers [on cancer in the community] are not that good. They've got lots to hide."

"I would like to see a good study... What's bringing the rare cancer?... Why?... Something like that, they should be really digging, and trying to figure out where in the heck that came from?"

"They should also look at the stuff that comes out of Lake Claire... Lake Mamawi... that's where we do most of our hunting... Whether it comes from the oil companies, or if it comes from up in the Birch Hills... the McIvor River... it would be nice to know if you could take a cup and go have a drink of this water... They say... drink tap water, don't drink this water... but why?"

If Lake Athabasca becomes too polluted to use as a water source, "then what do we do have?... all because of somebody wanting to make a whole bunch of money."

OTHER DATA and OBSERVATIONS

1. Chronic and Acute Spills of Bitumen and Tailings

Large and small oil and tailings spills have occurred in the basin, particularly in the oil sands area of the lower Athabasca River. Finding information to document these spills is no small task. Some examples are provided below.

A failure of a power plant at Suncor (Great Canadian Oil Sands) on 30 November 1967 resulted in a spill to an Athabasca River backwater (Shewchuk 1968). "The flare accumulator became flooded with oil because of the upset condition in the plant. The oil over flowed the accumulator into the flare pond and then over flowed the flare pond into a rather inaccessible heavily wooded slough area, unknown to operating personnel. Warm weather during the weeks of February 26 to March 7 resulted in heavy surface run-off carrying some of the oil to the Athabasca River. It was not known how much oil was lost..." On 7 March 1968, the government received a complaint of oil in the Athabasca River; on 11 March, an investigation began. While the documentation is unclear, it appears that in late March, "a bituminous layer of oil under the ice was evident and the Oils and Grease concentration was estimated to be 20,000 mg/L... The west side of the river was opened approximately ½ mile downstream from the Great Canadian Oil Sands plant and covered with a black layer of oil" (Shewchuk 1968).

In June 1970, a Suncor pipeline break spilled ~ 19,123 barrels of oil [roughly 3 million liters]. "Appreciable quantities did reach the river and were visible down to Lake Athabasca... oil was... visible in certain sections of the west end of the lake for approximately six days" (Hogge et al. 1970) (Figure 11). Even allowing for the passage of time, the actions on the part of industry and government to contain, mitigate, and monitor the spill were perfunctory. A government report (Hogge et al. 1970) stated that: "a surface boom had been installed below the 28th Base Line to contain free oil and the emulsion in Big Point Channel [date and location not specified]... a boom was being constructed to prevent the flow of oil into Des Rochers River... application of emulsifiers to Lake Athabasca was discontinued because of potential secondary effects and the oil appeared to have been dispersed by wind action... biological studies on aquatic life were being initiated to determine long term effects". No studies of long-term effects were found in a library search.

Due to conflicting reports, an independent biologist was hired by the Conservation Fraternity of Alberta to provide a biological assessment (Jakimchuk 1970). While the spill had occurred on 6 June 1970, as of 12 June, Jakimchuk found no evidence an effort had been made to stop the downstream flow of oil, during which time the slick had travelled some 240 km en route towards Lake Athabasca and the vicinity of Ft. Chipewyan. During a meeting on 11 June, Great Canadian Oil Sands (Suncor) "stated that all necessary men and equipment would be moved to the Embarras [Airport] location to stage a two front attack" (Hogge et al. 1970). The "attack" proved to be little more than a "low key" operation focussed on dispersing the oil with a chemical emulsifier (Jakimchuk 1970). "Opportunities to minimize the ecological significance of the spill have been lost with the entry of some oil into Lake Athabasca... There is justifiable reason for the existing controversy and a need for further investigations... The actual impact of the spill remains to be seen" (Jakimchuk 1970).

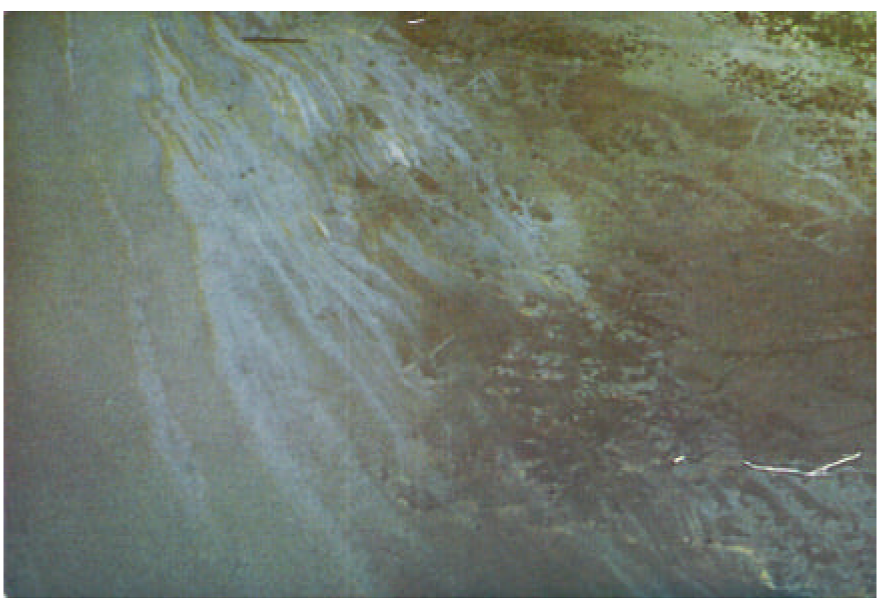

Figure 11. In June 1970, a Suncor pipeline break spilled ~ 19,123 barrels of oil [roughly 3 million liters]. "Appreciable quantities did reach the river and were visible down to Lake Athabasca... oil was... visible in certain sections of the west end of the lake for approximately six days" (Hogge et al. 1970). This is an aerial view of part of the oil slick that had reached the Peace-Athabasca Delta on 16 June 1970 (image from Hogge et al. 1970). The caption read: "Iridescence oil film on delta shore line."

Suncor Oil Spills (1981(?), 1982)

Suncor experienced at least one, perhaps two, spills in the early 1980s.

In 1981, “an oil spill in Fort McMurray affected the water and fish as far as Fort Chipewyan” (Brady 1985). No other documentation has been found to date.

In March 1982 there was a large spill from Suncor. While it would seem a matter of some importance to environmental officials and to the public, there is a dearth of readily available documentation for the spill. A prolonged search in the Alberta Environment library, and online, uncovered only one document pertaining to the spill. Alberta Environment (1982) is a single page terms of reference to investigate the spill of oil and contaminants from Suncor into the Athabasca River. The terms of reference, dated 17 March 1982, called for an investigation of the failures that led to the flow of oil and contaminants into a wastewater pond and the subsequent discharge of the oil and contaminants into the Athabasca River. If the study was ever carried out, there is no library record of it.

With the assistance of the Alberta Environmental Law Centre, I provide an excerpt of some of information in their law library.

From Judge Michael Horrocks’ decision:

1. Because of an earlier fire that had damaged a flare area, contaminated material escaped from a flare pond into the wastewater system. A major fire then took place on 21 January 1982 in the wastewater pond; one witness described the flames as being three hundred feet high. [This pattern of fire at a flare pond facility followed by a spill to the Athabasca River was the same sequence in the 1967-68 Suncor spill.]
2. Beginning on 17 February 1982 concentrations and volumes of oil and grease in the effluent rose above levels permitted in the Suncor license [420 kg/day]. Over the period 17-25 February, 42,129 kg of oil and grease were released. It is noteworthy that this volume is a minimum, as discharge occurred both before and after the 17-25 February period (see item 3).
3. On 16 February, an Alberta Fish and Wildlife Officer, T. A. Wendland, “saw a cloudy area and then we saw a sheen on the open water, an oil sheen on the open water.”
4. “There is no evidence that in the initial period these increasing rates of emissions into the Athabasca River gave any concern to the employees of Suncor.”

