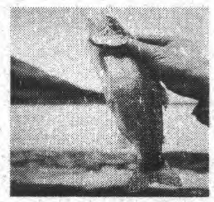
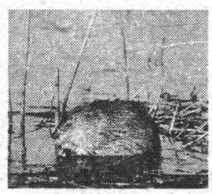
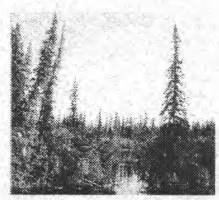
Canada Alberta Northwest Territories

Northern River Basins Study





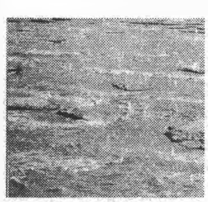




NORTHERN RIVER BASINS STUDY PROJECT REPORT NO. 105

CONTAMINANTS IN ENVIRONMENTAL SAMPLES:

MERCURY IN THE PEACE, ATHABASCA AND SLAVE RIVER BASINS



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by

David B. Donald, Heather L. Craig and Jim Syrgiannis
Environment Canada

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PREFACE:

The Northern River Basins Study was initiated through the "Canada-Alberta-Northwest Territories Agreement Respecting the Peace-Athabasca-Slave River Basin Study, Phase II - Technical Studies" which was signed September 27, 1991. The purpose of the Study is to understand and characterize the cumulative effects of development on the water and aquatic environment of the Study Area by coordinating with existing programs and undertaking appropriate new technical studies.

This publication reports the method and findings of particular work conducted as part of the Northern River Basins Study. As such, the work was governed by a specific terms of reference and is expected to contribute information about the Study Area within the context of the overall study as described by the Study Final Report. This report has been reviewed by the Study Science Advisory Committee in regards to scientific content and has been approved by the Study Board of Directors for public release.

It is explicit in the objectives of the Study to report the results of technical work regularly to the public. This objective is served by distributing project reports to an extensive network of libraries, agencies, organizations and interested individuals and by granting universal permission to reproduce the material.

This report contains referenced data obtained from sources external to the Northern River Basins Study. Individuals interested in using external data must obtain permission to do so from the donor agency.

NORTHERN RIVER BASINS STUDY
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Whereas the above publication is the result of a project conducted under the Northern River Basins Study and the terms of reference for that project are deemed to be fulfilled,
IT IS THEREFORE REQUESTED BY THE STUDY OFFICE THAT;
this publication be subjected to proper and responsible review and be considered for release to the public.

F. J. Wrona — 16 May 96
(Dr. Fred J. Wrona, Science Director) — (Date)

Whereas it is an explicit term of reference of the Science Advisory Committee "to review, for scientific content, material for publication by the Board",
IT IS HERE ADVISED BY THE SCIENCE ADVISORY COMMITTEE THAT;
this publication has been reviewed for scientific content and that the scientific practices represented in the report are acceptable given the specific purposes of the project and subject to the field conditions encountered.
SUPPLEMENTAL COMMENTARY HAS BEEN ADDED TO THIS PUBLICATION: [ ] Yes [ ] No

P. A. Larkin — May 12/96
(Dr. P. A. Larkin, Ph.D., Chair) — (Date)

Whereas the Study Board is satisfied that this publication has been reviewed for scientific content and for immediate health implications,
IT IS HERE APPROVED BY THE BOARD OF DIRECTORS THAT;
this publication be released to the public, and that this publication be designated for: **[ ] STANDARD AVAILABILITY [ ] EXPANDED AVAILABILITY**

Lucille Partington — May. 9/96
(Lucille Partington, Co-chair) — (Date)

Robert McLeod — May 21/96
(Robert McLeod, Co-chair) — (Date)

CONTAMINANTS IN ENVIRONMENTAL SAMPLES: MERCURY IN THE PEACE, ATHABASCA AND SLAVE RIVER BASINS

STUDY PERSPECTIVE

Contaminants within the aquatic ecosystem of the Peace, Athabasca and Slave rivers were identified as a principal concern of the Northern River Basins Study (NRBS). The public who addressed the Study Board at various community gatherings and presentations reenforced this concern. In its questions to scientists, the Board challenged researchers to gain a better understanding on the occurrence, movement and effect of contaminants on aquatic biota, particularly as they may affect human use.

There exists a human health consumption advisory for mercury in fish caught from different waters of the basin including the Athabasca River and some of its tributaries. Dioxin and furan are similarly the subject of an advisory and for this they came under scrutiny by NRBS.

Related Study Questions

4a) What are the contents and nature of the contaminants entering the system and what is their distribution and toxicity in the aquatic ecosystem with particular reference to water, sediments and biota?

4b) Are toxins such as dioxins, furans, mercury, etc. increasing or decreasing and what is the rate of change?

8) Recognizing that people drink water and eat fish from these rivers systems, what is the current concentration of contaminants in water and edible fish tissue and how are these levels changing through time and by location?

This project report describes the results of an effort to gather together all the existing analytical data on mercury within various elements of the Peace, Athabasca and Slave river aquatic ecosystem. The compilation was intended to describe the temporal and spatial changes of this contaminant within the study area. While historic provincial and federal data, along with data collected by NRBS between 1992 and 1994, were the principal source of information for this report, other sources were used if available. Considerable variation was found in the data sets held by various agencies and industry. In a number of instances the variation in collection, analysis and reporting the data raised questions about reliability.

Mercury is common to the sediments and biota of the study area. With few exceptions, there appears to have been a negligible increase in the occurrence of mercury within the aquatic ecosystem. This appears to contradict a general global trend which indicates an increase. Most of the exceptions within the NRBS area can be attributed to developments which promoted the release of mercury , e.g., flooding of previously exposed soils within the newly formed Williston Reservoir, run-off from site developments, and the effects appear to be localized. The compiled data illustrated the capacity for mercury to be bioaccumulated by living organisms and transferred (biomagnified) up the food chain. Consequently, fish, particularly predatory fish species like walleye, goldeye and northern pike, generally have higher levels of mercury than those species feeding on portions of the aquatic ecosystem with minimal mercury contamination. Fish, particularly walleye in the Athabasca River from the town of Athabasca to the southern boundary of Wood Buffalo National Park, were generally found to have levels that approached and / or exceeded Health Canada guidelines for human health consumption.

Information from this project will be compiled with other contaminant investigations in support of two reports to be prepared by the Contaminants Component. One report will examine the distribution of contaminants , and the other will endeavor to link these analytical findings with observed effects within the aquatic ecosystem of the Peace, Athabasca and Slave rivers.

REPORT SUMMARY

This report summarizes and describes environmental levels of mercury in water, sediment, invertebrates, and fish from the Athabasca, Peace, and Slave river basins. Data were obtained from existing provincial and federal databases, the Northern Rivers Basins Study, and from government and private sector reports and publications.

Mercury has been measured in several hundred water samples from the Basins. Mercury was detected in only a few of these samples. However, appropriate field and laboratory protocols to sample mercury in water were not used in the past; thus most detections of this element in water may not be reliable. It is noteworthy however, that because of high detection limits (0.05 to 0.1 µg/kg) mercury was not detected in most municipal effluents, and only occasionally in industrial effluents.

Mercury is ubiquitous to all soils and sediments of the earth, and it is not surprising that it was found in sediment samples from the Basins at levels that range from 27 to 123 µg/kg (dry weight). Levels of mercury found in sediments were well below the current draft interim sediment guideline for mercury that was developed to protect aquatic life. The guideline is 170 µg/kg mercury (dry weight). There was no obvious increase in mercury in sediments downstream of industrial effluents compared with sediment at upstream sites. Sediment cores from Lake Athabasca indicate that mercury levels have not increased over at the past 50 years or more, and they also suggest that the Athabasca River basin is the principal source of mercury to Lake Athabasca.

Mercury was not detected (< 20 µg/kg) in nine invertebrate samples collected from the Athabasca River in the Hinton to Whitecourt reach (km 1244 to 1067). However, in 1983 in the reach from km 270 to 258 that spans the Suncor operation, mercury increased in aquatic invertebrates in the downstream direction, from 70 to 1400 µg/kg. This significant increase, and the unusually high level in aquatic invertebrates, suggests that the Suncor operation in the early 1980s was a significant source of mercury to the lower Athabasca River. However, mercury levels in a single sample of invertebrates from 1994 for this same reach suggests that the Suncor operation is no longer a major source of mercury.

Mercury was detected in all fish of every species taken from all lakes and rivers. In general, mercury levels in the Basins were highest in predatory fish species such as pike, walleye, burbot, and bull trout and the maximum levels were found in large specimens of these species. For the Athabasca River basin, the decreasing order for concentration of mercury in fish was walleye > goldeye > northern pike > longnose sucker > mountain whitefish. Because of high levels of mercury, consumption guidelines have been established for walleye and pike from two lakes in the Athabasca River basin, and for walleye caught from the Athabasca River. Consumption guidelines are reported by Alberta Environmental Protection in their "Annual Guide To Sport Fishing". In the reach of the Athabasca River from the town of Athabasca (km 700) to the southern boundary of Wood Buffalo National Park (km 127), 25% of all walleye had mercury concentrations that exceeded the Health Canada limit of 500 µg/kg. Detailed studies are required to determine the relative contribution of natural and industrial sources to the mercury burden in walleye. From 1977 to 1992, mercury levels have not increased in walleye collected from western Lake Athabasca.

Bull trout taken from Williston Reservoir in British Columbia had the highest levels of mercury found in fish collected from all three Basins. The maximum concentration was 4870 μg/kg, almost 10 times higher than the Health Canada regulatory limit of 500 μg/kg. The high levels of mercury found in bull trout and other fishes from the Reservoir were not apparent in fish collected downstream.

It is recommended that:

1. Mercury concentration in walleye from Lake Athabasca and at sites along the lower Athabasca River downstream from the town of Athabasca be measured at regular intervals, perhaps every two years.

2. A detailed study be conducted in the lower Athabasca River to evaluate and to identify mechanisms and pathways of mercury uptake by aquatic biota. The tarsands, an organic rich substrate, forms a significant part of the banks of the Athabasca River and its tributaries in this reach. Tarsands may enhance mercury uptake into the food web. An evaluation of the contribution of the waste-water effluent from town of Fort McMurry and the contribution of the Suncor operation to mercury loading in the lower Athabasca River should be part of this study.

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1.0 INTRODUCTION

The Northern River Basins Study was initiated in September 1991 to assess current and future industrial development impacts on the Athabasca, Peace, and Slave rivers, their deltas, and major tributaries (Figure 1). Early in 1992, the Study Board developed more specific questions that would be addressed during the following four years. Sixteen Questions were articulated, including:

Question 4a. "Describe the contents and nature of the contaminants entering the system and describe their distribution and toxicity in the aquatic ecosystem with particular reference to water, sediments and biota."

Question 4b. "Are toxins such as dioxins, furans, mercury, etc. increasing or decreasing and what is the rate of change?"

Question 8. "Recognizing that people drink water and eat fish from these rivers systems, what is the current concentration of contaminants in water and edible fish tissue and how are these levels changing through time and by location?"

The purpose of this report is to summarize existing levels and distribution patterns of mercury in water, sediment, invertebrates, and fish from the Basins. A synthesis of historical unpublished data, information presented in reports and publications, and data collected under the Northern River Basins Study and the Slave River Monitoring Program are included in this report. Potential sources of mercury to the Basins are assessed in the context of municipal and industrial effluents, and the Williston Reservoir on the Peace River in British Columbia. For fish in particular, mercury concentrations are evaluated against the Health Canada regulatory limit which is 500 µg/kg. A summary of consumption guidelines are included, but the analyses required to develop these guidelines are not part of this report. This activity is under the jurisdiction of provincial and federal health agencies, not Environment Canada or the Northern River Basins Study Office.

1.1 DATA SOURCES AND EVALUATION

With few exceptions, the principal source of mercury data used in this report were electronic compilations of historic provincial (Alberta Environmental Centre, AEC) and federal (Department of Fisheries and Oceans, DFO) data on mercury assembled by D.A. Westworth and Associates (1996) and those data obtained by the Northern Rivers Basin Study (NRBS) from 1992 to 1994. Data collected for the Slave River Monitoring Program (SRMP, Grey et al. 1995) were also summarized. All of these electronic compilations are available from Alberta Environmental Protection, or for the SRMP, from Indian and Northern Development Canada, Yellowknife. The Study (NRBS) determined mercury levels in a few sediment samples collected from the Basins from 1989 to 1990 by Alberta Environmental Protection. Much of the historic information was originally in government data files and unpublished data reports that are unsuitable for public distribution. For this reason, we do not cite in our report the original sources of information unless the source documents are both readily available for public distribution and contain a complete data set. For example, we would not cite Moore et al. (1986) as the

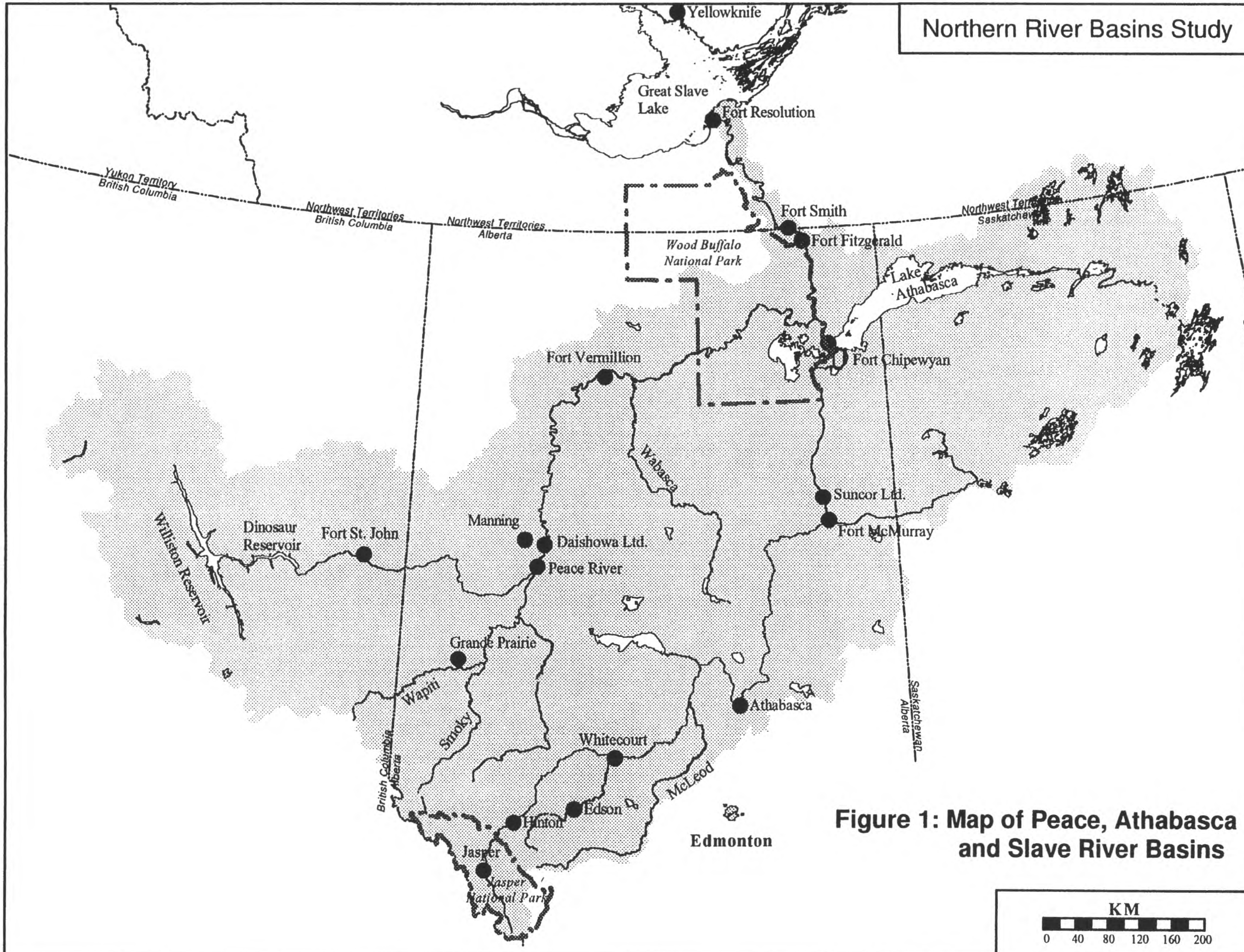


Figure 1: Map of Peace, Athabasca and Slave River Basins

source of mercury data for Muskwa Lake. They analysed and interpreted mercury data for only 10 walleye from Muskwa Lake that were collected in 1985. The electronic data base prepared for the Northern River Basins Study and held by Alberta Environmental Protection contains data on 30 walleye from Muskwa Lake that were collected over four years.

The historic mercury data for water, sediment, invertebrates, and fish synthesized in this report were collected in different seasons over several decades using different field and laboratory protocols, and variations on analytical methods. An unknown but probably significant amount of the variation in mercury concentration could be the result of these different field and laboratory protocols and methods. In this report, however, historic and NRBS data are often grouped and presented together and thus our intrepretation of these data are necessarily cautious. The electronic data bases and relevant source documents should be obtained by those who want to obtain information on mercury at specific sites in the basins or by those wishing to analyze the historic and current data presented herein in more detail.

