Athabasca State of the Watershed Assessment Phase 4: Organic Compounds in Surface Water and Sediments, and Trace Metals in Sediments

March 2014

Prepared for:

Athabasca Watershed Council
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DISCLAIMER: This report does not necessarily reflect the opinions of all stakeholders or sectors within the AWC-WPAC.

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AESRD	Alberta Environment and Sustainable Resource Development
Al-Pac	Alberta-Pacific Forest Industries Inc.
AOX	Adsorbable Organic Halides
ARD	Athabasca River Delta
AWC-WPAC	Athabasca Watershed Council - Watershed Planning and Advisory Council
CCME	Canadian Council of Ministers of the Environment
CEMA	Cumulative Environmental Management Association
CEPA	Canadian Environmental Protection Act
CSQG	Canadian Sediment Quality Guidelines
CWQG	Canadian Water Quality Guidelines
EC	Environment Canada
EEM	Environmental Effects Monitoring
ISQG	Interim Sediment Quality Guidelines
LTRN	Long-Term River Network
MRBB	Mackenzie River Basin Board
MTRN	Medium-Term River Network
NRBS	Northern River Basins Study
NREI	Northern Rivers Ecosystem Initiative
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PEL	Probable Effect Level
POP	Persistent Organic Pollutant
PPER	Pulp and Paper Effluent Regulations
QA/QC	Quality Assurance/Quality Control
RAMP	Regional Aquatics Monitoring Program
SOW	State of the Watershed
USEPA	United States Environmental Protection Agency

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EXECUTIVE SUMMARY

The Government of Alberta has committed to protecting and managing the water resources of Alberta pursuant to the *Water for Life (WFL) Strategy* and *Water for Life Action Plan*. The Athabasca Watershed Council Watershed Planning and Advisory Council (AWC-WPAC) was formed in late 2009 and was mandated with the development of a State of the Watershed (SOW) Report for the Athabasca watershed to inform a future integrated watershed management plan for the watershed. Phase 4 of the report involves an assessment of the water and sediment quality of the Athabasca watershed in relation to organic compounds in surface waters and sediments and trace metals in sediments.

This report compiled, assessed, and summarized available water and sediment quality data for the Athabasca watershed, specifically related to organic compounds in water and trace metals in sediments. Consistent with the SOW Phase 3 report, the Phase 4 assessment considered a current data period of 2007 to 2012. With help from the AWC, data were requested from numerous different sources including Alberta Environment and Sustainable Resource Development (AESRD), Environment Canada (EC), the Joint Canada-Alberta Oil Sands Environmental Monitoring (JOSM) Information Portal, pulp mills, coal mines, and municipalities within the Athabasca watershed. Current surface water data were obtained from 35 AESRD stations, 64 Regional Aquatics Monitoring Program (RAMP) stations, and 38 EC stations via the JOSM Information Portal. Current sediment quality data were obtained from 30 RAMP stations, along with five stations from AESRD. Various other, relevant information sources were collected, such as academic publications and point-source effluent data (e.g., from pulp mills and municipalities) which were incorporated into the report where possible; and secondary sources were used to provide context and augment discussions in this assessment.

Spatial comparisons were conducted on fall 2012 data for selected organic compounds across stations within the Athabasca watershed, data were compared against provincial and federal guidelines for the protection of aquatic life and both qualitative and quantitative historical trend assessments were carried out for compounds with sufficient long-term datasets. Any gaps in data or knowledge were identified and recommendations for addressing these gaps were provided.

Most surface water data for organic compounds were obtained from four AESRD Long Term River Network (LTRN) stations in the Upper Athabasca, Upper Central Athabasca, Lower Central Athabasca, and Lower Athabasca sub-watersheds, or from RAMP stations within the Lower Athabasca and Clearwater sub-watersheds. No surface water data were obtained for any organic compounds in the La Biche and Lake Athabasca sub-watersheds and sparse data were available for the central part of the watershed in general.

Availability of sediment data for organic compounds and trace metals was relatively sparse within the Athabasca watershed. Data were obtained from four AESRD LTRN stations in the Upper Athabasca, Upper Central Athabasca, Lower Central Athabasca, and Lower Athabasca sub-watersheds, and from RAMP stations within the Lower Athabasca and Clearwater sub-watersheds. All AESRD sediment data were only available for one year within the current period and no data were obtained for any organic compounds in the Pembina, La Biche, and Lake Athabasca sub-watersheds indicating a general gap in sediment quality monitoring frequency and distribution.

Current water and sediment data were compared to the most recent AESRD draft Environmental Quality Guidelines for Alberta Surface Waters (specifically guidelines for the protection of aquatic life) (AESRD 2013a) along with Canadian Council of the Ministers of the Environment (CCME) guidelines for the protection of aquatic life in surface waters and sediments (CCME 2011). Data were also compared against the British Columbia guidelines for the protection of aquatic life, where AESRD or CCME guidelines did not exist.