From the Edmonton Journal, 19 October 1982 (Struzik 1982a):

5. In the fall of the year, Suncor was in court to face the first two of 22 charges of spilling effluent into the Athabasca River.
6. “The charges were laid following spills last February which closed the commercial fishing season on Lake Athabasca and allegedly caused illnesses among natives in Fort Mackay.”
7. Joe Kostler, an Alberta Environment engineer, told court he first learned of the spill through a conversation with a fish and wildlife officer, four days after the first major spill. “Under the Clean Water Act, the company is required to report such spills within 24 hours.”
8. Bob Martin, Suncor’s water environment manager, testified that he believed the sheen on the river to be an “esthetic problem.”

From the Edmonton Journal, 23 October 1982 (Struzik 1982b):
9. A federal contaminant expert, Otto Langer, “said a 20-tonne spill could be ‘extremely catastrophic’ to the river system”. A minimum of 42 tonnes were spilled.
10. A provincial official, Joe Kostler, “was not of the opinion that the alleged spill would have an adverse effect on the river.”
11. “The provincial official said the environmental standard was set to meet the technological capabilities of the oil sands plant in controlling pollution and not necessarily to control the impact on the environment.”
12. Judge Michael Horrocks “asked Kostler why the department allowed Suncor to use a pollution monitoring device which was not standard or approved in the company’s license.”... “He also questioned why the department did not regularly check Suncor’s procedures for pollution monitoring, which are being challenged as unreliable evidence in the trial by the company’s lawyers. Kostler answered to both questions that he didn’t know.”

No data on contaminants such as mercury and arsenic in the spill were found. Nor was a study found of the ecological and human health impacts. Whether there were “catastrophic” downstream effects on the ecosystem and the people, we may never know. As a result of this spill, commercial fishing by local people was cancelled due to an oily taste in the fish (Brady 1985).

Has the situation improved in recent decades? That is difficult to tell due to the veil that has been drawn down over provincial river monitoring activities. In a recent book, Marsden (2007) noted that “Suncor admitted in 1997 that its Tar Island Pond... leaks approximately 1,600 cubic metres of toxic fluid into the Athabasca River every day.” That volume is 1,600 tonnes, roughly 38 times the size of the big spill in 1982 described above. If that statement is even remotely accurate, the Athabasca River is in trouble. Perhaps most of the leakage is captured and returned to Tar Island Pond—without publicly available data, the question is difficult to answer.

Other Spills

On about 20 October 1985 an estimated 10,000 gallons (about 45,000 litres) of fuel were spilled into Lake Athabasca at Uranium City (Saskatchewan Legislature 1986).

On 1 August 2000, one million liters of light crude oil were spilled into the Pine River, a tributary of the Peace River, from a ruptured pipeline (Oil Spill News, undated).

Despite a concerted effort, I was unable to quantify the oil spill rate for the lower Athabasca River. For the province as a whole from 1980-1997, there were 4,596 hydrocarbon pipeline releases of <100,000 litres, 88 releases of 100,000 to <1,000,000 litres, and 7 releases of 1,000,000 to <10,000,000 litres (AEUB 1998).

The question of *how much* oil and grease is in the river is important to the people of Fort Chipewyan. Yet, as with how much hydrocarbon is in Athabasca River, it is difficult to answer. Alberta Environment no longer relies on oil and grease as an indicator of hydrocarbons in surface waters (except in the cases of spills). “Oil and grease” includes fats, waxes, oils and other non-volatile materials such as sulfur. Much of this material is “natural”, particularly in water with abundant humic acids and where exposed oil sands deposits undergo erosion. Analyses of individual hydrocarbons are used instead, such as of extractable and volatile priority pollutants and polycyclic aromatic hydrocarbons (L. Noton, pers. comm., May 2006). Unfortunately, the latter analyses were not done until recently and are difficult to compare to earlier data. Secondly, datasets for the parameters of interest often contain large data gaps or too few observations for the data to be meaningful.

Analysis of the data often raises troubling questions. One example should suffice: On 13 July 2000, in the Muskeg River, 2.2 miles northeast of Fort Mackay at the Water Survey of Canada gauge, the extractable hydrocarbon concentration (carbon chain C8 and up) was 100 mg/L (data file: atha ab07D organic2.csv, supplied by Alberta Environment). The data file note read: "PAH not collected. water clean and clear, slight yellow color, oily sheen on surface, good flow, lots of minnows". Why was a PAH sample not collected? What caused such a high hydrocarbon concentration?

Failure to consider earlier oil and grease data creates an institutional amnesia and limits the ability to assess change. If a threshold of 5 mg/L of oil and grease is used to indicate an oil spill (P. McEachern, pers. comm., May 2006), Athabasca River spills took place on or around:

28 June 1973 (176 mg/L) [Sometime around August 1973, Oliver Glanfield, a long-time resident of Fort Chipewyan, observed a large oil slick in the Athabasca River while he flew at low elevation in an aircraft. He followed the slick upriver to the vicinity of the Steepbank River.]

24 Aug. 1976 (5 mg/L)

2 Sept. 1976 (7 mg/L)

9 July 1980 (8.2 mg/L)

and 30 March 1982 (5.9 mg/L).

As about 89% of Alberta Environment data for lower Athabasca River water quality pre-date the 1990s, the lack of more recent spills may be due, at least in part, to lack of data —this seems likely in light of the AEUB (1998) report.

Chronic human-caused pollution of the lower Athabasca River and adjacent western Lake Athabasca comes from licensed discharges; from above-ground and below-ground pipeline leaks and breaks; and from tailings pond leaks that are not captured and returned to the tailings ponds. There are thousands of kilometers of pipelines in the oil sands area and hundreds of stream crossings.

Abandoned tailing ponds pose a major threat of oil sands contamination (P. McEachern, Alberta Government, pers. comm., May 2006). While a mine is in operation, monitoring and pumping of tailing pond leaks is continuous. No one knows what will happen when a mine has exhausted a site, shuts down it operation, and leaves. Tailings pond abandonment is an unproven technology whose success is predicated on modeling rather than real world experience.

Based on a study of tailings pond management around the world, Morgenstern (2001) concluded: "There are too many failures involving waste containment structures... The reliability of mine waste containment structures is among the lowest of earth structures and risk-taking on the part of all stake-holders is excessive... Closure design involves time frames that exceed the performance history of most engineered structures."

The Tar Island Dike is a hydraulic fill structure about 3.5 km long and up to 90 m high. It rests in part on a deep layer of alluvial clay and has demonstrated a unique history of lateral creep. The dike, which rests on a weak foundation, was never intended to reach its current height. The nearby main tailings dam at Syncrude is a closed containment structure, ~18 km long with a height of 40 to 88 m and appears to be the largest earth structure in the world. It rests on a foundation of high plasticity clay shales with extraordinarily low strength.

On average, each oil sands company pumps 60 million cubic meters of water into tailings ponds each year. What will happen to the contaminated water? The McMurray Formation is known to be porous with active subsurface water movements. Billions of cubic meters of contaminated water soon will be sitting untended, with no active pumping, in abandoned ponds adjacent to the Athabasca River.

<u>Observations by Elders</u>

Some years ago, John Piche worked for Syncrude. He once saw a leak from the lease that made an oil slick in the Athabasca River. When he worked near Fort McMurray, he would sometimes go down to the Athabasca River for a picnic. Near Suncor, the river water tasted bad; he could not drink it. He recalled the big oil spill of 1981 and the shutting down of the fish plant in Fort Chipewyan due to oil pollution.

Ray Ladouceur: "That [oil spill, early 1970s or late 1960s] buggered up our fishing... even the fish later on tasted like oil... God knows how much fish we lost..." He observed some oiled ducks.