2.0 ENVIRONMENTAL SOURCES AND EFFECTS OF MERCURY

Mercury is found in all fresh and marine waters at concentrations typically < 0.005 µg/L, and in sediments and soils through out the earth at concentrations usually < 1000 µg/kg (Eisler 1987). In the aquatic environment it is found in the elemental form Hg^0, the ionic form (Hg^{2+}) in various organic and inorganic complexes, and in biota primarily as methylmercury (CH_3Hg^+). In the past, mercury had a variety of industrial applications including the production of chlorine (chloroalkali process), use in electrical apparatus, in antifouling paints, as a slimicide in pulp and paper mills, and in pharmaceuticals. For agriculture, it was also was used in seed treatment as a fungicide (Fimreite 1970).

Elevated levels of mercury occur in soils (Nater and Grigal 1992), lake sediments (Swain et al. 1992), and peat bogs (Jensen and Jensen 1991) in regions associated with intense human activity and the industrial use of mercury. Beginning in the 1970s, there was a concerted effort by governments and industry to remove mercury from industrial and agricultural applications, and by the 1980s mercury use was significantly reduced throughout much of the globe.

In the Peace, Athabasca, and Slave river basins, there are currently no major industrial sources of mercury. However, pulp and paper mills that were in operation before 1970 could have used significant quantities of mercury at that time. At present, hospitals, municipal effluents, incinerators and fossil fuels burning would contribute minor amounts of mercury to the environment in these basins. Atmospheric deposition of mercury in dust and precipitation, perhaps from anthropogenic rather than natural sources (Slemr and Langer 1992), would be the largest single input of mercury to the Basins. Input of mercury would be balanced at least in part by export of mercury by volatilization to the atmosphere (Rada et al. 1993) and in the discharge of the Slave River.

At high concentrations, mercury is a toxic substance to most living organisms. The toxic effects on humans were highly publicized by the Minamata (Japan) epidemic of the 1950s and 1960s (D'Itri 1972). Many Japanese families were poisoned by the regular consumption of seafood contaminated by mercury from industrial sources. Many other but less publicized cases of human poisoning from mercury have been reported. For example, in 1972 there were 6,530 hospital admissions and 459 deaths among Iraqi farmers who ate bread from wheat treated with methylmercury fungicide (Das et al. 1982, Elhassani 1983). At low concentrations, mercury has little or no effect on lower organisms such as aquatic invertebrates. However, forms of mercury that have low toxicity (elemental mercury) are transformed through biological processes into a form (methylmercury) that can be bioconcentrated and biomagnified through the food chain to levels that are unacceptable (Huckabee et al. 1979). People living traditional life styles can be exposed to high mercury levels by ingesting country foods, especially those people living near contaminated sites (Wheatley and Paradis 1995).

3.0 MERCURY IN WATER

Mercury levels have been measured in water samples collected at a number of sites in the Athabasca, Peace, and Slave river basins. Mercury was detected in some water samples at levels typically ranging from 0.01 to 0.10 µg/L. However, recent developments in "clean methods" in sampling for mercury in water together with improvements in analytical techniques have shown that environmental levels of mercury in waters that are not directly contaminated typically range from 0.0001 to 0.005 µg/L (Mierle 1990, Watras, et al. 1995). To obtain accurate measurements of mercury in water, sampling protocols include using distilled acid to rinse Teflon sample bottles, complete covering of field technicians in nylon or plastic, sampling from fibreglass boats, analyses conducted with limited or no contact with indoor air, and separate "clean" laboratories used to analyze environmental levels of mercury especially in water (Gill and Fitzgerald 1985, Boutron et al. 1992, Watras et al. 1995). Few or none of these protocols were implemented in the past to sample mercury in water in the Basins, and therefore, the accuracy and reliability of mercury detections and values in the existing databases are suspect.

Because of the high analytical detection limits, mercury was not found in most water samples collected in the basins. For example, of 143 samples taken for total mercury from the Athabasca River downstream of Jasper taken from 1979 to 1991, mercury was detected in only four samples (DL = 0.02 µg/L, Block et al. 1993). Noton and Shaw (1989) recorded mercury in five of 100 samples taken from the Athabasca River from upstream of Hinton to Lake Athabasca during 1988 and 1989 (DL = 0.10 µg/L). Environment Canada (1991) reports mercury in 13 of 20 samples collected from the Athabasca River at the upstream boundary of Wood Buffalo National Park (DL = 0.01 µg/L).

Similarly, water quality data from the Peace River indicate that mercury was not usually detected. Noton (1992) reports that mercury (total) was only detected in two of 79 samples collected from 1987 to 1991 from the Wapiti and Smoky rivers, and Shaw et al. (1990) reported a single detection of total mercury in 173 water samples collected during 1988 and 1989 from throughout the Peace River basin in Alberta (DL = 0.05 µg/L). Environment Canada (1991) reported mercury (total) in 9 of 22 samples taken from the Peace River at Peace Point (DL = 0.01 µg/L). This high frequency of detection for mercury is probably caused by contamination of the samples.

Concentration of total mercury has also been assessed in the principal effluents from municipal and industrial sources from both the Athabasca and Peace river basins (Hamilton et al. 1985, Noton and

Concentration of total mercury has also been assessed in the principal effluents from municipal and industrial sources from both the Athabasca and Peace river basins (Hamilton et al. 1985, Noton and Shaw 1989, Shaw et al. 1990, Noton 1992). Mercury was not detected in most municipal effluents, and was only occasionally detected in industrial effluents. However, high levels of total mercury were detected in the combined municipal and pulp mill effluent at Hinton in 1984 (maximum 0.2 µg/L) and again in a single sample from winter 1989 (0.8 µg/L, N = 6 samples). One of six samples taken from the pulp mill near Grand Prairie in 1988 also had high levels of mercury (0.35 µg/L), and one of seven samples taken from this same site from 1989 to 1991 was also relatively high (0.12 µg/L).

3.1 SUMMARY AND SIGNIFICANCE OF MERCURY IN WATER

Historically mercury has not been sampled or analyzed in water by appropriate "clean" methods, and therefore environmental levels of mercury in waters of the Athabasca, Peace, and Slave river basins remain unknown. Effluents from Hinton and the pulp mill at Grand Prairie occasionally had relatively high levels of mercury, and these might be a source of mercury to the mainstem rivers, or the effluents may enhance mercury methylation and thus the bioavailability of this element to the aquatic food chain. Elevated levels of mercury in municipal effluents were not observed. However, suitable collecting and analytical methods have to be adopted before the contribution of mercury from industrial and municipal effluents to the background natural levels of mercury in river water can be determined.

4.0 MERCURY IN SEDIMENT

4.1 ATHABASCA BASIN

Mercury levels were measured (NRBS) in sediment from the Athabasca River at eight sites in 1989 that were distributed from near the mouth (km 0) to upstream of Hinton (km 1253). The eight sites included samples from upstream and downstream from pulp mills at Hinton and Whitecourt (Figure 2). Concentration of total mercury at these eight sites ranged from 43 to 59 µg/kg (mean = 52.6 µg/kg). With one exception, the ratio of methylmercury to total mercury was 100%. Concentrations of mercury were similar at sites upstream and downstream of pulp mills on the Athabasca River.

Mercury levels were determined (NRBS) for sediment collected from the Athabasca River in 1993 in the reach from Whitecourt to Hinton (km 1067 to 1253). Mean total mercury concentration was 32 µg/kg (range 24 to 38 µg/kg, N = 6).

In 1976, sediments were collected from Athabasca River from Fort McMurry to the Peace-Athabasca Delta (Allan and Jackson 1977). Mean mercury concentration in this reach at that time ranged from 30 to 63 µg/kg.

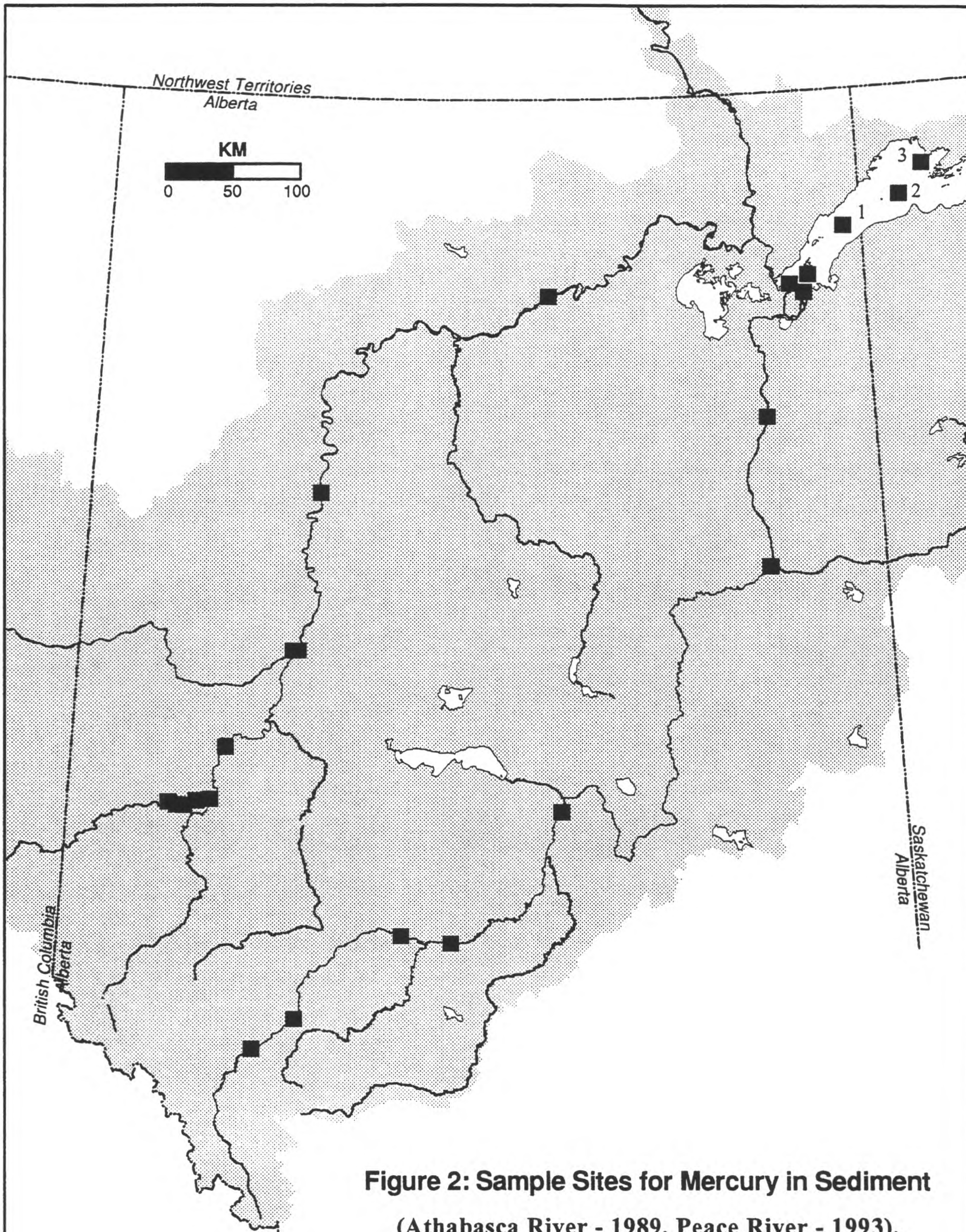


Figure 2: Sample Sites for Mercury in Sediment

(Athabasca River - 1989, Peace River - 1993).

Mercury levels were measured in 1992 (NRBS) in surface sediments from 10 sites in the Athabasca River delta including Richardson Lake, Flour Bay, and sites within depositional areas in western Lake Athabasca (NRBS). Total mercury at these 10 sites ranged from 50 to 89 µg/kg (mean = 71.2 µg/kg).

In 1992, 20-cm gravity cores were taken from three sites in Lake Athabasca (NRBS, Bourbonniere et al. 1996). Site 1 was in the western portion of Lake Athabasca off Burntwood Island; Site 2 was in the centre of the Lake near William Point, and Site 3 was west of Uranium City (Figure 2). Lead^{210} dating of the sediment indicated that the core at Site 1 and 2 represented about ninety years of depositional history, the core at Site 2 about fifty years. Mercury levels in sediment at each of these site has remained relatively constant over time with no obvious increase or decrease in concentration (Figure 3). This is in marked contrast to sediment profiles from lakes in Ontario, Wisconsin, and Minnesota where mercury increased in the profile, especially in the top few centimetres (Meger 1986, Rada et al. 1989, Swain et al. 1992).

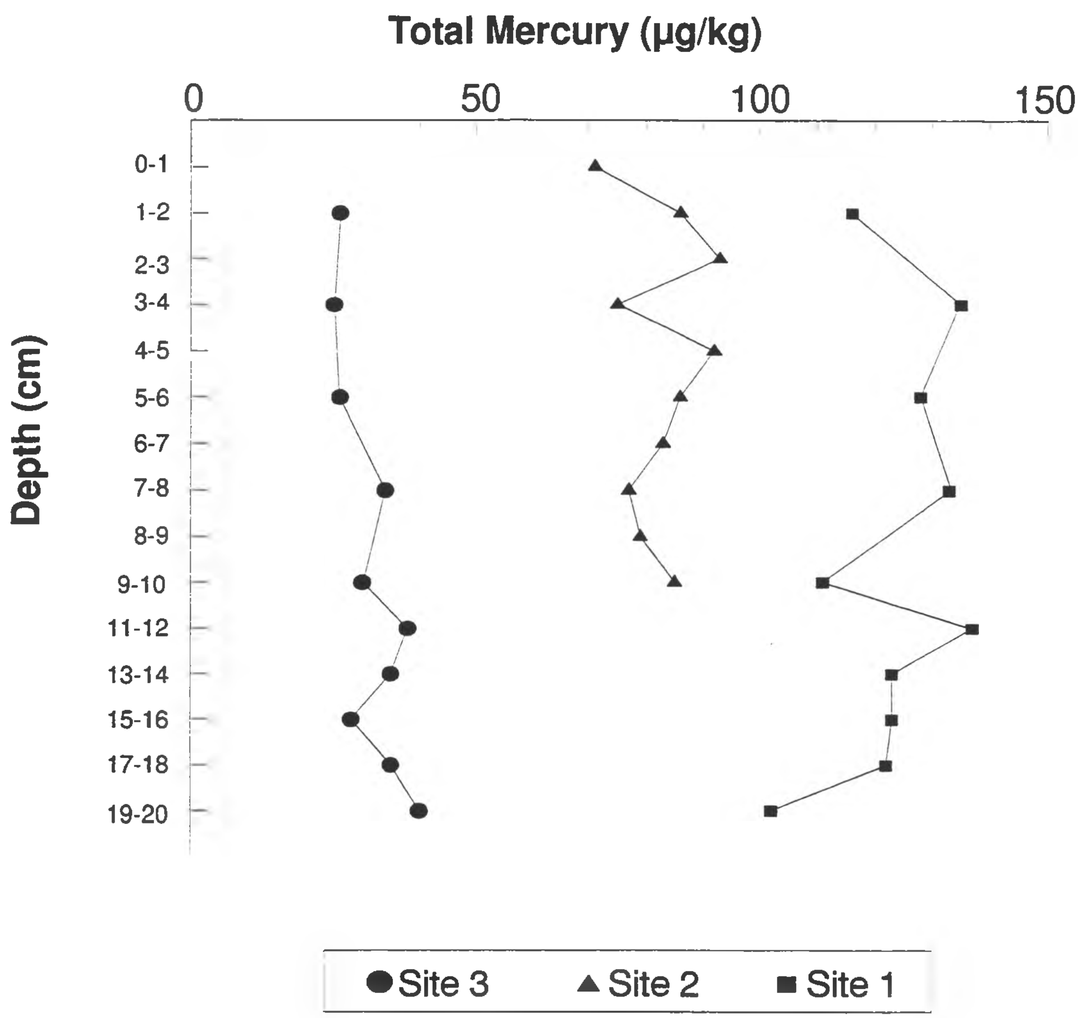
Mercury levels were significantly higher at Site 1 in the western part of the Lake (mean = 123 µg/kg, SD = ± 11.1, N = 10) than at the site at the centre of the Lake (mean = 82.7, SD = ± 7.2, N = 10), and were lower near Uranium City (mean = 31.7, SD = ± 4.0, N = 10). These differences have remained constant over time suggesting that the Athabasca River, and perhaps the Peace River during high flows, are the principal source of mercury to Lake Athabasca.

4.2 PEACE BASIN

Mercury levels in sediments were determined from five sites on the Wapiti River and two sites on the Smoky River in 1993 (NRBS). The Wapiti is a tributary of the Smoky River, which in turn is tributary to the Peace River (Figure 1). Total mercury in sediments from the Wapiti River ranged from 54 to 63 µg/kg (mean = 59.6 µg/kg, N = 5), and for two sites on the Smoky River mercury was 54 and 74 µg/kg (mean = 64.0 µg/kg). For the Wapiti River, there was a slight but not a significant increase ($t = 1.66$, $p > 0.05$) in mercury in sediment downstream from the pulp mill effluent near Grand Prairie compared with upstream sites. Mean total mercury upstream of the mill effluent was 56.5 µg/kg (N = 2), while downstream the mean concentration was 64.8 µg/kg (N = 4).