Johnny Courtereille remembered the big oil spill in spring 1968. People tried to clean up the oil. He was out spring hunting and shot a pintail duck that was sitting on the water. It was coated with oil. This was near the Embarras River, a distributary of the Athabasca River.

Jumbo Fraser remembered a couple of spills ... early 1970s? Straw bales were put along the shore of Lake Athabasca to soak up oil. They had a big store of hay bales on the lake in Fort Chipewyan for a while in case of another spill.

Big Ray Ladouceur remembered winter fishermen angling through the ice on Lake Athabasca during the 1980s. When they punched holes in the ice, they observed oil in the water. This oil may have been from the October 1985 spill of fuel oil at Uranium City.

About 15 years ago [in the 1990s], Jumbo Fraser was boating up the Athabasca to McMurray. "There was a gush of real black looking stuff coming out of a pipe...up in a berm, quite a ways up above the river, ... gushing out... I didn't have a camera... I continued on up and got a hold of the Coast Guard... We went right back down again [in Jumbo's boat, with the Coast Guard] and they had shut it off [the flow from the pipe]... it was going down to the river..." He asked: "What better way to get rid of it" [discharge of oil sands fluid waste into the river]?

Five or six years ago, Big Ray Ladouceur boated upriver to Fort McMurray for groceries. Right below Suncor, by Fort Mackay, for ten miles there was foam in the river. He wondered what has happening. "All of a sudden, I can see this foam coming out right about the middle of a river. There's a pump house there... Suncor. These guys seen me getting close, they went inside [the pump house]... I was looking at them... They shut it down... I went right close to them and I pointed... They were discharging foam... Again, this spring [2007], there was all kinds of foam right after break-up... My cousin, Mike Cardinal, he took some of that foam, dried it for few hours, he lit it, just like gas it burned." "What are they discharging into the river? ... we're getting so much foam here [in the Athabasca River Delta]... in the spring..."

Based on the contaminant spill documentation, data, and observations of elders, it seems reasonable to conclude that inadvertent and intentional pollution events have and will continue to impact the aquatic health of the lower Athabasca River and adjacent Lake Athabasca.

2. Contaminated Sites Within or Near Fort Chipewyan

At least two contaminated sites are known within Fort Chipewyan: a diesel fuel-contaminated site west of The Northern store at a former generating station and on the grounds of the health clinic. At the former generating station (Figure 12), diesel fuel contamination has spread west through the deep sand towards Lake Athabasca. The nearby fish processing plant will reportedly be moved in consequence of the fuel in the subsoil. For some reason, this site does not appear to be listed under the Federal Contaminated Sites Inventory.

At the health clinic, in 1998 and 2000, about 620 cubic meters of soil contaminated with petroleum hydrocarbons were removed as were underground and aboveground fuel tanks (Treasury Board of Canada 2005).

There are three other contaminated sites within Fort Chipewyan, one at the High Island Beacon in Lake Athabasca, one at Jackfish, a devegetated site with heavy metals on Bustard Island, and eight contaminated sites at Allison Bay. To date, little or no information is available on these sites (see Federal Contaminated Sites Inventory).

The degree to which these sites have in the past affected, or continue to affect, the health of Fort Chipewyan residents is unknown.

Figure 12. Part of the excavation to remove sands contaminated by diesel fuel in Fort Chipewyan. 2 June 2007.

3. Mercury in Walleye (Pickerel), Lake Whitefish, and Other Fishes

Mercury concentrations in commonly consumed mature fish of the lower Athabasca River pose a human health risk (Figures 13, 14). In September 2005, mean mercury concentrations in female and male walleye were 0.51 and 0.35 mg/kg while those in lake whitefish were 0.11 and 0.08 mg/kg (Table 16).

Mean mercury concentrations were ~ 4-5 times higher in walleye than in whitefish for both sexes. There was a clear trend of increasing mercury concentration with increased size of walleye. Virtually all walleye longer than 40 cm or weighing more than 500 g contained more than 0.20 mg/kg of mercury, the Health Canada subsistence fisher guideline (RAMP 2006, their Figures 5.1-29 and -30).

The Health Canada general consumer guideline for mercury was exceeded in ~ 30 % of male and ~ 40 % of female walleye. The Health Canada subsistence fisher guideline for mercury was exceeded in all female walleye and ~ 70 % of male walleye. If the more stringent US EPA standards are applied, all walleye, all female whitefish and ~ 90 % of male whitefish exceeded subsistence fisher guidelines. These values constitute a human health concern.

It is not known whether fishes caught in Lake Athabasca, or near Fort Chipewyan in particular, have similar mercury concentrations to those near the Muskeg and Steepbank Rivers. It would seem likely, however, as mercury is readily transported on suspended sediments (Ullrich et al. 2001). If a fish bioaccumulation factor of 1 to 10 million times (in keeping with US EPA 2001) is applied to the methylmercury concentrations observed near Fort Chipewyan in this study, predatory fishes in the lower Athabasca River and adjacent Lake Athabasca would be expected to contain about 0.12 mg/kg to 1.34 mg/kg of mercury. Mercury concentrations in walleye (pickerel) in the lower Athabasca River are indeed within this predicted range (mean 0.51 mg/kg in females, 0.35 mg/kg in males) while those in lake whitefish lie near the lower end of that range (mean 0.08 mg/kg in males and 0.11 mg/kg in females).

RAMP (2006) stated that the fish mercury concentrations observed were "consistent with the natural range of concentrations observed in this region of northern Alberta", but did not provide locations. RAMP (2006) further stated that significant temporal trends in tissue mercury were not found, but only three years of data were available and no statistics were provided. See section 6 (below) for a discussion of trends in mercury concentration.

Health Canada (2004) recommends that consumption of large predatory fish should not exceed one meal per week for adults. Pregnant women, women of child-bearing age, and children should consume no more than one fish meal per month. The predominant form of mercury in fish is methylmercury, but quantitative data on the ratio of organic to inorganic mercury in fish is scant due to the expense of analysis of individual mercury species. For the purposes of health risk assessments, it is assumed that all mercury in fish is in the form of methylmercury (Health Canada 2007).

For protection of the fetus, the World Health Organization has recommended that daily methylmercury intake should not exceed 0.23 micrograms/kg body weight (Health Canada 2007). For a 50 kg pregnant woman, the daily limit would be 11.5 micrograms methylmercury/day. If a 50 kg pregnant woman consumed 500 g of lower Athabasca region female walleye, she would consume, on average, 255 micrograms of mercury, roughly 22 times the recommended limit.

Another study (Golder 2003) observed even higher levels of mercury than reported above. Fillets of lake whitefish, sucker, and goldeye contained 0.18 to 5.9 mg/kg of mercury (n=28). Fillets of pike, walleye, burbot, and lake trout contained 0.1 to 3.4 mg/kg of mercury (n=45).Under US EPA subsistence fisher guidelines, all of these fishes would be considered unsafe to eat.

Due to the nutritional value of fish, and the traditional-cultural and economic importance of fish to Fort Chipewyan residents (Figures 15, 16), the mercury levels observed pose a serious dilemma. It would be prudent to determine local mercury levels in fish species consumed in Fort Chipewyan and mercury levels in human volunteers from Fort Chipewyan—this can be done through hair samples.

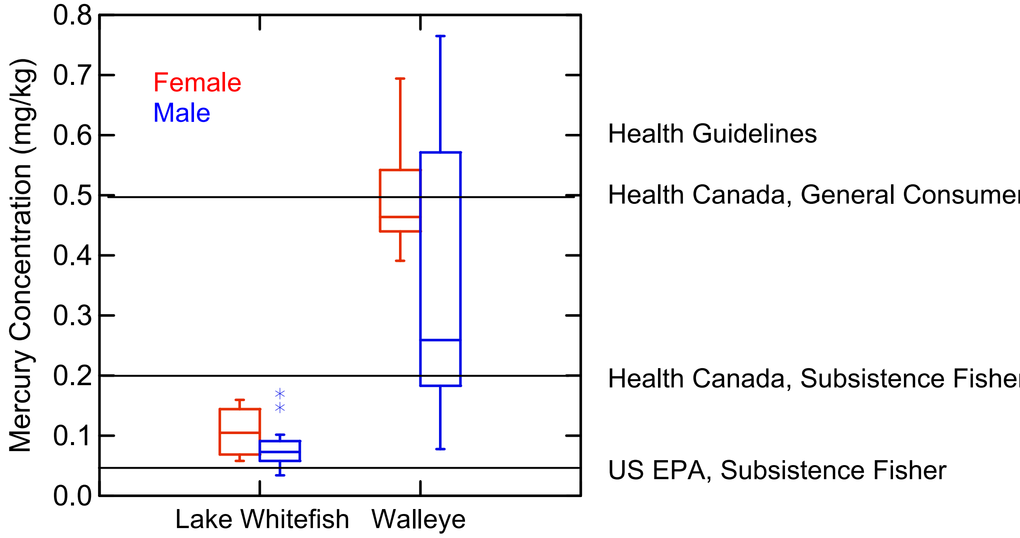

Figure 13. Health guidelines in relation to concentration of mercury (mg/kg, wet weight) in muscle of mature lake whitefish and walleye from the Athabasca River (from the Muskeg and Steepbank River areas), September 2005. Data summarized from RAMP (2006, their Table 5.1-15). See Table 16 for details.

Table 16. Concentration of mercury (mg/kg, wet weight) in muscle of mature lake whitefish and walleye (pickerel) from the Athabasca River (from the Muskeg and Steepbank River areas), September 2005. Data summarized from RAMP (2006, their Table 5.1-15).

	Whitefish (Hg mg/kg)		Walleye (Hg mg/kg)	
	Male	Female	Male	Female
Mean	0.081	0.106	0.352	0.510
Median	0.073	0.105	0.259	0.464
Maximum	0.170	0.160	0.765	0.694
Minimum	0.034	0.058	0.078	0.391
S.D.	0.037	0.040	0.237	0.110
95% CI, upper	0.101	0.133	0.478	0.595
95% CI, lower	0.061	0.079	0.225	0.425
Normality (p)*	0.445	0.850	0.246	0.709
N	15	11	16	9

* Kolmogorov-Smirnov one-sample normality test, two-tailed p

Figure 14. Forage fish in the throat of a walleye. As top predators, walleye effectively accumulate mercury. 31 May 2007

Figure 15. Elder John Piche at his summer fish camp preparing a supper of jackfish fillets. Locally-caught fish form an important part of the diet of many people in Fort Chipewyan. 31 May 2007.

Figure 16. Freshly-netted walleye, lake whitefish, and burbot caught by John Piche at his fish camp on the Rochers River. 31 May 2007.

4. Fish Deformities

Scientific Data

Fish abnormalities include a number of internal and external deviations from a normal, healthy condition. Depending on the study, abnormalities may include fin erosion, the presence of parasites, lesions, skeletal deformities, and tumors (Figure 17).

Observations on fish pathology types and rates vary widely between the various studies. Frequencies of abnormalities ranged from zero to 77% across a number of studies conducted from 1992 to 1994 in the Athabasca, Peace, and Slave Rivers and Lake Athabasca (Mill et al. 1997). Some of the variability in the frequency of abnormalities may be due to individual differences in classification of pathologies.

Mill et al. (1997) found: "Relatively low overall levels of gross pathology..." for most species, <1% of the fish... "Very high frequencies of pathological abnormalities" were sometimes observed (e.g., 23 of 30 lake whitefish). Occasionally, very high frequencies of abnormalities were observed in suckers (especially longnose suckers).

RAMP (2006) reported an abnormality frequency of 100% in Athabasca River female lake whitefish and walleye and 74% in males of those species [they reported an overall abnormality frequency of 81.5% for walleye and lake whitefish, but calculation of the weighted mean from data in their Table 5.1-12 indicated an overall mean of 83.9%]. The study noted that the data should be interpreted with caution due to the small sample size and the "lack of regional reference data characterizing the natural variability in the frequency of abnormalities."

RAMP (2006) estimated the frequency of external abnormalities in Athabasca River walleye and lake whitefish as 7.3% (75 of 1027 fishes). In Manitoba, the frequency of external deformities, erosions, lesions, and tumors on fish in the Red River was 7.9% and in the Assiniboine River was 15.6% (Cooley and Davies 2001). A survey of 100,000 fishes from US East Coast estuaries found 0.5% frequency of external abnormalities; the highest frequencies of abnormalities were observed in bottom-feeding fishes (US EPA 2003).

In its most recent report, RAMP (2007) used a 'pathology index' that is not comparable to estimates made earlier. While RAMP (2007) stated that 3.2% of the fish examined from 2006 showed external abnormalities, it is unclear from the data presented in their Section 5.1.5.1 and Tables 5.1-7 and 5.1-10 how that number was calculated. As typical of previous RAMP reports, changes in methods and means of reporting undermine the utility of the results.

At least 25% of female and 50% of male walleyes suffered from liver abnormalities in a recent sample from the Athabasca River (RAMP 2006, Table 5.1-12, n=24 fishes). It is of some concern that levels of PAHs in sediment of the Athabasca River are about twice that observed to induce liver cancers in fishes (Myers et al. 2003). The PAH signature in Athabasca River Delta sediments is consistent with that of tar sands bitumen (J. Short, pers. comm., October 2007).

Figure 17. These walleye caught in Lake Athabasca in 2007 exhibit external tumors, lesions, deformed spines, bulging eyes, abnormal fins, and other defects. Credit: L. Carota, Vancouver, BC.

Observations of Elders

Ray Ladouceur: “There’s deformed pickerel in Lake Athabasca... Pushed in faces, bulging eyes, humped back, crooked tails... never used to see that. Great big lumps on them... you poke that, it sprays water...” A friend caught a jackfish recently with two lower jaws... He had seen deformed jackfish before, but never one with two jaws.

Ray Ladouceur: “The skins on the whitefish are starting to turn red. Before they used to be white...What’s in the water?... Even goldeyes... they’re red... never seen that before. The lake trout on Lake Athabasca, great big heads and skinny little bodies... One of the healthiest lakes in Canada is now one of the deadliest lakes.”

Ray Ladouceur: “About five years ago, ... two of those boxes full of deformed pickerel... we sent them out to fish and wildlife... they sat there over the weekend, everything was rotten... they never sent those fish out to get tested... They should have put them in the cooler... I think they did that on purpose. They didn’t want to get the feedback... They’re scared.”

Johnny Courtereille: “Whitefish caught at Dog Camp... years back, they were white, no color; now they’re an orange color, a reddish color on the outside... red nose; sometimes they have one eye.”

John Piche: Burbot liver used to be light brown, clean, and clear. Now the liver is spotted. He now longer eats the liver, but still eats the meat.

Jumbo Fraser has noticed that walleyes have red bruises beneath the scales, but the meat beneath is okay. Some of the walleye have external growths.

Possible Causes for the Fish Abnormalities

Fish abnormalities are not necessarily related to water pollution or toxic discharges. Injury, disease, parasites, unusual water quality conditions (e.g., high temperatures), poor nutrition, and toxic algal blooms can also cause abnormalities. In the Northern River Basins Study, high frequencies of pathological abnormalities were observed in fish near pulp mill effluents and in lake whitefish perhaps "related to physiological and behavioural responses to spawning" (Mill et al. 1997).