Sediments from the Wapiti and Smoky rivers were unusual for samples taken in the Basins because ionic and elemental mercury were more prevalent than methylmercury. Methylmercury was on average only 36% of the total mercury measured while at other sites on the Athabasca and Peace river basins methylmercury often accounted for 100% of total mercury. In northern Manitoba,

Figure 3. Mercury concentration in sediment, Lake Athabasca, 1992.



however, methylmercury was often from 15% to 30% of total mercury (Jackson 1988). Lower levels of methylmercury in sediments from the Wapiti and Smoky rivers could be due either to higher grain size and low organic content or due to active demethylation by bacteria, photolysis, and/or leaching.

In Williston Reservoir in British Columbia, mercury was measured in sediments at five sites in 1988 (Watson 1992). Concentration at these sites ranged from 24 to 29 μg/kg (mean = 27.2 μg/kg). These levels are relatively low compared with other reaches and tributaries of the Peace River.

Mercury concentration was measured in sediments from three sites on the Peace River within Alberta in 1993 (NRBS), from upstream of the Smoky River confluence to near the western boundary of Wood Buffalo National Park. Concentration of total mercury at these three sites ranged from 68 to 75 μg/kg (mean = 70.7 μg/kg). Sixty-seven percent of total mercury at these sites was methylmercury.

4.3 SUMMARY AND SIGNIFICANCE OF MERCURY IN SEDIMENT

Sediment samples were taken from the Peace and Athabasca rivers, Williston Reservoir, and Lake Athabasca. For these basins, mean total mercury concentration ranged from 27.2 for Williston Reservoir near the headwaters of the Peace River in British Columbia to 123 μg/kg for a series of samples from a core taken from western Lake Athabasca.

Mercury concentrations in three cores from Lake Athabasca did not show an increase with depositional time. This pattern is not consistent with a number of studies on mercury in sediment. These studies show increasing concentration of mercury in sediments deposited in the twentieth century (Meger 1986, Rada et al. 1989, Swain et al. 1992).

Mercury is ubiquitous to soils and sediments throughout the world (Eisler 1987, Watson 1992). Mercury levels in lake sediments from northern Manitoba ranged from 60 to 124 μg/kg (Jackson 1984) and in rivers of southern Alberta from 41 to 60 μg/kg (George et al. 1994). Both of these regions have mercury levels in sediment that are similar to levels found in the Peace and Athabasca basins. The average mercury content of selected Canadian soil horizons was 81 μg/kg (McKeague and Kloosterman 1974) which is also similar to levels found in sediments from northern Manitoba and from the Peace and Athabasca basins.

For sediment samples taken upstream and downstream of municipal and pulp mills effluents, mercury levels either did not increase (Hinton) or increased by less than 10% (Whitecourt, Grand Prairie). Although the number of samples taken from upstream and downstream of effluents was not large, they suggest that effluents are not a major source of mercury in the Basins. More intensive sampling of depositional sediments and effluents would be required to test this hypothesis.

The current draft interim sediment guideline for protection of freshwater aquatic life is 170 µg/kg[1] mercury (dry weight). The draft "Probable Effect Level", the level above which mercury in sediment would probably have an adverse biological effect is 490 µg/kg[1]. None of the sediment levels reported for the Basins exceeded the draft guideline levels, suggesting that mercury levels in sediments in the Basins are not affecting aquatic life.

5.0 MERCURY IN INVERTEBRATES

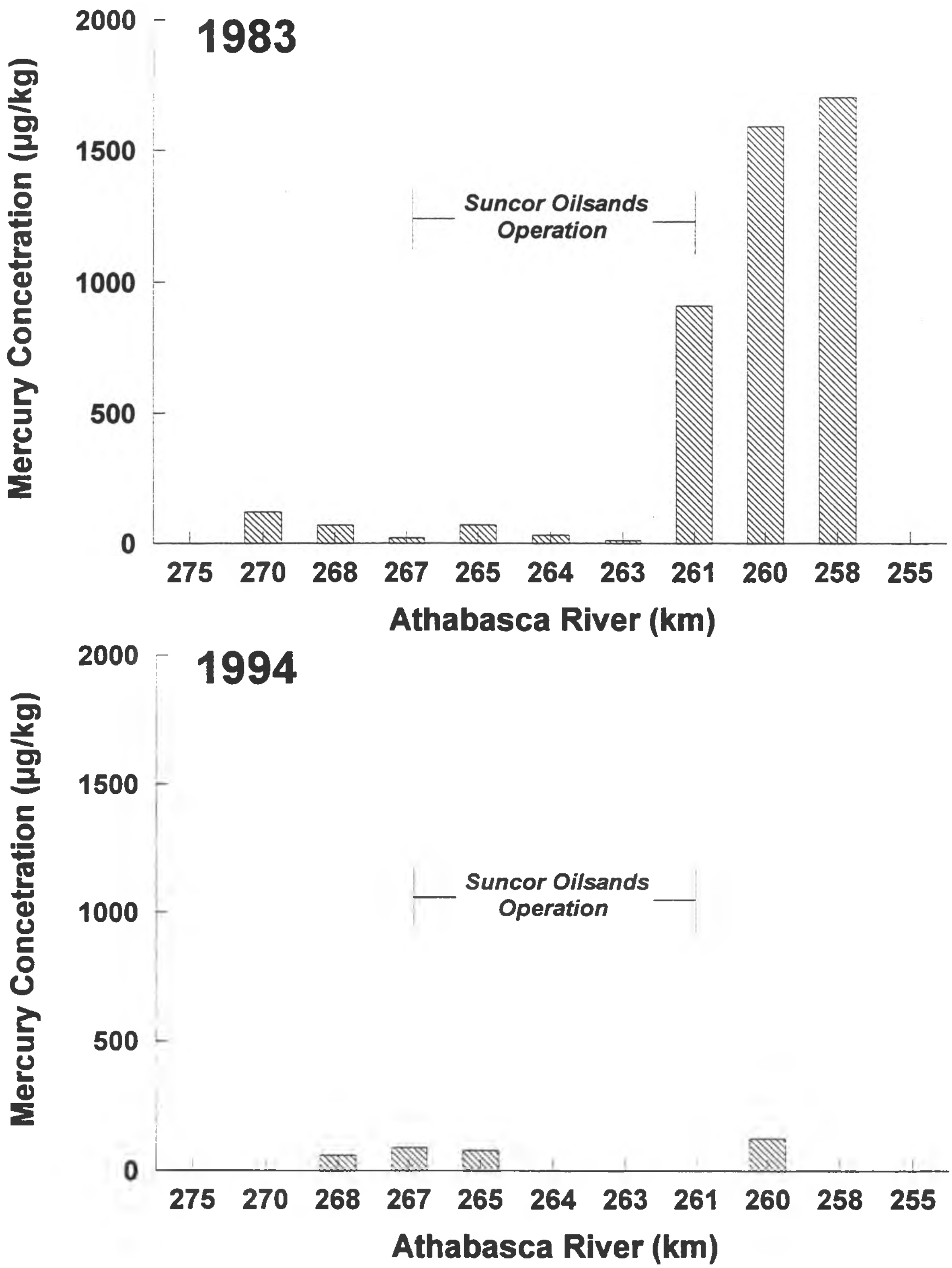
Mercury was measured in aquatic insects collected from four sites on the Athabasca River in May 1992 (NRBS, R.L.& L 1993). The sites were in the Hinton reach, from kilometre 1067 upstream from Whitecourt to kilometre 1244 just downstream from Hinton. Mercury was not detected in larval stoneflies (Plecoptera, N = 3), mayflies (Ephemeroptera, N = 3), or caddisflies (Trichoptera, N = 3). The detection limit was 20 µg/kg (dry weight).

In 1983, mercury levels were determined in samples comprised primarily of chironomids, at nine sites in the reach of the Athabasca River that flows beside the Suncor tailings pond, open pit bitumen mine, and oil extraction plant (kilometre 270 to 258, Figure 4, Beak 1988). The process effluent from Suncor is discharged at km 261. Levels of total mercury increased substantially from upstream "control" sites to downstream sites. Mean mercury in invertebrates at the three upstream sites was 70 µg/kg (wet weight, SD = ± 50, range 20 to 120 µg/kg, N = 3), and in the three downstream sites it was 1400 µg/kg (wet weight, SD = ± 428, N = 3), with a maximum concentration of 1700 µg/kg. These upstream - downstream differences in mercury concentrations were highly significant, suggesting that Suncor operation was a source of mercury in the early 1980s. In 1983, mercury concentration was determined in sediment at the same nine sites where benthic invertebrates were collected (Beak 1980). At the six upstream sites from km 263 to 270 mean mercury concentration was 22.8 µg/kg (range = 10 to 41 µg/kg, N = 6), and at the three sites where mercury levels were elevated in benthic invertebrates, mean mercury concentration in sediment was 21.7 µg/kg (range = 11 to 29 µg/kg, N = 3). Thus, mercury levels in sediment did not increase downstream from the Suncor operation.

In 1994, benthic invertebrates were once again collected from the Athabasca River along the Suncor lease. Mercury in invertebrates ranged from 58 to 125 µg/kg (dry weight, Figure 4) with the highest concentration once again at km 260. Data from 1983 are reported µg/kg wet weight, from 1994

[1] - The values reported here are taken from a draft CCME (Canadian Council of Ministers of the Environment) document that has not been approved for citation. The guideline levels reported here, however, will probably not change significantly from those receiving final approval.

Figure 4. Mercury concentration in benthic invertebrates (µg/kg), Athabasca River (km from mouth) for 1983 (data from Beak 1983) and 1994 (data from Suncor).

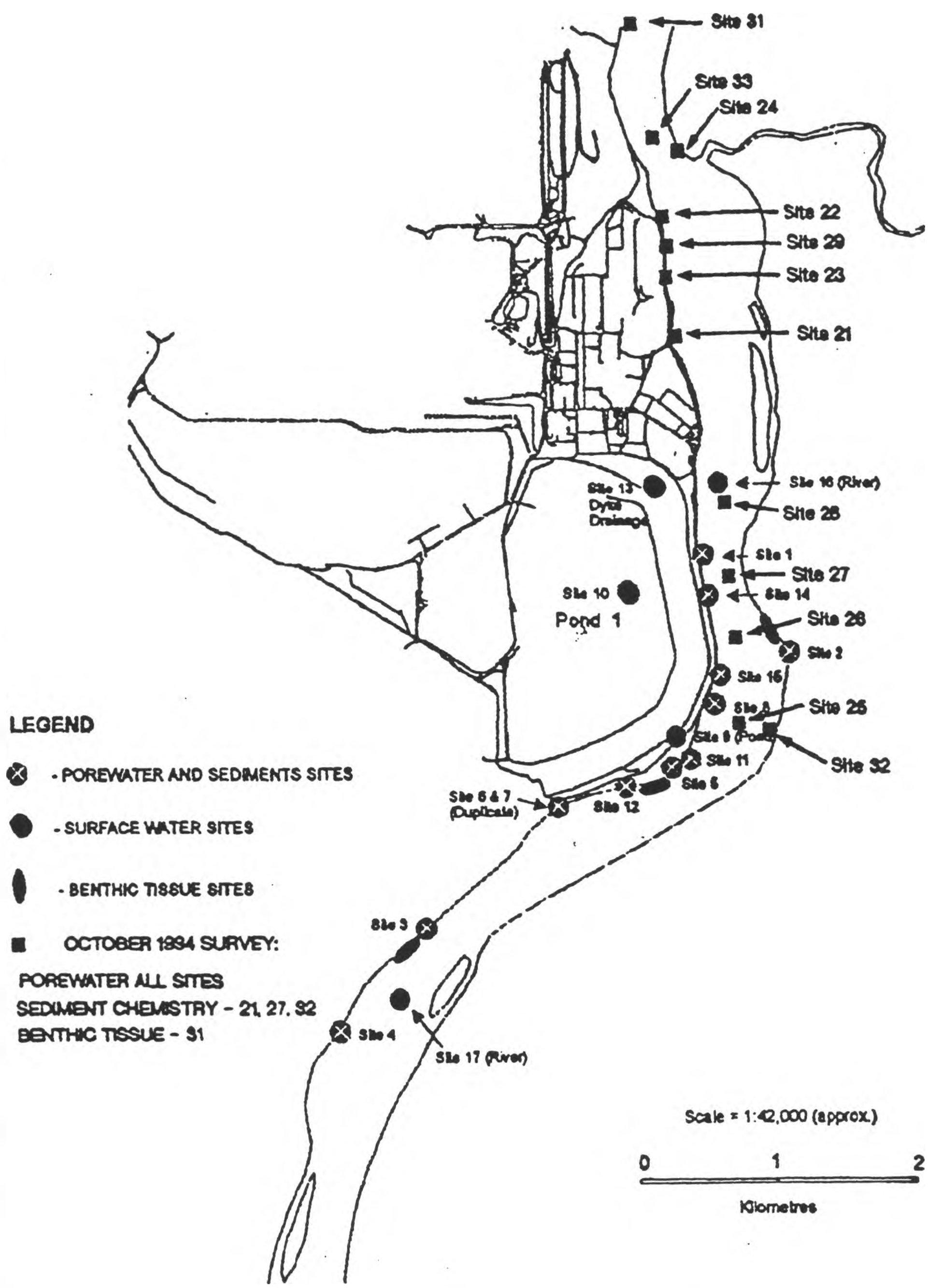


μg/kg dry weight. Thus, data from these two years are not strictly comparable. Dr. R. Shaw prepared a summary of the 1994 mercury data for Suncor. With permission from Suncor, the data are presented in Appendix H, and Dr. Shaw's (Suncor) interpretation of these data follow:

> "Mercury levels from sites upstream of Tar Island Dyke, (TID, west bank, Figure 5) across from TID (east bank) and TID (west bank) were comparable to those reported by Beak, and ranged from 58-78 μg/kg. One sample collected from the west bank, downstream of Suncor at approximately the same location as Beak site 7 contained 125 μg/kg Hg compared to 1700 μg/kg reported by Beak."
>
> "If the current data are correct, then there must have been a contributing source for mercury in 1983 that has since been removed. One obvious source is the coke pile coupled with the old sulphur pits. At low pH levels, mercury may be leached from the coke piles in the form of inorganic ligands ($HgCl_2$ and $Hg(0H)_2$) that would be highly mobile in water. There is evidence that conditions of low pH and elevated mercury levels existed in groundwater in the early 1980s in areas near the coke piles and sulfur pit. For example, pH levels as low as 1.8 and mercury levels as high as 48 μg/L were measured at wells near the coke pile and sulphur storage area (Golder Associates 1985). This groundwater would be expected to seep into the Athabasca River along a reach extending between sites 4 and 5 on Figure 5, which is consistent with the trends in mercury levels in benthic invertebrate tissues noted by Beak."
>
> "Throughout the 1980's, surface runoff from the coke and sulphur storage areas was collected and diverted through the upgrader wastewater treatment system. In 1984 an interceptor system was installed to collect groundwater at the riverbank. By 1993, the stored sulphur was removed for market and the site reclaimed. Ongoing monitoring of groundwater wells has confirmed that pH levels have increased and mercury levels have dropped since that time. For example, in 1993 the lowest pH measured at any of the monitoring wells was 2.8 and mercury was not detected in any of the groundwater samples. The low mercury levels recorded in benthic invertebrates in 1994 are consistent with this trend of reduced mercury levels following removal of the sulphur pads and diversion of the coke piles. Other potential anthropogenic sources of discharge to the river (e.g. seepage of process-affected waters from TID or the wastewater effluent) contain very low or non-detectable concentrations of mercury."

High levels of mercury in biota are often the result of enhanced methylation of mercury by bacteria, and are not necessarily the result of high ambient mercury levels in water or sediment. Thus, relatively low concentration of total mercury in sediment in the lower Athabasca River in 1983 (10 to 41 μg/kg at km 258 to 270, Beak 1988), and in 1989 (55 and 59 μg/kg at km 26 and 169, respectively), does not necessarily indicate that mercury concentrations would be low in aquatic biota.

Figure 5. Suncor Field Investigations, 1994.



PROJECT 942-2373 DRAWN CG REVISED DATE 07 APR 95

Golder Associates

5.1 SUMMARY AND SIGNIFICANCE OF MERCURY IN INVERTEBRATES

Mercury was not detected in aquatic insects in Hinton reach of the Athabasca River at levels greater than 20 µg/kg, but this element probably occurs as methylmercury in all aquatic invertebrates at levels less than the analytical detection limit. The mean concentration of methylmercury in depositional sediments in this reach was 45.3 µg/kg dry weight (N = 3, range 43 to 49 µg/kg). Because concentrations of mercury were less in insects than in sediments in this reach, methylmercury was not bioaccumulating from sediment to insects.

Mercury was detected in aquatic invertebrates, primarily chironomids, in the Athabasca River at sites upstream and downstream of the Suncor oilsands operation. Concentrations increased in the downstream direction, with a maximum level of 1700 µg/kg in 1983. This significant increase and unusually high levels of mercury at the downstream sites suggests that the Suncor operation increased mercury levels in benthic invertebrates in the Athabasca River at that time. However, based on a single sample of invertebrates collected in 1994, mercury levels at Suncor have returned to background concentrations.

In the early 1990s, mercury concentrations in invertebrates in the Suncor reach were higher than in the Hinton reach by at least 67 µg/kg (N = 4). Differences between the two sites were not biased by laboratory (Chemex Labs for both sites), detection limit (both 20 µg/kg), and probably not by invertebrate trophic position (One sample from Hinton was Plecoptera which are often predators). Mercury concentration in sediments of the lower Athabasca River ($\bar{x}$ = 57 µg/kg, SD = ± 0.00, N = 2) were similar to concentration in the upstream reach ($\bar{x}$ = 51.2 µg/kg, SD = ± 0.00, N = 6).

6.0 MERCURY IN FISH

6.1 NORTHERN PIKE

Mercury (total) levels have been determined for pike populations in 32 lakes in the Peace and Athabasca river basins in Alberta (Figure 6, Appendix A). These data were collected mostly by the Alberta Environmental Centre, Vegreville, from 1977 to 1992. Mean mercury concentration for these lakes ranged from 59 to 825 µg/kg (N = 9 and 2 fish, respectively). Mean concentration of mercury exceeded the Health Canada limit of 500 µg/kg only in Edwards Lake where analyses were conducted on two large pike that both weighed more than 3 kg. However, a few large fish from nine of the 32 lakes had mercury levels that exceeded the 500 µg/kg limit. In general, large pike have higher concentrations of mercury than small pike (Figure 7). Without exception pike less than 1 kg had mercury levels that were less than the Health Canada limit.

A consumption advisory for northern pike has been established for Muskwa Lake by Alberta Environmental Protection based on a Health Canada assessment (Figure 8). The advisory and assessment follow the principles and guidelines in Health and Welfare Canada (1989), Moore et al.

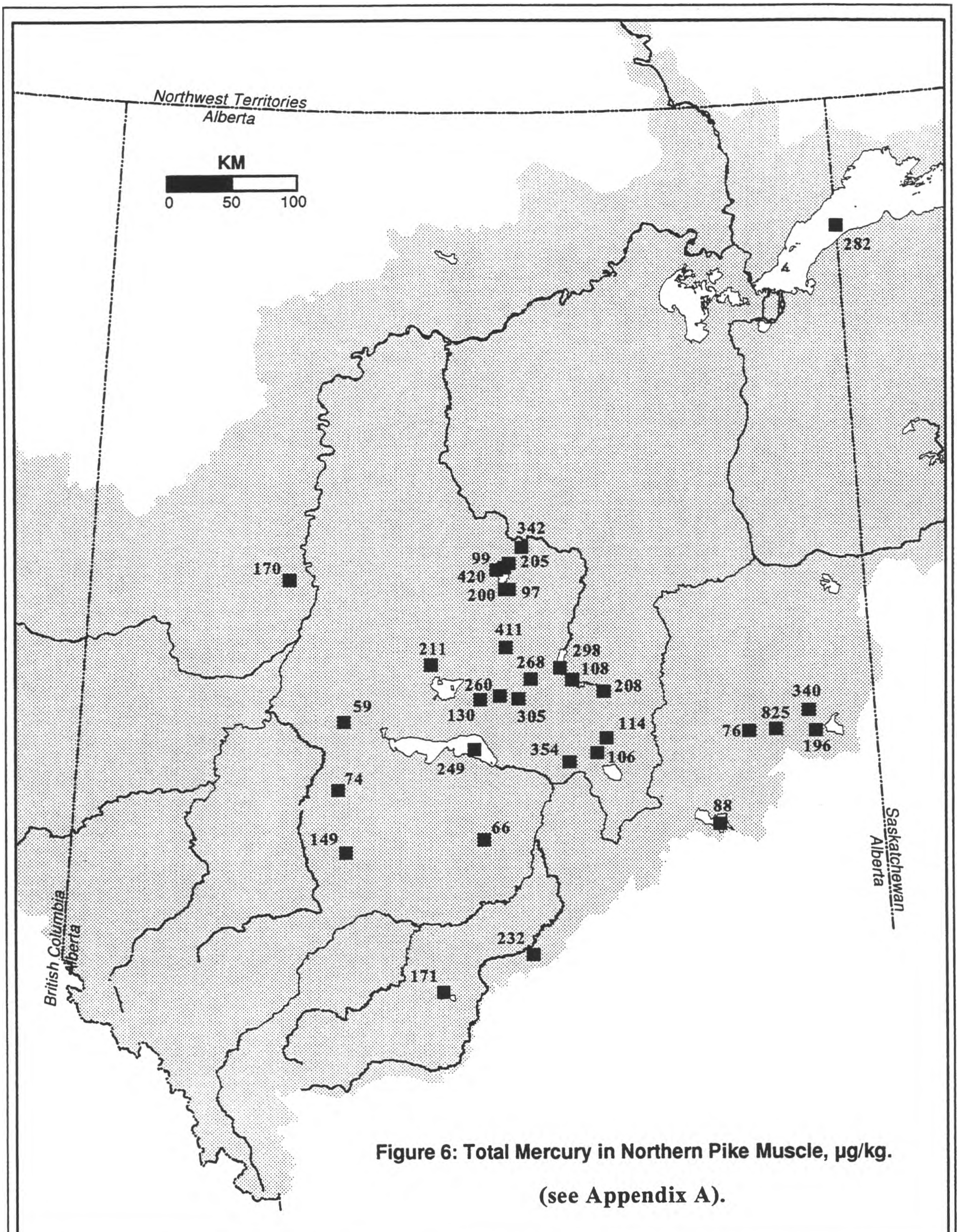


Figure 6: Total Mercury in Northern Pike Muscle, μg/kg.

(see Appendix A).

Figure 7. Relationship between northern pike weight and total mercury concentration in northern pike muscle tissue, Fawcett Lake, Alberta (AEC data from 1979 to 1990).

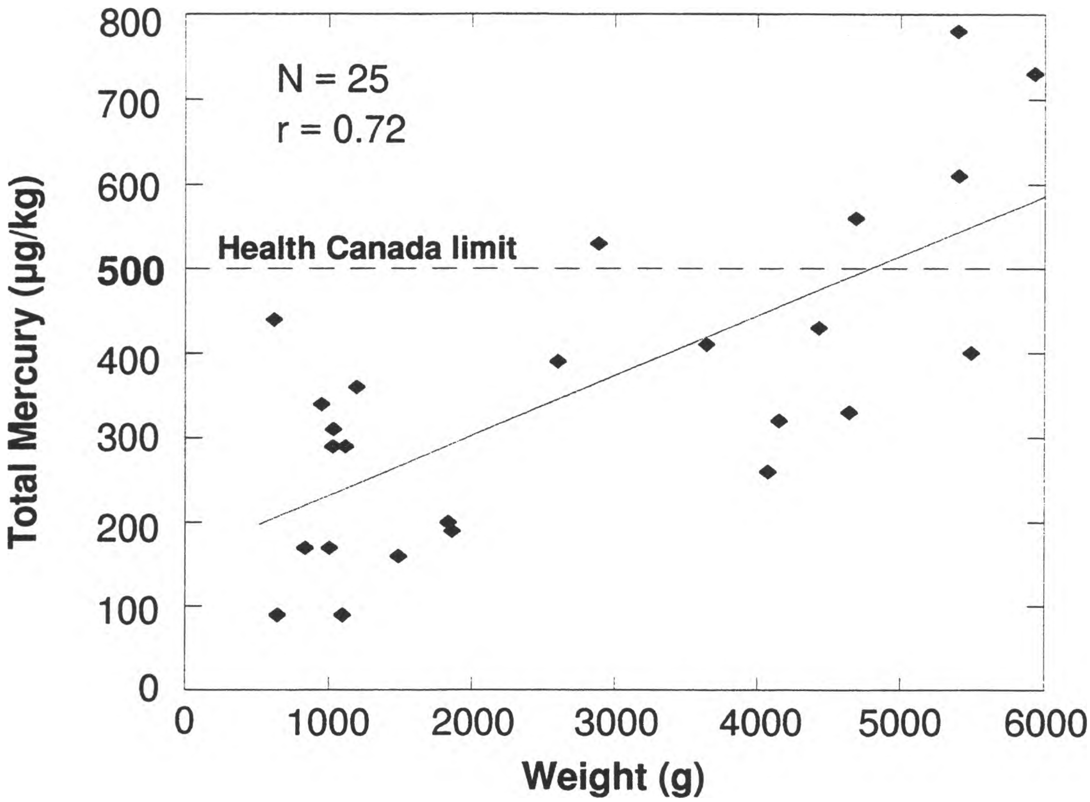
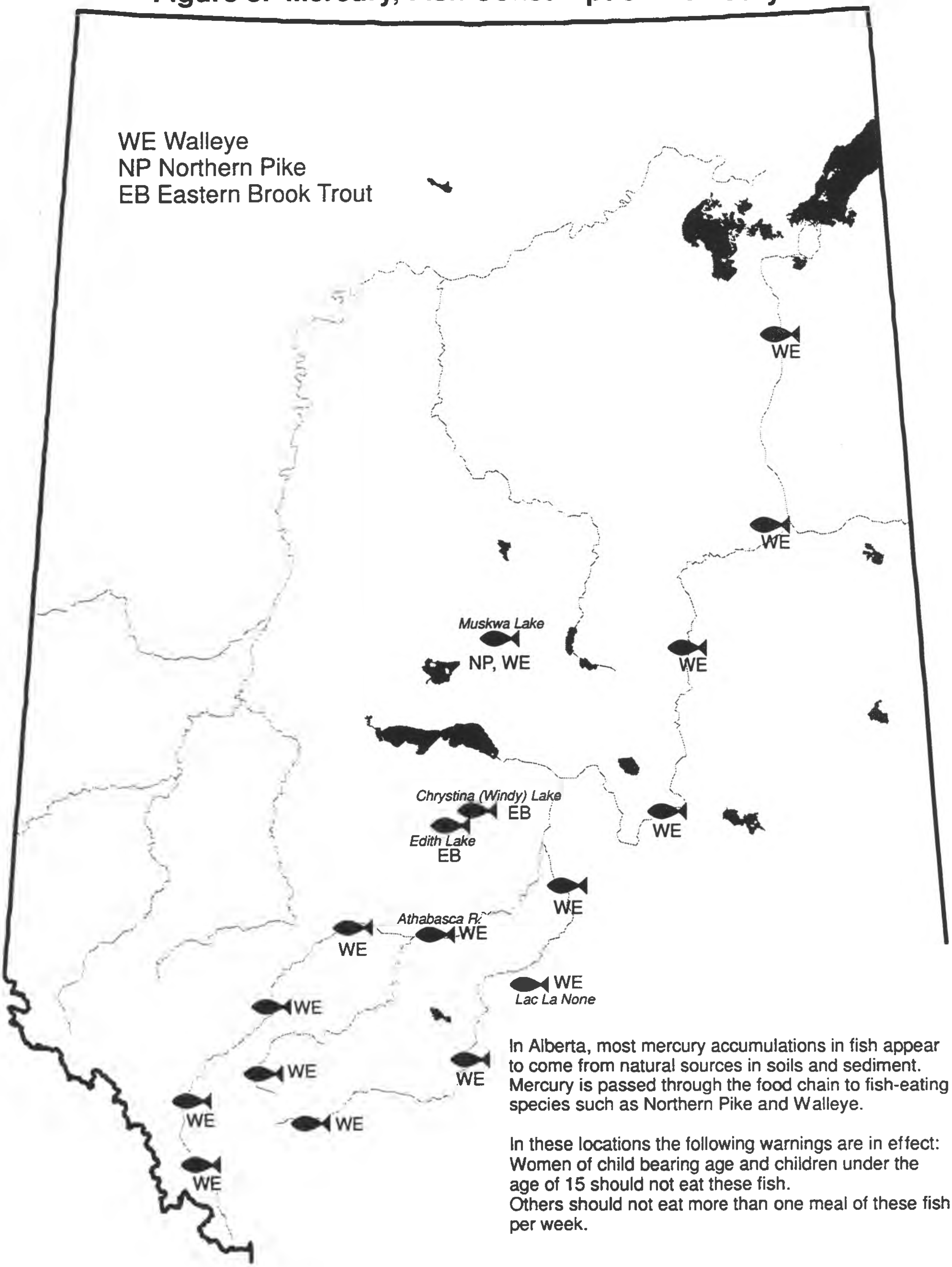


Figure 8. Mercury, Fish Consumption Advisory



In Alberta, most mercury accumulations in fish appear to come from natural sources in soils and sediment. Mercury is passed through the food chain to fish-eating species such as Northern Pike and Walleye.

In these locations the following warnings are in effect: Women of child bearing age and children under the age of 15 should not eat these fish.
Others should not eat more than one meal of these fish per week.

(1989), and The Food and Drugs Act, Canada. Women of child-bearing age and children under the age of 15 should not eat pike from Muskwa Lake, and others should not eat more than one meal of pike per week.

Mercury concentrations have been assessed in northern pike from five sites on the Athabasca River that were distributed from Lake Athabasca to Hinton (Figure 9, Appendix C, Barton et al. 1993). The pike muscle tissue was collected in 1984 (AEC) and 1992 (NRBS). Although sample size was less than 5 in most cases, mercury concentration in all pike from these sites was less than the Health Canada limit.

From 1988 to 1993, mercury concentrations were determined for pike caught from the Slave River at Fort Smith (SRMP, Grey et al. 1995, Appendix H). Five of 104 fish at this site exceed the Health Canada Limit of 500 µg/kg total mercury. The maximum concentration reported was 600 µg/kg.

In general, mercury levels in pike from the Basins were similar to levels found in other regions in Canada, but are well below concentrations found at contaminated sites (Lockhart et al. 1972).

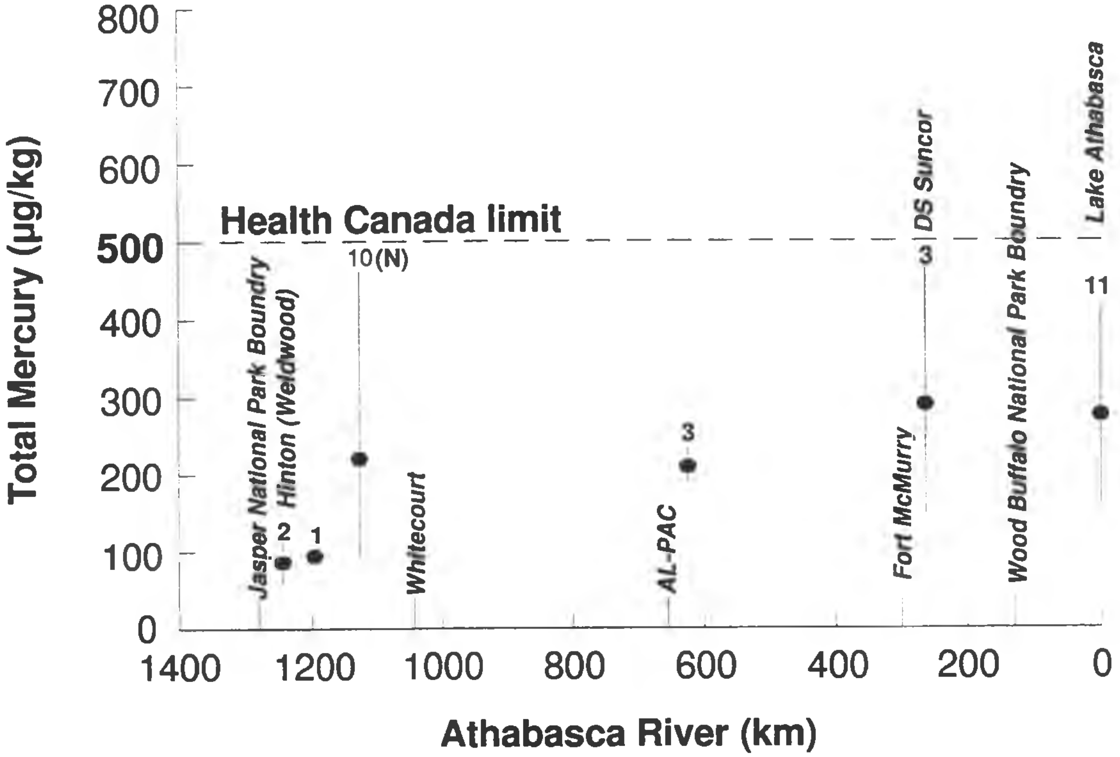
6.2 WALLEYE

Mercury concentration was measured in walleye from 11 lakes in the Athabasca and Peace river basins by the Alberta Environmental Centre. Mean mercury concentration in walleye from these lakes ranged from 100 to 467 µg/kg (Figure 10, Appendix B). The maximum level reported for a single fish was 810 µg/kg. Levels exceeded the Health Canada limit in walleye from 3 of the 11 lakes. Consumption guidelines have been established for Muskwa and Lac La Nonne lakes by Alberta Environmental Protection (Figure 8). Women of child-bearing age and children under the age of 15 should not eat walleye from these two lakes, and others should not eat more than one meal of walleye fillet per week.