Athabasca River natural bitumen and oil-refining wastewater pond sediments caused significant hatching alterations and increases in mortality, malformations, and reduced size in young fathead minnows (*Pimephales promelas*) (Colavecchia et al. 2004). "Larval deformities included edemas, hemorrhages, and spinal malformations." Fish embryos exposed to complex mixtures of petrogenic PAHs display a characteristic suite of abnormalities that include cardiac dysfunction, edema, spinal curvature, and reduction in the size of the jaw and other craniofacial structures (Incardona et al. 2004). Exposure to different PAH compounds leads to different and specific effects on young fishes (Incardona et al. 2004).

Four metals appear to exceed fish protection threshold effects levels in Athabasca River walleye and lake whitefish: aluminum, selenium, silver, and vanadium (RAMP 2006, their Table 5.1-17). Of these metals, selenium levels may present the largest risk to fish health (values of 0.46, 0.60 mg/kg in female and male walleye, and 0.45, 0.38 mg/kg in female and male lake whitefish). Selenium can contribute to reproductive failure, deformities, and death among aquatic organisms and water birds, and can adversely affect people (CRBSCF 1999).

At Beaverlodge Lake, as a result of uranium mining, elevated levels of selenium and relatively high levels of growth deformities in fishes have been observed (WUO 2005). Selenium levels are believed to be high enough to cause significant reproductive failure in fish populations over the next several decades.

It is difficult at this time to draw general conclusions about spatial patterns or temporal trends in the fish deformities from the scientific data alone. When combined, the scientific data and traditional knowledge suggest that rates of fish abnormalities may be higher than expected, may be increasing, and may be related to changes in water quality.

The changes in taste, texture, and deformities observed in the local fishes appear to signal ecological degradation. Some of the changes may be chemically-induced, but others may be a food-web effect. Soft, watery flesh noted in the traditional knowledge interviews might indicate starvation. Fish consume protein when starving and replace cell mass with water (P. Hodson, pers. comm., November 2007). Fishes with big heads and small bodies ("pinheads") are clearly starving. Starving fish suggest: (a) reduced productivity of food organisms due to pervasive pollution effects; (b) a break in the food web (e.g., a pollution-related loss of a keystone species); or (c) direct toxicity effects (P. Hodson, pers. comm., November 2007). Research by fisheries biologists and toxicologists is needed.

5. Cancer Risk and Arsenic Exposure

Estimating the effect on cancer rates of lifetime exposure to even one contaminant, such as arsenic, is analytically challenging and sensitive to assumptions. Suncor (2005) concluded that lifetime exposure to arsenic in the Wood Buffalo region could result in 312-453 additional cases of cancer per 100,000 people depending upon levels of local fish and vegetable consumption. Alberta Health and Wellness (2007) responded to the Suncor report and concluded that lifetime exposure to arsenic could result in an additional 17 to 33 cases of cancer per 100,000 people. Both the Suncor and Alberta Health and Wellness estimates were in excess of the "acceptable" rate of additional cancers of 1 per 100,000 people.

The Alberta Health and Wellness (2007) report concluded:

> "the current indigenous population is at little, if any, risk of developing cancer as a result of exposure to inorganic arsenic contributed by both naturally-occurring sources and existing anthropogenic sources in the region via the exposure pathways examined as part of the work"

Regarding the future, the government report concluded:

> "the current indigenous population is at essentially no risk of developing cancer as a result of exposure to any inorganic arsenic that might be contributed by projected future anthropogenic activity in the region via the exposure pathways examined. Added confidence is provided by the conservatism incorporated into the re-assessment."

The two reports are unlikely to settle the question of increased cancer risk due to arsenic exposure. Both reports are unpublished 'gray literature' that have not been subjected to impartial peer review. Both reports were modeling exercises that did not include fieldwork and interviews with the people of Fort Chipewyan. How realistic were assumptions about rates of exposure for commercial fishermen and traditional users who handle and clean many thousands of fish each year and consume more fish than assumed? The fact that the reports reached different conclusions only adds to the feelings of uncertainty about level of risk and demonstrate that risk assessment is sensitive to the assumptions used in the models.

Models of contaminant exposure are only as good as the data input into those models. In the case of the Alberta Health and Wellness report (2007), the statistics used for arsenic levels in soil and water appear open to question on several points. These are:

1. The model relied upon confidence limits of mean values of arsenic, but extreme values of a toxin may have disproportionate effects on human health.
2. The model used statistics (upper confidence limits of the mean) that rely upon a normal statistical distribution, yet the dissolved arsenic data for the Athabasca River are decidedly non-normal. For example, for datasets of Athabasca River dissolved arsenic (analyzed earlier in this report), the data are strongly non-normal. The effect on the calculation of cancer risk of using an incorrect statistical distribution of arsenic concentrations should be addressed.
3. There was unresolved uncertainty in the kinds of arsenic data in the government report (dissolved vs. total, organic vs. inorganic) which could affect the values used in the model. For example, mean dissolved arsenic values reported in RAMP (2006, their Table 6.6-5) are roughly 84% the concentration of total arsenic.

4. The arsenic levels assumed by the Alberta government for both water and sediment were underestimates (see respective sections in arsenic results). For water, the government used a mean arsenic concentration of 1 μg/L and an upper 95% confidence limit of the mean of 1.2 μg/L (n = 42). Depending on how the statistics were calculated and compared, the arsenic concentrations used by the government were 1.4-1.5 times lower than those relevant to the lower Athabasca River and Lake Athabasca.
5. For sediment, a similar underestimate of arsenic concentration and exposure resulted. The government used a mean arsenic concentration of 0.85-1.1 mg/kg and an upper 95% confidence limit of the mean of 1.3 mg/kg (n = 62). Depending on how the statistics were calculated and compared, the sediment arsenic concentrations used by the government were 3.5 to 10.6 times lower than those relevant to the lower Athabasca River and Lake Athabasca.

Why the government study reported lower levels of arsenic than those in this study is uncertain. The government study used RAMP Athabasca River and Ells River water quality data from the years 2002-2004 while the sediment data were derived from eight areas in the oil sands region. Limiting the data to only three years within a fairly small upstream area characterized by coarse-textured parent materials may have resulted in a skewed sample in the government study.

6. The government model of arsenic exposure was based on a wealth of assumptions about arsenic levels in wildlife and country food consumption rates that have scant data to support them. Yet the results are presented without recognition of the uncertainties inherent in the model. Much of the uncertainty in the government report could have been eliminated had that study gathered actual data in Fort Chipewyan. Rather than estimate arsenic exposure based on assumptions, empirical values for arsenic burdens in human tissue could have been determined.

There is a disconnect between the government report assumptions and the reality of life in Fort Chipewyan. The report, e.g., considered the consumption of "sport fish". People in Fort Chipewyan do not eat "sport fish" any more than they eat sport ducks and sport moose. Fish are a respected staple of the diet, not something to be dismissed as sport.

Arsenic and its metabolites bioaccumulate (but do not biomagnify) in the tissues of aquatic organisms (EPA 2003). Bioconcentration factors based on laboratory studies were found to be far lower than the bioaccumulation factors observed in real-world field studies. The degree to which aquatic organisms accumulate arsenic varies widely across species groups in relation to foods consumed. Bioaccumulation factors for trophic level three and four fishes in lakes reported by EPA (2003) were in the range of 19 to 96 L/kg. Bioaccumulation factors for trophic level three and four brook trout and white suckers in rivers were in the range of 238 to 571 L/kg. In other words, these fishes accumulate arsenic in their bodies to levels about 19 to 571 times higher than the concentration of dissolved arsenic in the water column.