Walleye were collected for mercury analyses from several sites on the Athabasca River (Appendix D, AEC - Moore et al. 1986, SENTAR - Shellast et al. 1994, NRBS), from Lake Athabasca (Appendix E), and the Slave River at Fort Smith (Grey et al. 1995). For the sites on the Athabasca River, mean concentration of mercury ranged from 268 to 2980 µg/kg (Figure 11). All walleye were collected for mercury analysis before ALPAC became operational (September, 1993) Concentration in individual fish ranged from 111 to 3850 µg/kg. In the reach between the town of Athabasca and the southern boundary of Wood Buffalo National Park, 25% of walleye exceeded the Health Canada limit of 500 µg/kg for total mercury (N = 60). A consumption guideline, identical to the one described above for lakes, is in place for walleye caught from the Athabasca River.

For walleye collected from Lake Athabasca from 1977 to 1992, mean concentrations of mercury ranged from 238 to 520 µg/kg (Figure 12). Mercury concentration did not increase in walleye during this 16-year period. Six percent of the walleye collected from Lake Athabasca exceeded the Health Canada limit of 500 µg/kg total mercury (N = 87).

Figure 9. Mean total mercury in pike muscle tissue (µg/kg), Athabasca River. (vertical lines = maximum and minimum, values = number of fish analyzed, data from 1992, Appendix C).



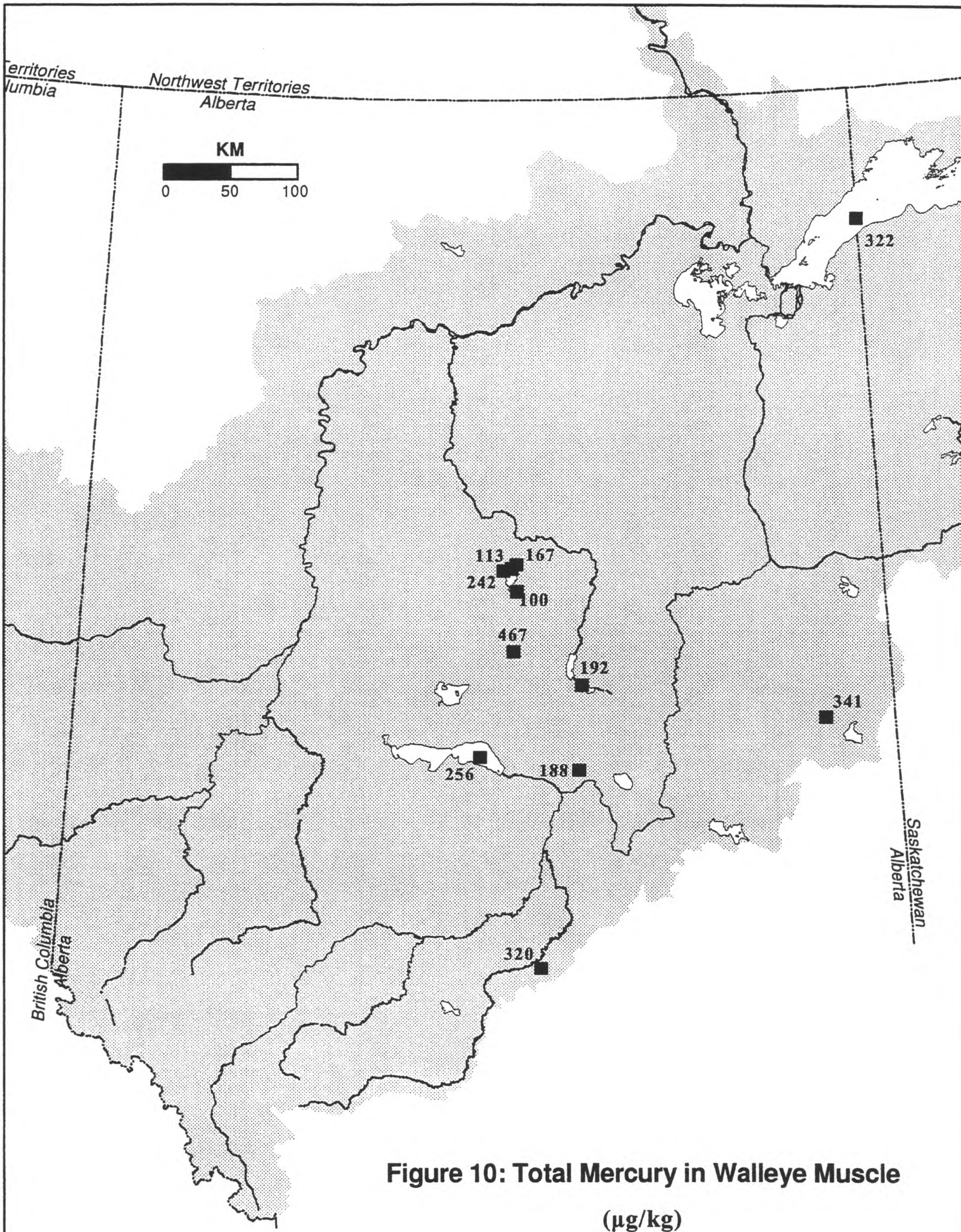


Figure 10: Total Mercury in Walleye Muscle

(μg/kg)

Figure 11. Mean total mercury in walleye ▲ and longnose sucker ● muscle tissue (µg/kg), Athabasca River. (vertical lines = maximum and minimum, N values = number of fish analyzed, data from 1977 to 1992, see Appendix C and D).

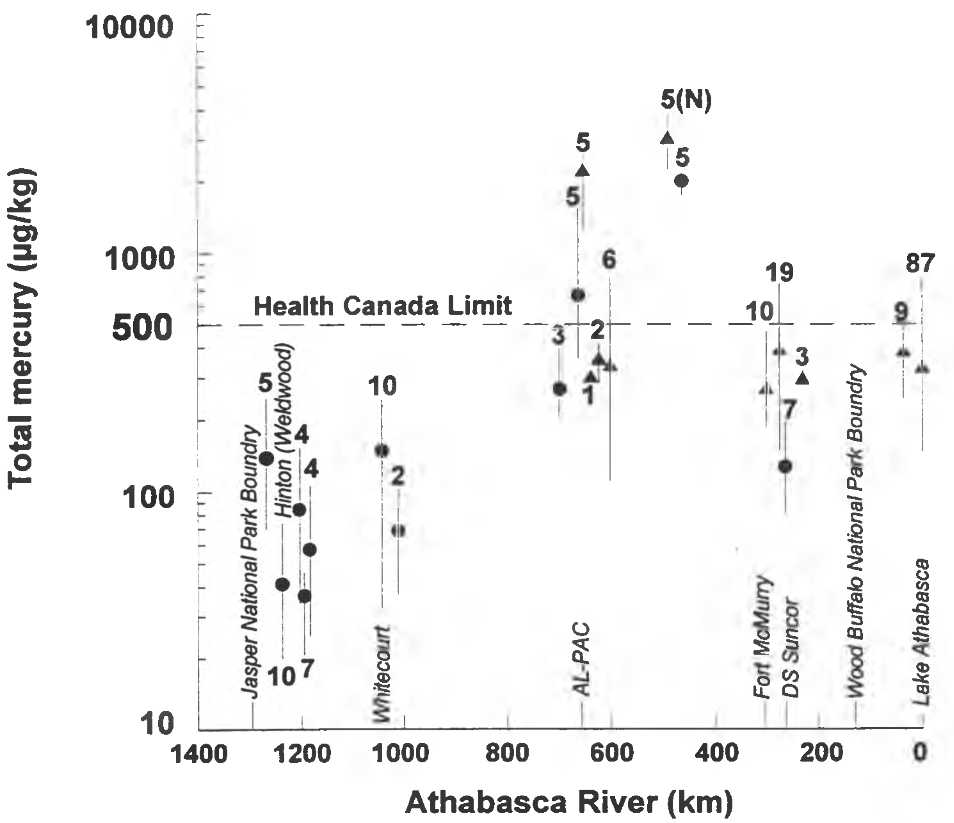
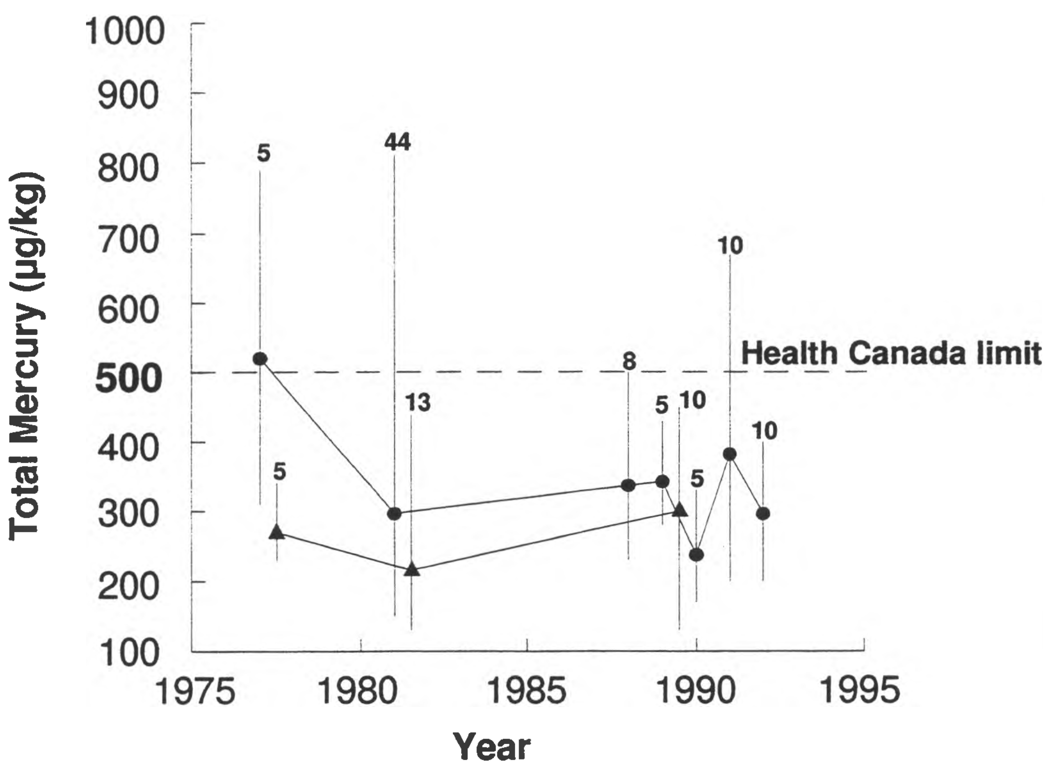


Figure 12. Mean total mercury in walleye ● and goldeye ▲ muscle tissue, Lake Athabasca. (vertical lines = maximum and minimum, values = number of fish analyzed, data from 1977 to 1992, see Appendix E).



Mercury levels were measured in walleye collected from the Slave River at Fort Smith from 1988 to 1993 under the Slave River monitoring program (Grey et al. 1995, Appendix A). The individual minimum and maximum mercury concentration for these six years was 60 and 800 μg/kg, respectively. Five percent of the fish collected (N = 135) exceeded the Health Canada limit of 500 μg/kg.

6.3 LONGNOSE SUCKER

Mercury concentrations were measured in longnose suckers from eleven sites on the Athabasca River from 1984 to 1992 (Figure 11, Appendix C, Barton et al. 1993). Concentrations of total mercury for all individuals from all sites ranged from 20 to 2180 μg/kg with an overall mean of 415 μg/kg (N = 40). In general, concentration of mercury in longnose suckers was less than the levels found in predacious species such as walleye and pike collected from the same reach of the Athabasca River. This suggests that diet is an important route for mercury uptake.

In the Wapiti/Smoky rivers, mercury levels in longnose suckers were determined for four sites strategically located upstream and downstream of municipal and pulp mill effluent discharge locations (Moore et al. 1986). Mean mercury levels in suckers taken from upstream and immediately downstream of the effluents on the Wapiti River were 343 and 170 μg/kg, respectively. Farther downstream on the Smoky River, the mean mercury concentration was 247 μg/kg (SD = ± 150, N = 7). This was similar to levels at an upstream "control" site on the Smoky River (mean = 230 μg/kg, SD = ± 109, N = 7).

Swanson (1993) found that mercury levels on the Smoky/Wapiti rivers were significantly higher in three of six longnose suckers (540 to 1000 μg/kg) compared with reference fish from the North Saskatchewan River (60 to 200 μg/kg). These relatively high levels were similar to background concentrations in other regions and they were not attributed to mercury in effluents from the pulp mill near Grand Prairie.

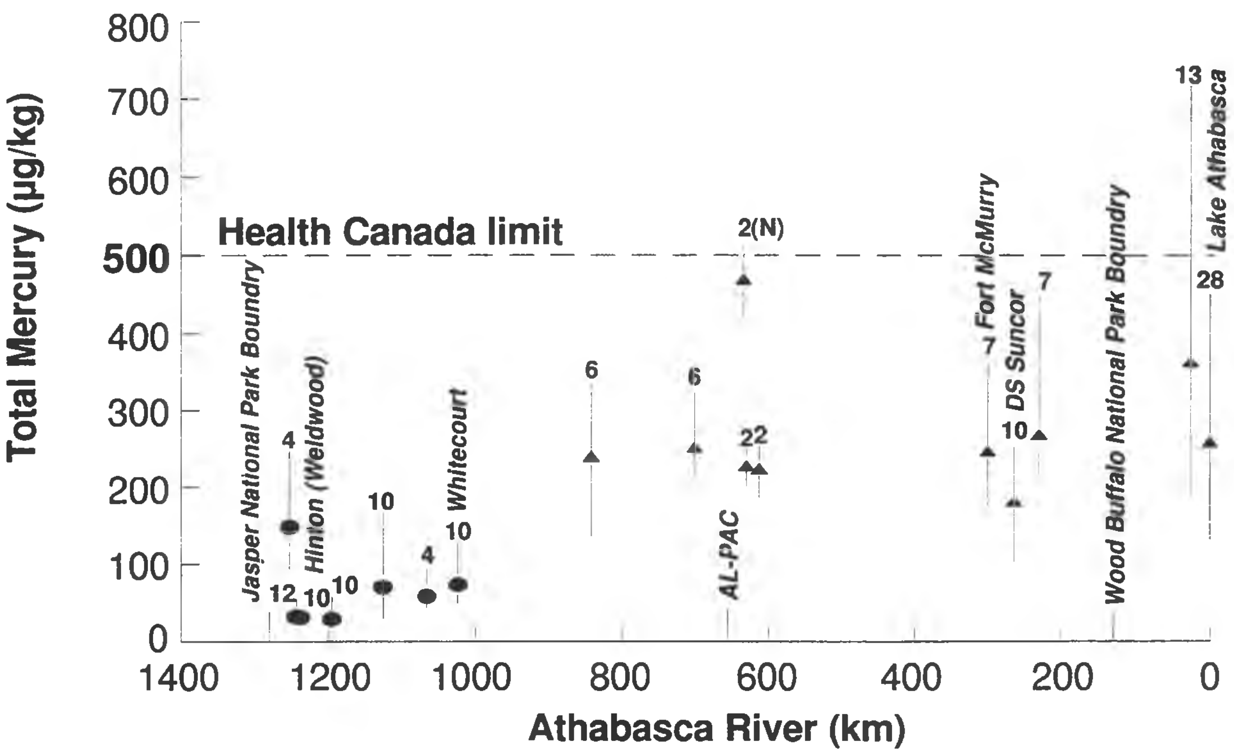
6.4 WHITE SUCKER

Mercury levels in white sucker (Appendix C) collected from Lake Athabasca in 1981 ranged from 30 to 220 μg/kg with a mean of 100 μg/kg (N = 10). These levels are well below the Heath Canada guideline limit.

6.5 MOUNTAIN WHITEFISH

Mercury levels were determined in mountain whitefish collected from the Athabasca River in the Hinton reach from the eastern boundary of Jasper National Park to Whitecourt (NRBS). This fish were collected in May 1992 (Barton et al. 1993). For this reach, mean mercury concentration ranged from 29 to 147 μg/kg (Figure 13). None of the mountain whitefish had mercury levels that exceeded the Health Canada limit. Mercury concentrations were higher in mountain whitefish collected from

Figure 13. Mean total mercury in mountain whitefish ● and goldeye ▲ muscle tissue (µg/kg), Athabasca River. (vertical lines = maximum and minimum, N values = number of fish analyzed, data from 1977 to 1992, see Appendices C and D).



upstream compared with downstream of the combined municipal and pulp mill effluent at Hinton. This suggests that the Hinton effluent is not a major source of mercury to the Athabasca River. However, the known migratory behavior of mountain whitefish (Clayton and McLeod 1994) would complicate any interpretation of upstream/downstream concentration of mercury relative to source.

6.6 GOLDEYE

Mercury levels have been measured in muscle tissue of goldeye taken from the Athabasca River and Lake Athabasca from 1977 to 1992 (Appendix D). Goldeye from these sites are probably from the same general population that overwinters in the lower Peace River downstream from the Vermilion Chutes (Donald and Kooyman 1977, Bond 1980). For nine sites along the reach of the Athabasca River from the junction with the Lesser Slave River to Lake Athabasca, mean mercury concentration ranged from 179 to 466 µg/kg (Figure 13). One or 2% of 55 goldeye analyzed from this reach, had a mercury level that was more than the Health Canada limit of 500 µg/kg. Mercury concentration did not increase in goldeye in a downstream direction.

Mercury levels were assessed in goldeye collected from Lake Athabasca in 1977, 1981 and 1989. The mean concentration of total mercury for these three years ranged from 216 to 300 µg/kg (Figure 12). None of the fish collected during this period exceeded the Health Canada limit of 500 µg/kg.