About 85-90% of the arsenic in edible portions of marine fish and shellfish is in organic forms (such as arsenobetaine, arsenocholine, dimethylarsenic acid); about 10% is inorganic arsenic. Less is known about the forms of arsenic in freshwater organisms, but field data indicated that 88-99% of the total arsenic in fishes were in organic forms (EPA 2003). The fact that organic forms of arsenic constituted a higher proportion of total arsenic than has been observed in laboratory settings indicates that biomethylation in real world ecosystems may exceed rates observed in the laboratory.

Each form of arsenic differs in its toxicity; it is therefore important to estimate the levels of each arsenic form when attempting to assess the level of risk to human health of consumption of arsenic-contaminated wildlife (EPA 2003). The Alberta Health and Wellness (2007) report stated that organic forms of arsenic are less harmful to humans than is inorganic arsenic. That view is in need of revision. “Recent research indicates that when compared to arsenite [inorganic arsenic], trivalent methylated arsenic metabolites exert a number of unique biological effects, are more cytotoxic and genotoxic, and are more potent inhibitors of the activities of some enzymes” (EPA 2003).

Data on local fish tissue arsenic levels are sparse, but values of ~ 0.17 and 0.26 mg/kg have been reported (AWG 2003) for northern pike and lake whitefish, respectively, in Lake Athabasca. Such arsenic levels are more than 52 times the US EPA subsistence fisher guideline of 0.00327 mg arsenic/kg. More data on fish arsenic levels are needed.

The relevance of these results to the people of Fort Chipewyan is large. They mean that: (1) the concentration of dissolved arsenic in water is a poor predictor of actual arsenic exposure; (2) for people who eat locally-caught fish, the health risk from arsenic exposure may be greater than assumed previously.

6. Are Levels of Arsenic, Mercury, and PAHs Rising?

As noted earlier in the report, three contaminants of high concern are arsenic, mercury, and PAHs. Current levels of all three contaminants are sufficiently high to present a risk to either humans or wildlife. Are levels of these contaminants rising?

While there are abundant data, the observations are spread among a variety of datasets, making time series analyses difficult to conduct. Clearly, answering this question is central to maintenance of public and ecosystem health and to future management, political, and legal actions. A concerted effort should be made to meta-analyze all the available data. In the interim, several observations (below) indicate that, yes, concentrations of these contaminants appear to be rising above “historical” levels. The increases in contaminant concentrations may prove to be underestimates given the fact that “historical” (RAMP 2001) refers to a period that spans 1976-87 (water) and 1976-99 (sediment), well within the oil sands industrial era.

Mercury:

(1) Levels of total mercury in sediments at Big Point Channel (80 µg/kg, in 2000), Flour Bay (90 µg/kg, in 2000) and in the Rochers River near Mission Creek (60 µg/kg, in 2007) were about 76%, 98%, and 32%, respectively, above the historical median level of total mercury (45.5 µg/kg, 1976-99) reported in RAMP (2001).

(2) Data in RAMP (2001, Table 5.9) suggest that mercury levels in the Athabasca River upstream of the Embarras River and in the ARD have risen above the historical median (1976-87).

(3) Mean mercury concentration in lower Athabasca River walleye collected in 1992 and analyzed under the Northern River Basins Study (n=12, from two sites, 35 and 230 river km upstream of Lake Athabasca, Appendix D from Donald et al. 1996) was 0.360 +/-

0.067 mg/kg. In comparison, the mean mercury concentration in lower Athabasca River walleye collected in 2005 was 0.409 +/- 0.191 mg/kg (n=25, see Table 16).

Arsenic:

(1) Levels of total arsenic upstream of the Embarras River (<1.0 µg/L, in 2000) and in the ARD (1.0 µg/L, in 2000) have risen above the historical medians (0.5 µg/L and 0.6 µg/L, respectively, 1976-87, RAMP (2001)) by about 100% and 67% respectively.

(2) If the historical median level of dissolved arsenic in the ARD (0.6 µg/L, RAMP 2001) is applied, values observed in 2007 for the Rochers River near Mission Creek (3.4 µg/L), at the Fort Chipewyan water intake (2.6 µg/L), and in the Fletcher Channel (1.6 µg/L) are about 466%, 333%, and 167% above historical levels.

(3) Levels of arsenic in sediments at Big Point Channel (6.2 mg/kg, in 2000), Flour Bay (5.8 mg/kg, in 2000), in the Rochers River near Mission Creek (9.1 mg/kg, in 2007) and at the Fort Chipewyan water intake (9.2 mg/kg, in 2007) were about 44%, 35%, 112%, and 114%, respectively, above the historical median level of sediment arsenic (4.3 mg/kg, 1976-99) reported in RAMP (2001).

PAHs:

(1) Median PAH levels in 2000 in Big Point Channel and Flour Bay increased 14% and 6% above historical levels (1976-99) while mean PAH levels for those areas increased 42% and 29% above historical levels (Table 17, using “<” values as “no data”).

(2) If only alkylated PAHs are considered as indicative of petrogenic PAHs, the increases are more pronounced. Median alkylated PAHs in 2000 in Big Point Channel and Flour Bay were 14% above historical levels while mean alkylated PAH levels for those areas were 72% and 52% above historical levels.

Table 17. Concentrations of PAHs in sediments of the ARD from historical data (1976-99) compared to concentrations in 2000 (data analyzed from RAMP 2001, their Table 5.21).

	Concentration (µg /kg)			Percent Change @		Percent Change @@	
	Big Point Channel	Flour Bay	ARD	Big Point Channel	Flour Bay	Big Point Channel	Flour Bay
PAH	2000	2000	Historical				
naphthalene	24	22	19	26	16	26	16
C1 naphthalenes	40	47	35	14	34	14	34
C2 naphthalenes	49	54	43	14	26	14	26
C3 naphthalenes	48	50	54	-11	-7	-11	-7
C4 naphthalenes	<4	<10	32			-88	-69
acenaphthene	<10	<5	<1			900	400
C1 acenaphthene	4	3	3	33	0	33	0
acenaphthylene	<8	<4	<4			100	0
anthracene	<3	<2	<4			-25	-50
dibenzo(a,h)anthracene	<5	<7	<6			-17	17
benzo(a)anthracene / chrysene	26	31	31	-16	0	-16	0
C1 benzo(a)anthracene / chrysene	250	230	36	594	539	594	539
C2 benzo(a)anthracene / chrysene	63	<140	15	320		320	833

benzo(a)pyrene	6	9	13	-54	-31	-54	-31
C1 benzo(b&k) fluoranthene / benzo(a)pyrene	<11	<7	<15			-27	-53
C2 benzo(b&k) fluoranthene / benzo(a)pyrene	<4	<3	<13			-69	-77
benzofluoranthenes	26	27	30	-13	-10	-13	-10
benzo(g,h,i)perylene	20	18	17	18	6	18	6
biphenyl	5	6	8	-38	-25	-38	-25
C1 biphenyl	<5	<3	<2			150	50
C2 biphenyl	<2	<2	<2			0	0
dibenzothiophene	3	<5	<3			0	67
C1 dibenzothiophene	18	14	17	6	-18	6	-18
C2 dibenzothiophene	70	<8	75	-7		-7	-89
C3 dibenzothiophene	140	180	110	27	64	27	64
C4 dibenzothiophene	<5	<4					
fluoranthene	8	6	7	14	-14	14	-14
C1 fluoranthene / pyrene	59	63	43	37	47	37	47
C2 fluoranthene / pyrene	110	110					
C3 fluoranthene / pyrene	100	89					
fluorene	4	5	3	33	67	33	67
C1 fluorene	<3	<4	<4			-25	0
C2 fluorene	<8	<6	<3			167	100
C3 fluorene	<8	<4					
indeno(1,2,3,cd)pyrene	15	13	11	36	18	36	18
phenanthrene	25	24	26	-4	-8	-4	-8
C1 phenanthrene / anthracene	78	77	69	13	12	13	12
C2 phenanthrene / anthracene	89	75	64	39	17	39	17
C3 phenanthrene / anthracene	74	75	71	4	6	4	6
C4 phenanthrene / anthracene	85	25	350	-76	-93	-76	-93
1-methyl-7-isopropyl-phenanthrene(retene)	65	67					
pyrene	19	19	15	27	27	27	27
Median Change %				14	6	13	6
Mean Change %				42	29	57	49

@ uses '<' values as = no data
@@ uses '<' values as = to the stated value

CONCLUSIONS

General Observations on Health and Environmental Concerns

In aquatic environments, metal concentrations are generally higher in areas with fine-grained sediments, such as in the Peace-Athabasca Delta and western Lake Athabasca, than in areas with coarse-grained sediments (Stone and Droppo 1996). Metal levels tend to increase downstream from the Athabasca River mainstem to its delta then to Lake Athabasca as finer-textured suspended sediments carry the metals to areas of deposition (Allan and Jackson 1978; Bourbonniere et al. 1996). In the similar Slave River Delta, mercury, cadmium, and arsenic concentrations of all sediment samples exceeded potential effect levels of the Canadian Sediment Guidelines for the Protection of Aquatic Life (Milburn et al. 2000).