6.7 LAKE WHITEFISH

Lake whitefish were collected for mercury analyses from seven sites in the Basins. The sites were the Athabasca River downstream of Fort McMurry (AEC) and Jackfish Village (NRBS), from Lake Athabasca (DFO), from the Williston and Dinosaur reservoirs (Watson 1992), from the Peace River downstream of Dinosaur Reservoir (Watson 1992), and from the Slave River at Fort Smith (Grey et al. 1995). Mean mercury concentration for the Athabasca River sites and Lake Athabasca ranged from 62 to 80 µg/kg, respectively. For Williston and Dinosour reservoirs and a downstream site on the Peace River, mean concentration was 210, 95, and 70 µg/kg (N = 78, 25, and 11), respectively, and mercury levels obviously did not increase in the downstream direction (Watson 1992). All 114 lake whitefish from the three upstream sites on the Peace River in British Columbia had mercury concentrations that were less than the Health Canada regulatory limit of 500 µg/kg.

At the Slave River site from 1988 to 1993, mean mercury concentrations was 57.6 µg/kg (SRMP, Grey et al. 1995). All fish (N = 70) had levels that were less than the Health Canada limit.

6.8 BURBOT

Liver rather than muscle tissue was used to assess levels of contaminants for burbot because the liver is relatively large compared with other fish species, and because it is consumed by people in the Basins.

However, mercury levels are generally higher in burbot muscle compared to liver (Table 1). For example, mercury concentration in a composite (several fish) sample of muscle (274 µg/kg) was 2.3 times higher than in livers (120 µg/kg) from the same fish. These burbot were collected from near Jackfish Village on the Athabasca River in 1994 (NRBS).

Table 1. Concentration of Mercury in Composite Samples of Burbot Tissue Collected from the Peace-Athabasca Delta, December, 1994.

Location	Muscle (µg/kg)	Liver (µg/kg)	Number of fish	Mean length (mm)	Mean Weight (g)
Quatre Fourches	114	< 20	8	532	1016
Potato Island	144	36	10	507	1145
Jaskfish Village	274	120	5	654	2685

Mercury levels were assessed in burbot livers at five sites on the Athabasa River in 1994 (NRBS, Figure 14, Appendix G). Mean concentration of total mercury in burbot livers for the Athabasca River ranged from 54 to 72 µg/kg for fish that weighed 945 and 903 g, respectively (N = 10 and 12 fish, respectively). None of the burbot caught from the Athabasca River had mercury levels that exceeded the Health Canada limit of 500 µg/kg. Mercury levels did not increase in burbot livers from the headwaters of the Athabasca River (km 1253) to near the mouth (km 240, Figure 14). Levels also did not increase from upstream to downstream of the combined pulp mill/municipal effluent at Hinton, or from upstream to downstream of the Suncor tarsands processing plant ($t = 1.759$, $df = 23$, $p > 0.05$).

Mercury has been measured in liver tissue from 13 sites on the Wapiti - Smoky - Peace - Slave river continuum in 1992 and 1994 (NRBS, Appendix G, Havenegard 1993). The mean mercury levels in liver for these 13 sites ranged from 35 to 375 µg/kg (Figure 15). Of the 151 burbot analyzed from these sites, only three exceeded the Health Canada limit of 500 µg/kg. A weak but significant correlation was evident between mercury concentration in liver and burbot weight (Figure 16). Thus, higher levels of mercury were generally, but not always associated with large fish (Figures 7 and 16).

Figure 14. Mean total mercury in burbot liver, Athabasca River.
(Mean burbot weight in brackets, N = 51 burbot, NRBS 1994).

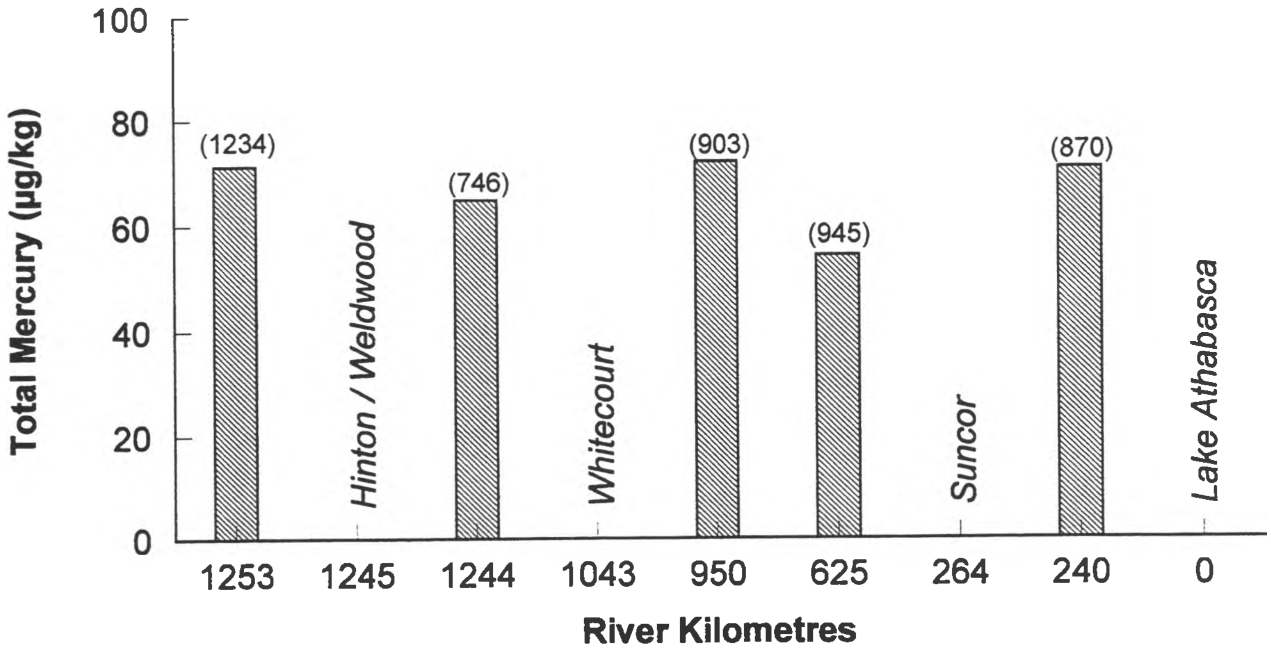


Figure 15. Mean total mercury in burbot liver, Peace River basin. (Mean burbot weight in brackets, N = 202 burbot total, NRBS 1992 and 1994).

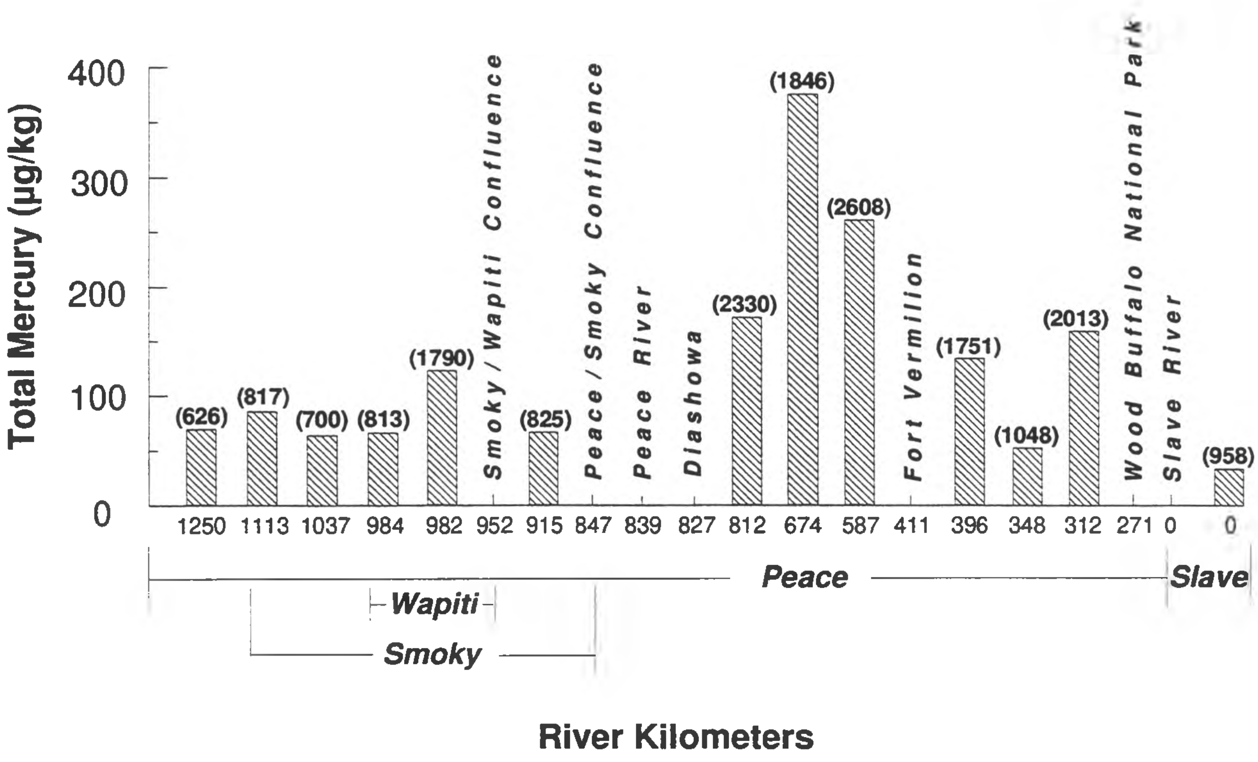
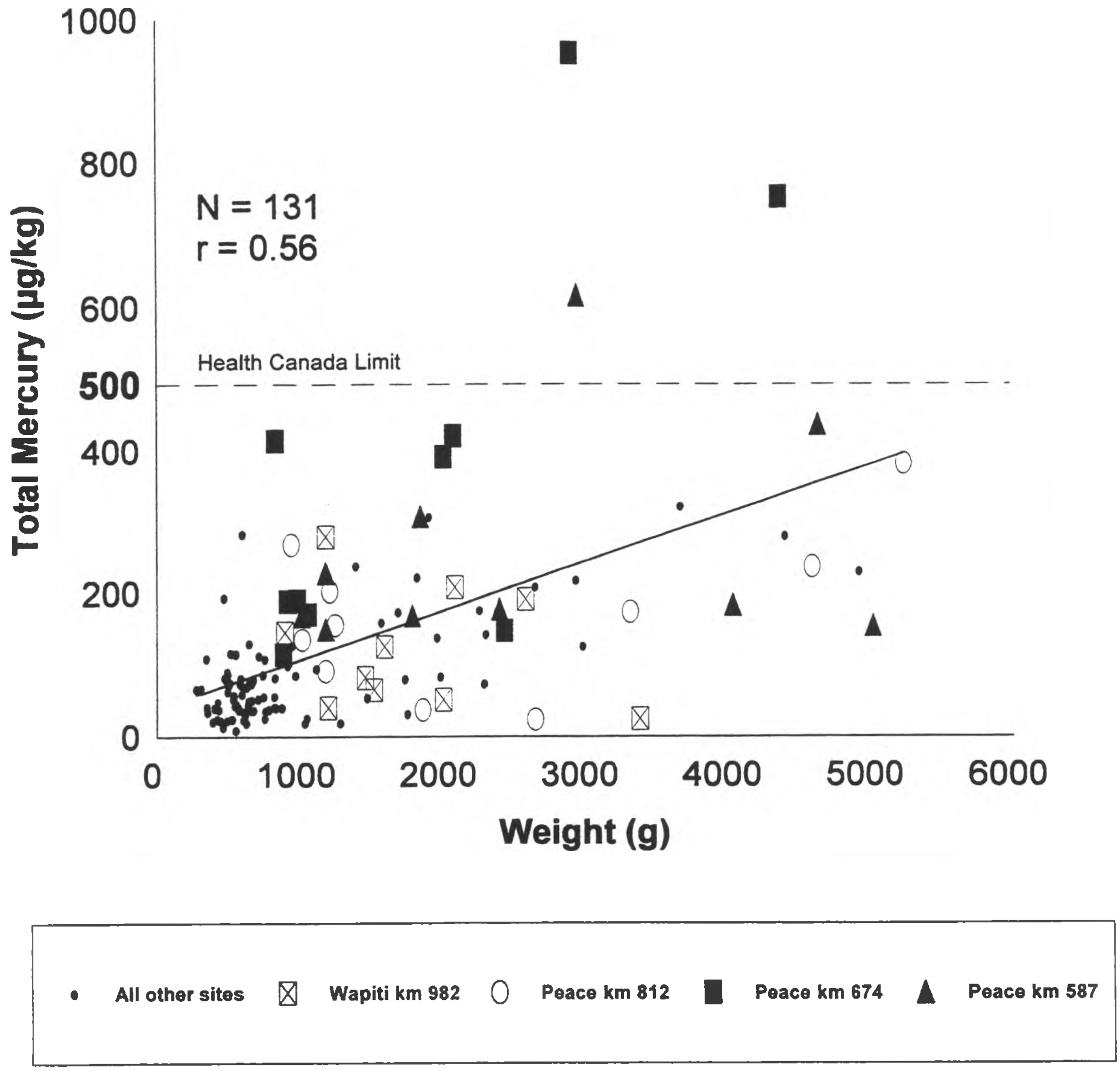


Figure 16. Relationship between burbot weight and total mercury concentration in burbot liver, Wapiti, Smoky, and Peace rivers, 1992 and 1994 (NRBS).



For the Wapiti to Slave continuum, there was not a upstream/downstream trend in mercury concentration in burbot livers (Figure 15). The sites at km 984 and 982 on the Wapiti River near Grand Prairie were upstream/downstream of a pulp mill effluent (Proctor and Gamble). Mean mercury concentration in livers at these site was 69 and 122 μg/kg, respectively. However, this upstream to downstream increase was not significant ($t = 1.59$, $p > 0.05$, $df = 20$). Some of the increase in mercury concentration would be related to the larger fish caught at the downstream site
(km 982, Fig. 15 and 16). Mercury levels at km 982 were greater than concentrations downstream of this mill on the Smoky River, at km 1037 and 915, and at a control site at km 1113 (Figure 15) on the Smoky River. However, these slight increases in mercury concentration in burbot livers were not significant ($p > 0.05$).

The highest levels of mercury were found in a 250 km reach downstream of the town of Peace River and Diashowa, a large pulp mill on the Peace River. The high levels of mercury at km 812 were probably due to the large size of fish caught at this sites (Figures 15 and 16). However, mercury levels in five burbot from km 674 and 587 were much higher than expected (Figure 16). Three large burbot (about 3 kg) caught in this reach exceeded the Health Canada guideline limit of 500 μg/kg for mercury. These high concentrations in individual fish might be due to anthropogenic sources of mercury originating along the Notikewin River, a tributary of the Peace River. The Kotikewin River receives municipal effluent from Manning and flows through a region with cattle and small grain farms (Chamber 1996). Additional samples of burbot from more sites would be required to identify a specific point or non point source for mercury.

Mean mercury concentrations in burbot livers from the Slave River delta were low, mean = 84 μg/kg, and none exceeded the Health Canada guideline limit.

Mercury levels were also measured in muscle tissue taken from burbot collected from Williston Reservoir on the Peace River in British Columbia, and from Muskwa Lake in the Athabasca River basin. For 26 burbot with mean weight 660g taken from Williston Reservoir, mean mercury concentration was 300 μg/kg (range from 130 to 680 μg/kg, Watson 1992). Three or 12% of the 26 fish exceeded the Health Canada limit, and all weighed more than 1.8 kg. Burbot from Muskwa Lake in Alberta had relatively low levels of mercury (99 μg/kg, $N = 8$, mean weight 3.4 kg).

6.9 BULL TROUT

Mercury was measured in bull trout from Williston Reservoir on the Peace River in British Columbia (Watson 1992). The reservoir was first closed at the W.A.C. Bennett Dam in 1968. Mercury levels in bull trout were the highest recorded for any fish species from the Peace, Athabasca, and Slave river basins. The mean concentration for the Reservoir was 804 μg/kg. The maximum concentration of mercury found in an individual was 4870 μg/kg. Thirty-five percent of bull trout exceed the Health Canada limit of 500 μg/kg (Watson 1992). Downstream from the Reservoir in the Peace River, the mean and maximum mercury concentration in bull trout was 210 and 840 μg/kg, respectively.

Large bull trout tended to have higher concentrations of mercury than small fish (Figure 17). The relationship between bull trout weight and mercury concentration was highly significant ($r = 0.80$, $p < 0.001$).