Small zooplankton and filter feeders appear to be dependent upon organic-bacterial detritus transported into the area's open drainage lakes by the Athabasca and other rivers (Timoney 2006). Contaminants carried into the area on organic detrital-bacterial complexes could undermine the aquatic food chain. PAHs, arsenic, mercury, and other contaminants are known to bioaccumulate. Athabasca Delta dredging, through resuspension of sediment adjacent to Ft. Chipewyan, may have been a factor contributing to cancers and other diseases there. Plans for recommenced dredging of the Athabasca River Delta to support barges supplying the oil sands industry should be viewed with alarm.

The data indicate that various chemical constituents have exceeded guideline levels at various times and places over the years. The proportion of time that each constituent of concern exceeds guidelines varies.

In water, chemical constituents of concern include: arsenic, aluminum, chromium, cobalt, copper, iron, lead, phosphorus, selenium, titanium, and total phenols. The herbicides dicamba, mcpa, bromacil, and triallate and the pesticide lindane are also of concern; they have exceeded guideline levels at various times and places, particularly in the Peace River sector.

In sediment, the constituents of concern include: arsenic, cadmium, a variety of PAHs, and resin acids.

Aluminum, selenium, silver, and vanadium levels may present a risk for fish health in some areas.

Mercury levels in fish used for human consumption present a serious concern.

More needs to be learned regarding the local concentrations of mercury, arsenic, polycyclic aromatic hydrocarbons, and naphthenic acids in water, sediments, and wildlife.

The people and biota of the Athabasca River Delta and western Lake Athabasca are exposed to higher levels of metals than those upstream. Higher arsenic levels than elsewhere, coupled with the clear link between arsenic exposure and various diseases, call for in-depth study of the issue. Arsenic exposure is associated with bile duct, liver, urinary tract, and skin cancers, vascular diseases, and Type II diabetes. Rates of exposure to arsenic and the resultant estimates of risk of cancer in the Alberta Health and Wellness-commissioned report almost certainly underestimate the actual arsenic-related cancer risks facing the people of Fort Chipewyan.

Adverse health effects from cadmium exposure may occur at lower exposure levels than previously thought, primarily in the form of kidney damage (Järup 2003).

There may be additional constituents of concern that were not addressed in this study, including ammonia, fluoride, antimony, molybdenum, and nickel (see McEachern 2004). Levels of these constituents in the waters and sediments near Fort Chipewyan should be determined in the near future.

Statistics for some constituents of concern (in water) have been summarized for Athabasca River reaches downstream of the Steepbank River and for upstream of the Embarras River (Suncor 2005, their Tables 60 and 61). Of those parameters with sufficient data for evaluation, aluminum and manganese had medians that exceeded water quality guidelines.

People most at risk of adverse health effects are those who eat an abundance of country food and those who do consume untreated surface water.

For the seven parameters assessed in the fieldwork, the water treatment plant appears to do a good job of removing impurities. In light of the findings of this study, a full chemical profile of the treated water should be conducted with low detection limits.

Increasing temperatures may, in light of the levels of phosphorus and nitrogen in the water, encourage increased algal blooms, some of which may be toxic to wildlife and humans who depend on them. Fishermen are reporting that nets set in rivers in winter are becoming fouled with a dark greasy material that may be decomposing algae. Reports of softer fish flesh and the apparent increase in total coliform levels lend support to the notion that increased water temperatures are bringing about aquatic changes.

Variability in Contaminant Levels

The data presented, assembled from a variety of studies, demonstrate that levels of contaminants tend to vary widely both in space and time. This spatial and temporal variability is important to both environmental and public health.

While the median and mean values of contaminants are useful measures, maximum values are often more important from a health perspective. The system is characterized by periods of 'normal' conditions punctuated by pulses of pollution.

The pulses may derive from high discharge during break-up, storms, or from spills of contaminants related to oil sands industrial activities.

What is the effect on human health of a brief pulse of pollution? Without a good human health monitoring program, it is impossible to determine the effect. But what is certain is that pulses of pollution do occur. For example, on 11 June 1980, the concentration of dissolved arsenic in the Athabasca River mainstem near Ft. Mackay was 27 µg/L, 45 times the median arsenic concentration in the river.

Many water quality parameters on the Lower Athabasca River follow a seasonal cycle with high concentrations during winter low discharge and low concentrations during the peak discharge of early summer.

Spatial variation in the levels of contaminants in the region stem from a number of sources of variation, principally the depositional environment, the grain size distribution of the sediments, local parent materials, and point sources. Based on principal components analysis, RAMP (2006) recognized four regions with regards to water and sediment characteristics (their data did not include Lake Athabasca). The majority of the Athabasca River Delta, one-half of the Athabasca River, and one-third of its western tributaries were characterized by high metal concentrations, high PAH concentrations showing little variability, and a high proportion of silts and clays with little sand.

Coliform Bacteria

Municipal water treatment at the plant produces drinking water safe from bacterial contamination. Currently surface waters around Fort Chipewyan have low populations of coliform bacteria.

People travelling by boat in the vicinity of Fort Chipewyan, the Rochers River, and perhaps the Quatre Fourches River, should be made aware that drinking untreated surface water may not be safe as the water does contain both total and fecal coliform bacteria.

During flow reversals on the Rochers River, municipal sewage entering the Rochers River from Mission Creek flows south to Lake Athabasca and may contaminate the waters around Fort Chipewyan. There is also concern that the town sewage treatment plant may be under-capacity for the size of the population. Another potential source of future contamination is sewage emptied into Lake Athabasca from the Allison Bay settlement northeast of Fort Chipewyan.

Contaminant Burden

The question of what proportion of the water and sediment contamination is due to natural sources vs. industrial activities is interesting if somewhat moot. What is not moot is that levels of some environmental contaminants have exceeded water and sediment quality guidelines.

Contaminant guidelines for protection of human and ecosystem health are defined in isolation for each contaminant. People and other organisms living in real-world ecosystems are, however, exposed to a host of toxins in a lifetime. Thus, an assessment of the concentration of each toxin in isolation from others does not address the true contaminant burden. Humans in the Fort Chipewyan area are exposed to an array of toxins in their food, water, air, and soil. In some cases exposure is a matter of choice, as in smoking tobacco, but in the majority of cases the exposure is involuntary.

Synergistic health effects of contaminants should be investigated. Two examples are provided.

1. Arsenic is a risk factor for development of Type II diabetes.
    - The impaired kidney function typical of people with diabetes places them at greater risk of adverse health effects from mercury exposure.
    - Might kidney damage due to contaminant exposure be related to the elevated rates of renal failure and hypertension observed in Fort Chipewyan?
2. Co-exposure to inorganic arsenic and PAHs is common in the environment.
    - Co-exposure to arsenic and benzo(a)pyrene can increase rates of genotoxicity 8-18 times above rates observed after exposure to either carcinogen (Maier et al. 2002; Fischer et al. 2005).
    - Co-exposure to arsenic and PAHs in the local food supply should be investigated.

Those who consume a significant portion of their diet as country food, especially fish, may be exposed to a greater toxin burden than those who eat store-bought food. While this may seem counter-intuitive, the wildlife of the region live within a sedimentary basin that receives, bioaccumulates, and stores toxins originating within a large watershed.

Future Monitoring and Study

The current situation in which the Regional Aquatics Monitoring Program (RAMP) gathers 'private' data subject to vetting is inadequate. The approach is:

1. Analytically weak in that (a) the statistical power to detect change is not addressed; (b) the temporal baseline proscribed for change detection is too short (5-9 years); (c) no effort is made to analyze relevant water quality and biological data; (d) no empirical justification is provided for delineation of "reference" sites and "potentially influenced-oil sands sites"; (e) there is a paucity of comparisons with relevant study sites both within and outside the region; (f) references to the scientific literature are sparse— there is little or no context provided for the data.
2. Biased. The steering committee, which acts as the funding source, is dominated by the oil industry and provincial government with a vested interest in oil sands development.
3. Overly conservative. There is a tendency to dismiss exceedences of wildlife contaminant and water and sediment quality guidelines as anomalous or inconclusive.
4. Subject to errors. There are errors of fact. The report, e.g., states that water withdrawals for oil sands operations in 2005 were 98.8 million cubic meters, when the actual withdrawal was over four times that amount.
5. Inconsistent. The composition of the monitoring team varies over time. Continuity in monitoring personnel is critical for change studies. Morever, continual changes in methods and means of presentation render the report of limited utility. Often there are unexpected and unacceptable data gaps. For example, in 2006 (RAMP 2007), there was no sampling of sediment quality, benthic invertebrate community, and fish tissues for the Athabasca River mainstem. For the Athabasca River Delta, RAMP (2007) conducted no sampling.

Ad hoc reports, funded by the Alberta government or industry, do not attain the standard of impartiality and peer review that is required in matters of public health. And finally, boards charged with overseeing or managing public concerns, such as the Energy Resources Conservation Board and the Cumulative Effects Management Association are hampered in their mandates by restrictive terms of reference and bureaucratic structures. The result is the *appearance* of monitoring and management of environmental concerns in the public interest. The *reality* is a lack of timely publicly available information and the perpetuation of business as usual.

Synthetic aperture radar (SAR) and other techniques have proved useful in detection and monitoring of oil spills at sea. Similar techniques might prove useful for monitoring of bitumen and tailings spills on the Athabasca River. Optimum wind speeds for oil spill detection are about 3-6 meters per second. These wind speeds create small waves (wavelets) on an oil-free water surface which makes it generate a larger backscatter than does an oil covered area. The contrast in backscatter from oil-free water vs. oil-covered water enables the detection of oil spills (Figure 18).

Because rivers are more sheltered than open sea, they may have few wavelets critical for oils spill detection (J. van der Sanden, pers. comm., October 2007). As a first step, it might be useful to search databanks to determine dates of appropriate SAR imagery for the lower Athabasca River. If images exist at the time of known spills, the imagery could be examined to assess how well it detects those spills. If the technique provides useful information it could be used to document future contaminant releases.

The people of Fort Chipewyan deserve straight answers about their environmental health concerns. In order for the people to have timely and accurate information on water and sediment quality relevant to their health, a monitoring program independent of control by vested interests is needed. Such a program need not be large and expensive. The program should be designed to be cost-effective, focussed on information-rich parameters, and report regularly to the people of Fort Chipewyan. Ideally, the program would be designed by academics, health professionals, and local people, funded independently, with data gathering and reporting done in cooperation with a university. The monitoring program should be sufficiently flexible such that research questions could be addressed that would facilitate the involvement of graduate students. Costs could be minimized through use of data gathered under pre-existing programs such as the National Pollution Release Inventory, assuming that the data could be accessed in a form amenable to analyses.

Figure 18. A visible-band satellite image of the Athabasca River and an adjacent Suncor tailings pond illustrates the dangerous juxtaposition of contaminated ponds (left) and the Athabasca River (right). Note the bright, wave-textured surface of the Athabasca River in comparison to the darker, smoother surface of the tailings pond. In a radar image, there could be a large contrast in the backscatter of the two water bodies. Image from Google Earth.

It is unlikely that the controversy of elevated disease rates in the community will be settled any time soon. The problem is of course, sample size. The statistics of epidemiology in small communities are biased towards not finding effects, i.e., they have low statistical power. If an epidemiologic study were expanded to the entire Municipality of Wood Buffalo, the sample size would be much improved. The geographic focus of the study would be lost, however, and the large, recent influx of immigrants to the region would complicate interpretation of the results. In short, epidemiology seems a poor tool under the circumstances.

Toxicology is a more powerful tool. Levels of exposure to suspect environmental toxins in communities of the lower Athabasca River would provide much needed insight into concerns about human diseases. As of 2006, the Regional Municipality of Wood Buffalo was home to about 79,810 people. The geographically dispersed population of the municipality would allow for a regional description of contaminant exposures. A well-designed study would allow for control for factors such as time of residence, location, occupation, diet, lifestyle, water supply, and demographic factors. Conversely, since toxicological investigations do not require large human populations, focus on contaminant exposures in and around Fort Chipewyan would provide much needed local data. The explosive growth of the oil sands industry in northeastern Alberta poses risks to environmental and public health that demand immediate attention independent of provincial and industrial oversight.

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Appendix 1. Laboratory analytical methods

Arsenic concentrations in water and sediment were determined by EPA 3015 (preparation) and EPA 6020 (analysis).

Mercury. The methylmercury analyses in water and soil employed cold vapor atomic fluorescence (EPA 1630).

The total mercury in sediment analyses used the ICP-MS method (EPA 6020).

The total mercury in water analyses, done by Flett Research Ltd., used the "Oxidation, Purge and Trap, and CVAFS (T00120 version 4) method. "Detection Limit: MDL = 0.04 ng Hg/L (based on 7 replicates of analytical blanks (99% confidence level)). The ML of 0.5 ng/L, as stated in Method 1631e, has been adopted for our laboratory to reflect occasional elevated bottle blanks (< 0.5 ng/L) observed in reused acid-cleaned Teflon bottles. Estimated Uncertainty: The estimated uncertainty of this method has preliminarily been determined to be ± 14.7 % @ 95 % confidence at a concentration level of 0.2 - 50 ng/L."

PAH concentrations in water were determined by EPA 3510 (preparation) and analyzed by GCMS (gas chromatographic mass spectrometric, EPA 3510/8270-GC/MS).
PAH concentrations in sediment were determined by EPA 3540/8270-GC/MS.

Dioxin and furan concentrations in water and sediment were determined by EPA 1613 Revision B.

Naphthenic acid concentration in water and sediment was determined by FTIR, Syncrude, 1994.

Total nitrogen concentration in water was determined by APHA 4500N-C –Dig.-Auto-colorimetry. Total nitrogen in sediment was determined by combustion, SSSA (1996), pp. 973-974. Total nitrate-nitrite in water was determined by APHA 4500 NO3-H - Colorimetry. Total nitrate-nitrite in sediment was not requested.

Total coliform counts in water were determined by APHA 9222B MF. Fecal coliform counts in water were determined by APHA 9222D MF. Total and fecal coliform counts in sediment were determined by HPB MFHPB-19; MFO-14.

For sediment, concentrations were corrected for percent moisture. Moisture was determined by the oven dry 105C-Gravimetric method.