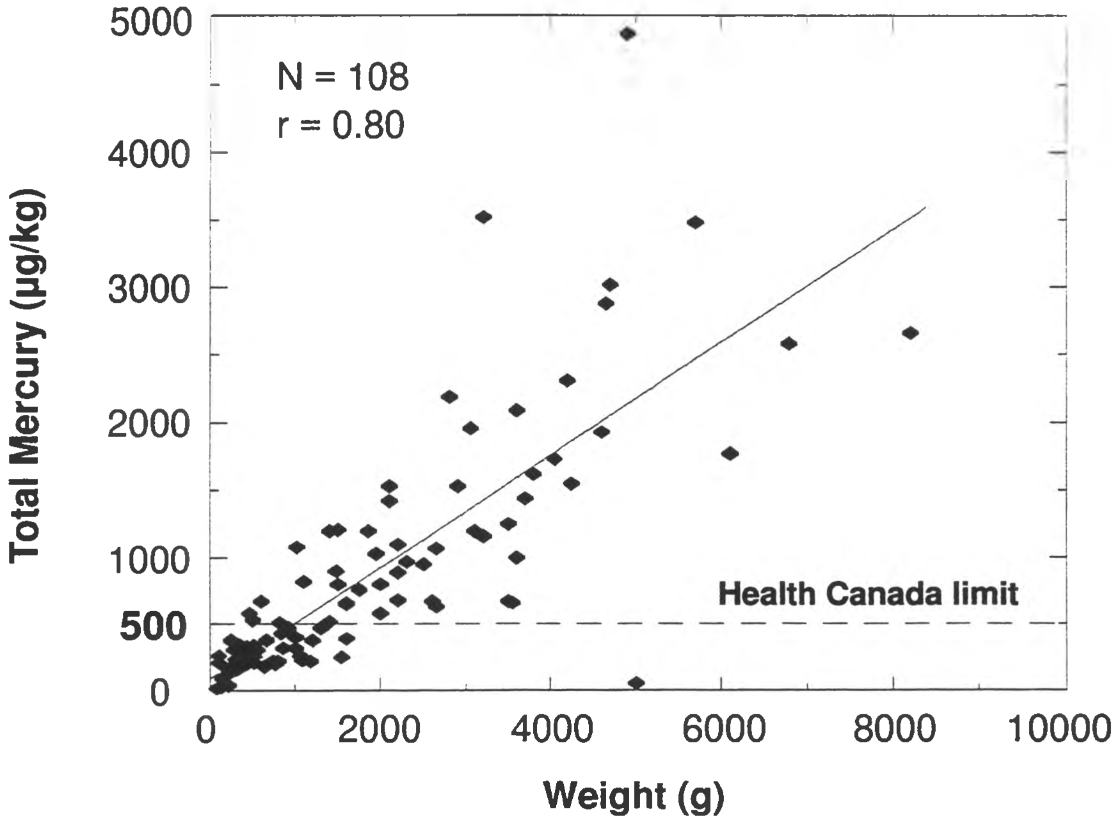
Other species of fish in Williston Reservoir generally had much lower levels of mercury than bull trout. The order of decreasing concentration of mercury in fish was bull trout > burbot > lake trout > lake whitefish > kokanee > rainbow trout. The first three species in this list are predators. Mercury bioaccumulates through the food chain (Phillips et al 1980, MacCrimmon et al 1983, and Cope et al. 1990), and higher levels in large predators would be expected. Also, flooded organic soils in reservoirs are known to enhance mercury methylation (Jackson 1988), and it is common for fish in reservoirs to have elevated levels of methylmercury.

6.10 SUMMARY AND SIGNIFICANCE OF MERCURY IN FISH

Mercury was found in fillets or liver of all fish species in the Athabasca, Peace, and Slave river basins. In general, mercury levels were highest in predatory fish species such as pike, walleye, burbot and bull trout. Fish that primarily forage on invertebrates such as mountain whitefish, lake whitefish, and suckers generally had lower concentrations of mercury. For the Athabasca River basin, the concentration of mercury was highest in walleye followed by goldeye then northern pike then longnose sucker, and was lowest in mountain whitefish. An identical pattern and similar concentrations of total mercury were reported by Ramamoorthy et al. (1985) for the North Saskatchewan River in Alberta. There, mean mercury concentration in walleye (645 µg/kg) was greater than goldeye (594 µg/kg), which was greater than northern pike (314 µg/kg), followed by longnose sucker (245 µg/kg). For the predatory fish species, concentration of mercury increased with fish size, a pattern that has been reported for other fish populations in lakes (Fagerstrom et al 1974, Moore et al. 1986, Gutenmann et al. 1992). For the Basins in Alberta specific guidelines for consumption of large predatory fish have been established for two lakes and for the lower Athabasca River.

The highest levels of mercury found in fish for the entire Basin were those reported for large bull trout taken from Williston Reservoir in British Columbia. The mean concentration in bull trout was 804 µg/kg, and the maximum concentration recorded was 4870 µg/kg from a 4.9 kg bull trout, a level that is almost 10 times the Health Canada limit of 500 µg/kg. High mercury concentrations in reservoirs (Derksen and Green 1987, Scruton et al. 1994) are usually attributed to enhanced mercury methylation within flooded organic soils (Bodaly et al. 1987, Jackson 1988), and for the Williston Reservoir this mechanism was probably the main source of high levels of mercury in fish. Mercury levels in burbot, lake whitefish, bull trout, rainbow trout, and kokanee were lower in the Peace River downstream from Williston Reservoir than in these same fish species taken from the Reservoir. With few exceptions, fish taken from the Peace River downstream from the Reservoir had levels of mercury that were less than 500 µg/kg. Thus, the elevated levels of mercury found in fish in the reservoirs in British Columbia were not present in fish downstream into Alberta. This pattern is in contrast to the La Grande River in Quebec where lake whitefish have higher levels immediately downstream from the La Grande 2 Reservoir than lake whitefish from the Reservoir (Brouard et al. 1994).

Figure 17. **Relationship between bull trout weight and total mercury concentration in bull trout muscle tissue, Williston Reservoir, British Columbia (data from Watson, 1992).**



For the period 1977 to 1992, there was no indication that mercury levels have increased in fish from the lower Athabasca River basin, based on samples of goldeye and walleye taken from Lake Athabasca. Furthermore, mercury levels in fish collected upstream and downstream of pulp mill and municipal effluents at Hinton, Whitecourt, and Grand Prairie were generally similar, with no obvious common upstream/downstream trend. However, the highly migratory behaviour of fish in the mainstem rivers in these basins makes an upstream/downstream comparison of concentration impossible to assess in relation to potential point source inputs of mercury.

7.0 RECOMMENDATIONS

It is recommended that:

1. Mercury concentration in walleye from western Lake Athabasca and sites along the lower Athabasca River downstream from the town of Athabasca be measured every two years. Mercury concentration often exceeds the Health Canada guideline limit of 500 µg/kg in walleye caught from the lower Athabasca River. Few walleye from Lake Athabasca exceed this limit. However, processes, mechanisms, or the contaminant source that has enhanced levels of mercury in walleye from the lower Athabasca River might in the future also increase levels of mercury in the commerical stock of walleye from western Lake Athabasca which includes the Athabasca River delta.

2. A detailed study be conducted in the lower Athabasca River to evaluate and to identify mechanisms and pathways of mercury uptake by aquatic biota. The tarsands, an organic rich substrate, forms a significant part of the bank of the Athabasca River and its tributaries in this reach. Tar sands may enhance mercury uptake into the food web. An evaluation of the contribution of the waste-water effluent from the town of Fort McMurray and the contribution of the Suncor operation to mercury loading in the lower Athabasca River should be part of this study.

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APPENDICES

APPENDIX A. MERCURY CONCENTRATION IN NORTHERN PIKE, ATHABASCA AND PEACE RIVER BASINS (AEC).

Lake	Year analyzed	Mean Weight (g)	Total Mercury (µg/kg, DL=20 µg/kg)					
			mean	min	max	SD	N	percent >500 µg/kg
Brintnell	1980, '84, '85, '92	1309.9	260.0	140.0	474.0	83.3	25	0
Chip	1982, '83, '86, '87, '92	892.3	170.9	50.0	530.0	104.0	44	2.3
Christina	1982, '84, '85	2182.0	340.2	103.0	672.0	188.6	12	16.7
Driftwood	1987	2410.0	170.0	130.0	230.0	52.9	3	0
Edwards	1987	3604.0	825.0	760.0	890.0	91.9	2	100
Fawcett	1979, '84, '86, '90	2720.7	354.0	90.0	780.0	182.3	25	20
Goodfish	1985, '92	1030.8	420.0	190.0	530.0	109.3	10	20
Goosegrass	1992	1427.0	342.0	210.0	540.0	136.3	5	20
Graham	1978, '82, '84, '85, '92	1774.8	96.8	20.0	215.0	49.2	31	0
Kirby	1992	1197.0	196.0	100.0	290.0	86.2	5	0
Lac la Biche	1984	1523.5	88.1	30.0	180.0	52.7	16	0
Lac la Nonne	1973, '84, '85	1926.3	232.3	87.0	353.0	79.0	25	0
Athabasca	1977, '81, '84, '85	1871.2	282.0	160.0	420.0	84.5	21	0
Lesser Slave	1987, '91	1998.4	248.8	210.0	300.0	33.6	8	0
Long	1982	1979.0	98.9	30.0	270.0	75.4	9	0
McMillan	1980, '81	1159.8	305.4	100.0	410.0	77.8	13	0
Meekwap	1990, '92	1174.3	149.0	30.0	340.0	120.5	10	0
Mink	1985, '87, '92	964.9	210.6	110.0	390.0	73.5	16	0
Mistehae	1985, '87, '92	1099.1	268.2	140.0	520.0	97.6	22	4.5
Muskwa	84, '85, '90	2547.3	410.7	120.0	1070.0	237.5	30	23.3
Nipisi	1980, '85, '87, '92	2345.3	130.0	70.0	300.0	61.6	19	0
North Wabasca	1981, '84, '92	1491.5	298.4	100.0	650.0	103.1	80	6.3
Orloff	1984, '92	1896.4	106.0	60.0	160.0	38.6	10	0
Peerless	1992	2702.2	200.0	130.0	290.0	76.2	5	0
Roche	1990	1520.0	66.2	40.0	120.0	22.9	13	0
Rock Island	1989	2780.8	114.0	20.0	220.0	79.2	5	0
Round	1982,'84, '85, '92	2414.6	204.5	60.0	450.0	109.0	22	0
Sandy	1992	1672.0	208.0	110.0	390.0	111.0	5	0
Snipe	1992	885.4	74.0	60.0	100.0	19.5	5	0
South Wabasca	1981	1029.9	107.5	30.0	240.0	74.2	8	0
Wappau	1992	537.6	76.0	20.0	180.0	65.4	5	0
Winagami	1984, '92	1117.4	58.9	10.0	110.0	40.1	9	0

APPENDIX B. MERCURY CONCENTRATION IN WALLEYE (AEC).

Lake	Year analyzed	Mean Weight (g)	Total Mercury (µg/kg, DL=20 µg/kg)					
			mean	min	max	SD	N	percent >500 µg/kg
Christina	1982, '87	1180.3	341.3	80.0	770.0	238.7	15	26.7
Fawcett	1986	862.6	188.0	80.0	370.0	95.4	10	0
Goodfish	1985	216.2	242.0	190.0	370.0	74.6	5	0
Graham	1978, '81, '84, '85	1367.4	99.7	20.0	243.0	69.6	23	0
Lac la Nonne	1973, '84, '85	1093.9	320.4	100.0	694.0	154.4	29	10.3
Athabasca	1977, '81, '88, '89, '90, '91, '92	902.0	322.0	150.0	810.0	127.7	87	6
Lesser Slave	1991	1930.4	256.0	210.0	320.0	40.4	5	0
Long	1982	1135.8	113.3	50.0	280.0	101.3	6	0
Muskwa	1990	2246.7	466.7	300.0	680.0	167.1	6	33.3
Round	1982.'84, '85	1511.1	166.8	90.0	253.0	66.9	9	0
South Wabasca	1981	1145.8	191.7	50.0	340.0	105.2	6	0

APPENDIX C. MERCURY CONCENTRATION IN NORTHERN PIKE, LAKE WHITEFISH, MOUNTAIN WHITEFISH, WHITE SUCKER, AND LONGNOSE SUCKER FROM THE ATHABASCA RIVER.

Athabasca River			Fish species	Length (mm)	Weight (g)			Total Mercury (µg/kg, DL=20 µg/kg)						Source
Km	Year	Site		mean	mean	SD	N	mean	min	max	SD	percent methyl mercury	percent detections >500 µg/kg	
0	77, 81	Lake Athabasca	Northern Pike	642.6	1754.0	399.5	11	276.4	160.0	420.0	103.9	---	0	DFO
264	1984	DS Suncor		522.0	1108.7	---	3	290.0	148.0	464.0	---	87	0	AEC
625	1984	Calling/Athabasca Confluence		425.3	558.0	---	3	209.7	188.0	234.0	---	75	0	AEC
1127	1992	Knight Bridge		621.9	1902.5	1387.9	10	221.0	92.0	462.0	109.7	100	0	NRBS
1196	1992	Emmerson Lakes Bridge		698.0	2596.0	0.0	1	94.0	94.0	94.0	0.0	100	0	NRBS
1244	1992	Haul Bridge		436.0	598.0	258.8	2	85.5	58.0	113.0	38.9	100	0	NRBS
0	77, 81	Lake Athabasca	Lake Whitefish	429.9	962.6	275.4	13	61.5	30.0	150.0	35.6	---	0	DFO
35	92, 94	Jackfish Village		---	---	---	7	68.4	37.0	88.0	17.8	---	0	NRBS
264	1984	DS Suncor		388.2	888.2	219.0	10	80.4	49.0	171.0	34.9	55	0	AEC
1043	1992	Whitecourt	Mountain Whitefish	355.1	625.4	205.4	10	72.6	48.0	128.0	27.1	100	0	NRBS
1067	1992	Windfall Bridge		362.5	651.0	291.5	4	57.8	43.0	93.0	23.7	100	0	NRBS
1127	1992	Knight Bridge		387.5	715.0	243.2	10	69.6	29.0	167.0	46.7	100	0	NRBS
1196	1992	Emmerson Lakes Bridge		362.0	617.4	235.7	10	28.9	16.0	58.0	12.1	105	0	NRBS
1244	1992	Haul Bridge		350.4	573.2	289.3	12	31.9	17.0	55.0	11.8	68	0	NRBS
1238	1992	Weldwood		372.4	716.5	536.7	10	30.7	20.0	43.0	7.6	100	0	NRBS
1253	1992	US Hinton		337.5	441.0	267.0	4	147.8	93.0	248.0	69.1	100	0	NRBS
0	1981	Lake Athabasca	White Sucker	474.7	1005.9	130.6	10	100.0	30.0	220.0	57.2	---	0	DFO
264	1984	DS Suncor	Longnose Sucker	379.6	787.6	221.5	7	129.9	81.0	197.0	44.3	54	0	AEC
491	1988			426.0	---	---	5	1920.0	1740.0	2180.0	---	---	---	SENTAR
663	1988			403.0	---	---	5	670.0	360.0	1530.0	---	---	---	SENTAR
700	1984	Athabasca Bridge		338.0	538.3	---	3	270.7	203.0	400.0	---	84	0	AEC
1105	1992	Berland River Confluence		375.0	652.5	159.0	2	69.0	37.0	101.0	45.3	100	0	NRBS
1043	1992	Whitecourt		378.8	635.7	144.6	10	152.3	27.0	244.0	74.1	97	0	NRBS
1196	1992	Emerson Lakes Bridge		368.3	620.0	49.7	4	57.5	25.0	109.0	39.2	100	0	NRBS
1200	1992	Obed Mtn Coal Bridge		395.4	768.6	70.5	7	36.7	21.0	46.0	10.4	100	0	NRBS
1238	1992	Weldwood		371.8	623.8	117.8	10	41.7	20.0	74.0	16.3	100	0	NRBS
1244	1992	Haul Bridge		405.8	852.5	72.7	4	86.5	34.0	154.0	50.1	100	0	NRBS
1253	1992	US Hinton		391.4	710.0	161.4	5	151.4	70.0	250.0	71.2	100	0	NRBS

DFO=Department of Fisheries and Oceans; AEC=Alberta Environmental Centre; NRBS=Northern River Basins Study; SENTAR=Sentar Consultants Ltd.

APPENDIX D. MERCURY CONCENTRATION IN WALLEYE AND GOLDEYE FROM THE ATHABASCA RIVER.

Athabasca River			Fish species	Length (mm)	Weight (g)			Total Mercury (µg/kg, DL=20 µg/kg)						Source
Km	Year	Site		mean	mean	SD	N	mean	min	max	SD	percent methyl mercury	percent detections >500 µg/kg	
0	77,81,88,89,90,91,92	Lake Athabasca	Walleye	457.6	902.0	268.3	87	322.0	150.0	810.0	127.7	---	5.7	DFO
35	1992	Jackfish Lake Fishing Village		478.6	1060.7	352.4	9	381.7	245.0	485.0	81.1	100	0	NRBS
230	1992			386.0	654.3	405.3	3	293.3	275.0	322.0	25.1	100	0	NRBS
264	1984	DS Suncor		427.1	956.3	493.6	19	384.7	150.0	740.0	167.1	85	25	AEC
300	1992			377.3	467.0	173.2	10	267.7	185.0	467.0	88.7	100	0	NRBS
491	1992			477.0	---	---	5	2980.0	2250.0	3850.0	---	---	---	SENTAR
627	1992			331.8	322.5	117.8	6	335.0	111.0	790.0	255.9	100		NRBS
630	1992			368.0	482.0	288.5	2	352.0	285.0	419.0	94.8	100	0	NRBS
634	1992			325.0	290.0	0.0	1	299.0	299.0	299.0	0.0	100	0	NRBS
663	1992			481.0	---	---	5	2190.0	1250.0	2560.0	---	---	---	SENTAR
0	77,81,89	Lake Athabasca	Goldeye	349.8	433.8	158.7	28	255.7	130.0	450.0	85.3		0	DFO
5	1992	Athabasca Delta		355.8	516.6	87.0	13	360.7	186.0	717.0	151.1	100	15.4	NRBS
230	1992			283.1	224.6	65.2	7	265.7	204.0	445.0	83.1	100	0	NRBS
264	1984	DS Suncor		350.9	611.0	305.3	10	179.0	102.0	252.0	63.8	76	0	AEC
300	1992			314.3	323.7	116.4	7	244.4	173.0	362.0	62.3	100	0	NRBS
627	1992			293.5	264.0	101.8	2	220.5	186.0	255.0	48.8	100	0	NRBS
630	1992			236.0	115.5	34.6	2	224.5	199.0	250.0	36.1	100	0	NRBS
634	1992			368.5	456.0	12.7	2	466.0	422.0	510.0	62.2	100	50	NRBS
700	1984	Athabasca Bridge		328.3	420.5	75.8	6	249.3	211.0	323.0	41.8	82	0	AEC
842	1984	Hondo Bridge		315.2	382.4	60.7	5	217.6	136.0	280.0	71.7	81	0	AEC

DFO=Department of Fisheries and Oceans; AEC=Alberta Environmental Centre; NRBS=Northern River Basins Study; SENTAR=Sentar Consultants Ltd.

APPENDIX E. MERCURY CONCENTRATION IN WALLEYE AND GOLDEYE FROM LAKE ATHABASCA

Year	Fish species	Length (mm)	Weight (g)			Total Mercury (µg/kg, DL=20 µg/kg)						Source
		mean	mean	SD	N	mean	min	max	SD	percent methyl mercury	percent detections >500 µg/kg	
1977	Goldeye	252.0	158.0	16.0	5	270.0	230.0	340.0	41.8	100	0	DFO
1981		384.9	433.5	28.4	13	216.2	130.0	440.0	79.1	100	0	DFO
1989		353.1	572.0	88.8	10	300.0	130.0	450.0	90.3	100	0	DFO
1977	Walleye	451.0	1006.0	508.5	5	520.0	310.0	790.0	227.9	100	40	DFO
1981		461.1	863.4	226.6	44	296.4	150.0	810.0	114.8	100	4.5	DFO
1988		449.3	762.8	68.3	8	336.3	230.0	500.0	96.1	100	12.5	DFO
1989		452.0	679.0	109.6	5	342.0	280.0	430.0	55.4	100	0	DFO
1990		469.6	842.8	145.3	5	238.0	170.0	330.0	60.6	100	0	DFO
1991		464.5	1250.4	316.3	10	382.0	200.0	670.0	143.7	100	10	DFO
1992		442.3	923.8	116.4	10	296.0	200.0	400.0	70.4	100	0	DFO

DFO = Department of Fisheries and Oceans

APPENDIX F. MERCURY CONCENTRATION IN LONGNOSE SUCKER FROM THE WAPITI AND SMOKY RIVERS.

Km	Year	Site	Length (mm)	Weight (g)			Total Mercury (µg/kg, DL=20 µg/kg)					
			mean	mean	SD	N	mean	min	max	SD	percent methyl mercury	percent detections >500 µg/kg
Smoky River												
915	1984	Wanito-Hwy 49	364	680	313	7	247	59	475	150	100	AEC
1038	1984	Benzanson-Hwy34	364	625	229	7	230	102	376	109	100	AEC
Wapiti River												
959	1984	Wembley	367	604	192	10	34207	165	612	156	100	AEC
1004	1984	Alberta Railway Bridge	368	595	167	7	170	79	293	68	100	AEC

AEC = Alberta Environmental Centre

APPENDIX G. MERCURY CONCENTRATION IN BURBOT LIVER FROM THE ATHABASCA, WAPITI, SMOKY, PEACE, AND SLAVE RIVERS, NORTHERN RIVER BASINS STUDY, (NRBS - 1992 AND 1994).

Km	Year	Site	Length (mm)	Weight (g)		N	Total Mercury (µg/kg, DL=20 µg/kg)					
			mean	mean	SD		mean	min	max	SD	percent methyl mercury	percent detections >500 µg/kg
Athabasca River												
240	1994	Fort McKay	521	870.3	253.5	15	70.8	24	125	26.8	100	0
625	1994	Calling River	554	944.9	362.4	10	54.3	40	83	15.3	100	0
950	1994	Fort Assiniboine	539	902.8	638.1	12	72.0	43	113	24.0	100	0
1244	1994	D/S Hinton	532	746.3	324.2	3	64.8	33	139	43.2	100	0
1253	1994	U/S Hinton	574	1233.6	1137.4	11	71.3	43	161	36.3	100	0
Wapiti River												
982	1992	D/S Proctor & Gamble	664.9	1790.1	754.4	10	122.2	25.9	280.0	83.9	100	0
984	1994	U/S Proctor & Gamble	525.8	813.8	185.6	12	69.4	20.0	283.0	71.6	100	0
Smoky River												
915	1992	Watino	523.0	824.8	535.7	10	90.9	13.8	164.0	56.9	78	0
915	1994	Watino	460.3	526.0	141.4	16	62.1	20.0	194.0	43.2	100	0
1037	1992	Hwy #34	503.7	699.5	373.2	10	63.5	23.0	174.0	45.3	74	0
1113	1992	Canfor Haul Bridge	509.6	816.6	727.5	11	85.5	49.4	125.0	23.1	86	0
Peace River												
312	1992	Fox Lake	619.5	2013.1	1788.3	10	158.7	24.3	321.0	121.6	81	0
348	1992	John d'Or Prairie	553.6	1048.2	644.2	9	52.8	10.0	143.0	40.1	73	0
396	1992	Beaver Ranch	673.8	1751.0	646.6	10	133.4	19.2	238.0	75.3	79	0
587	1992	Carcajou	746.7	2607.8	1494.2	10	259.9	150.0	618.0	154.4	100	10
674	1992	Notikewin River	673.2	1845.7	1160.9	10	375.1	115.0	953.0	280.8	100	20
812	1992	D/S Daishowa	719.3	2329.5	1578.7	10	171.0	24.2	382.0	108.8	80	0
1250	1994	Many Islands	498.0	626.0	247.8	3	83.7	64.0	100.0	18.2	100	0
Slave River												
0	1994	Slave River Delta	518.0	958.1	502.1	20	35.2	21.0	55.0	8.6	100	0

APPENDIX H. MERCURY CONCENTRATION IN WALLEYE, LAKE WHITEFISH, NORTHERN PIKE AND BURBOT FROM THE SLAVE RIVER (SRMP*).

Year	Fish Species	Length (mm)	Weight (g)			Total Mercury (µg/kg, DL= 20 µg/kg)					
		Mean	Mean	SD	N	Mean	Min	Max	SD	percent methyl mercury	percent detections >500 µg/kg
1991	Walleye	425.6	932.6	294.0	11	253.6	90	400	92.1	100	0
1992		437.7	972.4	465.0	14	230.0	60	500	116.8	100	0
1993		453.1	1100.9	376.0	11	255.5	50	600	163.3	100	9
1991	Lake Whitefish	377.2	788.4	196.6	14	35.7	20	60	12.2	100	0
1992		385.8	869.4	208.5	21	46.7	20	120	25.2	100	0
1993		376.2	755.0	66.4	5	30.0	20	50	12.2	100	0
1991	Northern Pike	580.8	1440.2	382.4	12	188.3	60	300	61.3	100	0
1992		601.5	1692.5	874.2	20	314.5	130	520	105.5	100	5
1993		653.8	2220.2	707.2	9	186.7	90	340	73.8	100	0
1991	Burbot	539.2	1094.3	403.1	11	81.8	20	140	39.2	100	0
1992		542.8	1189.6	327.8	5	128.0	90	170	33.5	100	0
1993		588.4	1448.1	910.1	10	157.0	120	210	30.2	100	0

* - data from Peddle et al. 1995.

APPENDIX I. CONCENTRATION OF MERCURY AND OTHER METALS IN BENTHIC INVERTEBRATES TAKEN FROM THE ATHABASCA RIVER IN THE SUNCOR REACH, 1994.

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GOLDER ASSOCIATES
ATTENTION : RANDY SHAW

GROUNDWATER,SEDIMENT,BENTHOS / 17-10-94

Sample Description : SITE 31
Sample Date & Time : 17-10-94 N/A
Sampled By : R.S.C.
Sample Type : GRAB
Sample Station Code : GROUNDWATER

Chemex Worksheet Number : 94-07678-7
Chemex Project Number : GOLD121-0502
Sample Access
Sample Matrix : BENTHOS
Report Date : November 28, 1994

PARAMETER DESCRIPTION	NAQUADAT CODE	UNITS	RESULTS	DETECTION LIMIT
Arsenic (AA)		ug/g	0.9	0.2
Selenium (AA)		ug/g	< 0.2	0.2
Antimony (AA)		ug/g	< 0.2	0.2
Total Mercury- (CVAA)		ug/kg	125.	2.
Aluminum (ICP)		ug/g	1170	0.01
Barium (ICP)		ug/g	30.0	1.
Beryllium (ICP)		ug/g	0.2	0.1
Boron (ICP)		ug/g	2.	1.
Cadmium (ICP)		ug/g	< 0.3	0.3
Calcium (ICP)		ug/g	5300	20
Chromium (ICP)		ug/g	3.1	0.2
Cobalt (ICP)		ug/g	2.2	0.1
Copper (ICP)		ug/g	19.2	0.1
Iron (ICP)		ug/g	2770	1.
Lead (ICP)		ug/g	< 2	2.
Lithium (ICP)		ug/g	1.6	0.5
Magnesium (ICP)		ug/g	1590	20
Manganese (ICP)		ug/g	289.	0.1
Molybdenum (ICP)		ug/g	< 0.3	0.3
Nickel (ICP)		ug/g	8.2	0.5
Phosphorus (ICP)		ug/g	6740	10
Potassium (ICP)		ug/g	7440	20
Silicon (ICP)		ug/g	137.	5.
Silver (ICP)		ug/g	< 0.2	0.2
Sodium (ICP)		ug/g	7090	20
Strontium (ICP)		ug/g	19.5	0.5
Titanium (ICP)		ug/g	19.8	0.5
Uranium (ICP)		ug/g	< 50	50
Vanadium (ICP)		ug/g	4.2	0.2
Zinc (ICP)		ug/g	111.	0.1

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GOLDER ASSOCIATES
ATTENTION : RANDY SHAW

SUNCOR TID
PROJ.#942-2212-3000

Sample Description : SITE 3B
Sample Date & Time : 26-08-94 1400
Sampled By : RS
Sample Type : BENTHIC
Sample Station Code :

Chemex Worksheet Number : 94-02473-23
Chemex Project Number : GOLD121-0501
Sample Access :
Sample Matrix : ORGANISMS
Report Date : September 12, 1994

PARAMETER DESCRIPTION	NAQUADAT CODE	UNITS		RESULTS	DETECTION LIMIT
Arsenic (AA)		ug/g		0.8	0.2
Selenium (AA)		ug/g	<	0.2	0.2
Total Mercury- (CVAA)		ug/kg		58.	20
Aluminum (ICP)		ug/g		2000.	1.
Barium (ICP)		ug/g		44.0	1.
Beryllium (ICP)		ug/g		0.2	0.1
Boron (ICP)		ug/g		10.	1.
Cadmium (ICP)		ug/g	<	0.3	0.3
Calcium (ICP)		ug/g		7940.	20
Chromium (ICP)		ug/g		31.8	0.2
Cobalt (ICP)		ug/g		3.5	0.1
Copper (ICP)		ug/g		13.7	0.1
Iron (ICP)		ug/g		5660.	1.
Lead (ICP)		ug/g		3.	2.
Lithium (ICP)		ug/g		3.2	0.5
Magnesium (ICP)		ug/g		2230.	20
Manganese (ICP)		ug/g		193.	0.1
Molybdenum (ICP)		ug/g		2.2	0.3
Nickel (ICP)		ug/g		23.	0.5
Phosphorus (ICP)		ug/g		3950.	10
Potassium (ICP)		ug/g		4560.	20
Silicon (ICP)		ug/g		654.	5.
Silver (ICP)		ug/g	<	0.2	0.2
Sodium (ICP)		ug/g		4270.	20
Strontium (ICP)		ug/g		21.7	0.2
Titanium (ICP)		ug/g		38.9	0.3
Uranium (ICP)		ug/g	<	50	50
Vanadium (ICP)		ug/g		9.7	0.2
Zinc (ICP)		ug/g		78.1	0.1

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GOLDER ASSOCIATES
ATTENTION : RANDY SHAW

SUNCOR TID
PROJ.#942-2212-3000

Sample Description : SITE 58
Sample Date & Time : 26-08-94 1200
Sampled By : RS
Sample Type : BENTHIC
Sample Station Code :

Chemex Worksheet Number : 94-02473-22
Chemex Project Number : GOLD121-0501
Sample Access :
Sample Matrix : ORGANISMS
Report Date : September 12, 1994

PARAMETER DESCRIPTION	NAQUADAT CODE	UNITS	RESULTS	DETECTION LIMIT
Arsenic (AA)		ug/g	0.9	0.2
Selenium (AA)		ug/g	< 0.2	0.2
Total Mercury- (CVAA)		ug/kg	88.	20
Aluminum (ICP)		ug/g	1110.	1.
Barium (ICP)		ug/g	23.0	1.
Beryllium (ICP)		ug/g	0.1	0.1
Boron (ICP)		ug/g	10.	1.
Cadmium (ICP)		ug/g	< 0.3	0.3
Calcium (ICP)		ug/g	7300.	20
Chromium (ICP)		ug/g	13.3	0.2
Cobalt (ICP)		ug/g	2.0	0.1
Copper (ICP)		ug/g	18.4	0.1
Iron (ICP)		ug/g	2590.	1.
Lead (ICP)		ug/g	2.	2.
Lithium (ICP)		ug/g	1.5	0.5
Magnesium (ICP)		ug/g	1600.	20
Manganese (ICP)		ug/g	166.	0.1
Molybdenum (ICP)		ug/g	0.4	0.3
Nickel (ICP)		ug/g	10.	0.5
Phosphorus (ICP)		ug/g	5910.	10
Potassium (ICP)		ug/g	6660.	20
Silicon (ICP)		ug/g	294.	5.
Silver (ICP)		ug/g	< 0.2	0.2
Sodium (ICP)		ug/g	6690.	20
Strontium (ICP)		ug/g	18.8	0.2
Titanium (ICP)		ug/g	19.4	0.3
Uranium (ICP)		ug/g	< 50	50
Vanadium (ICP)		ug/g	3.8	0.2
Zinc (ICP)		ug/g	106.	0.1

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GOLDER ASSOCIATES
ATTENTION : RANDY SHAW

SUNCOR TID
PROJ.#942-2212-3000

Sample Description : SITE 2B
Sample Date & Time : 23-08-94 2000
Sampled By : RS
Sample Type : BENTHIC
Sample Station Code :

Chemex Worksheet Number : 94-02473-21
Chemex Project Number : GOLD121-0501
Sample Access :
Sample Matrix : ORGANISMS
Report Date : September 12, 1994

PARAMETER DESCRIPTION	NAQUADAT CODE	UNITS	RESULTS	DETECTION LIMIT
Arsenic (AA)		ug/g	0.9	0.2
Selenium (AA)		ug/g	< 0.2	0.2
Total Mercury- (CVAA)		ug/kg	78.	20
Aluminum (ICP)		ug/g	1330.	1.
Barium (ICP)		ug/g	24.0	1.
Beryllium (ICP)		ug/g	0.1	0.1
Boron (ICP)		ug/g	12.	1.
Cadmium (ICP)		ug/g	< 0.3	0.3
Calcium (ICP)		ug/g	5110.	20
Chromium (ICP)		ug/g	64.6	0.2
Cobalt (ICP)		ug/g	3.3	0.1
Copper (ICP)		ug/g	15.9	0.1
Iron (ICP)		ug/g	3170.	1.
Lead (ICP)		ug/g	< 2	2.
Lithium (ICP)		ug/g	1.8	0.5
Magnesium (ICP)		ug/g	1530.	20
Manganese (ICP)		ug/g	166.	0.1
Molybdenum (ICP)		ug/g	6.2	0.3
Nickel (ICP)		ug/g	41.	0.5
Phosphorus (ICP)		ug/g	5640.	10
Potassium (ICP)		ug/g	6610.	20
Silicon (ICP)		ug/g	359.	5.
Silver (ICP)		ug/g	2.4	0.2
Sodium (ICP)		ug/g	7000.	20
Strontium (ICP)		ug/g	15.4	0.2
Titanium (ICP)		ug/g	22.0	0.3
Uranium (ICP)		ug/g	< 50	50
Vanadium (ICP)		ug/g	4.6	0.2
Zinc (ICP)		ug/g	103.	0.1

APPENDIX J. TERMS OF REFERENCE

APPENDIX J: TERMS OF REFERENCE

No contractual Terms of Reference were prepared for the work documented in this report. The work was done by the authors as a contribution in kind from their employing agency and represents a part of their responsibilities to the working committee of the Contaminants Component of the Northern River Basins Study.