Concentrations of organic compounds in surface waters and sediments and trace metals in sediments were generally low throughout the Athabasca watershed. A brief summary of findings from each group of organic compounds are presented below:

Total Hydrocarbons

In water, the majority of total hydrocarbons samples were below common detection limits at all stations in all sub-watersheds with available data. Concentrations of toluene exceeded guidelines once from 2007 to 2012 at six RAMP stations located upstream or downstream of oil sands developments and three AESRD stations. In sediments, the majority of measurable total hydrocarbons at RAMP stations were heavier CCME F3, F4 fractions.

Polycyclic Aromatic Hydrocarbons (PAHs)

In water, the majority of PAH species were below detection at all stations. Benzo(a)pyrene exceeded guidelines in one sample at one RAMP water quality station and naphthalene exceeded guidelines at two RAMP water quality stations in the Lower Athabasca sub-watershed. In sediments, the majority of detectable PAH species were heavy, alkylated forms and six PAH species (benz(a)anthracene, benzo(a)pyrene, chrysene, dibenz[a,h]anthracene, phenanthrene, pyrene) exceeded guidelines at RAMP sediment stations between 2007 and 2012.

Aromatic Hydrocarbons

All aromatic hydrocarbons in surface waters were below detection at all stations, with the exception of 1,2,4-trimethylbenzene, which was detected in one sample downstream of Devil’s Elbow at Winter Road (AESRD station: AB07DD0105) in 2007. All aromatic hydrocarbons in sediments were below detection at all stations.

Pesticides

In water, the majority of herbicides were below detection for all stations and all fungicides and insecticides were below detection at all stations. In sediments, all fungicides, herbicides, and insecticides were below detection with the exception of one insecticide at one station. No guidelines were exceeded for any pesticides at any station.

Concentrations of pesticides were generally low or below detection at all stations, except at Wabash Creek near Pibroch (AESRD station: AB07BC0540) where nine herbicides were frequently measurable. This station is located in an area of heavy agricultural land use within the Pembina sub-watershed and was last sampled in 2008.

Naphthenic Acids

In water, the majority of naphthenic acid and oil sands extractable concentrations were detected at all stations. In sediments, naphthenic acids were measured in only one sample in 2010 and were detectable.

Resin and Fatty Acids

All resin and fatty acids in surface waters were below detection at all stations. No sediment data were available for resin and fatty acids.

Non-chlorinated Phenols and Total Phenols

All non-chlorinated phenols in surface waters and sediments were below common detection limits and guidelines at all stations. Concentrations of total phenols in surface water were measurable in almost all samples at all stations. No sediment data were available for total phenols.

Concentrations of total phenols showed increasing concentrations over time at many stations sampled by RAMP in the Lower Athabasca sub-watershed.

Organochlorines and Adsorbable Organic Halides (AOX)

In water and sediment, all organochlorines were below detection and below guidelines at all stations. Concentrations of AOX in surface water were detected in at least one sample at six of the seven stations with available data. No sediment data were available AOX.

A significant increasing trend in AOX over time was found downstream of Fort McMurray and Fort McKay (AESRD station: AB07DD0105), despite generally decreasing for AOX values upstream of Fort McMurray.

Polychlorinated Biphenyls (PCBs)

In sediments, all PCBs were below common detection limits and guidelines at all stations. PCBs surface water data were only available from 1987-1994; outside the scope of the current assessment.

Trace Metals

In sediment, the majority of metals were measureable in at least one sample at all stations in the Lower Athabasca and Clearwater sub-watersheds. Concentrations of arsenic exceeded CCME ISQG guidelines at six stations in the Lower Athabasca sub-watershed; mercury and copper exceeded guidelines at one station each. No CCME PEL guidelines were exceeded for any metals in sediments for the current data period.

Phthalates

In water, the majority of phthalate concentrations were below detection at all stations and no guidelines were exceeded for any phthalates at any station. In sediments, all phthalates measured were below detection for all stations.

Aliphatic Hydrocarbons

In surface water and sediments, all aliphatic hydrocarbons were below detection at all stations.

Flame Retardants

In sediments, all flame retardants were below detection at all stations. No surface water data were available for flame retardants.

Nonylphenols

In sediments, all nonylphenols were below detection and below guidelines at all stations. No surface water data were available for nonylphenols.

Conclusions and Recommendations

Overall, organic compounds in surface water and sediments of the Athabasca watershed are being measured by many different organizations and individuals. Ongoing efforts are being made to integrate these programs and this information in a useful way to inform future management plans and monitoring programs.

Many organic compounds are not measured routinely in surface water (i.e., resin and fatty acids, AOX, phthalates, pharmaceuticals), and most organic compounds have not been measured recently in sediments; therefore, inclusion of these compounds in a routine monitoring program should be considered. Future design of monitoring programs within the Athabasca watershed should consider a network approach to monitoring of organic compounds, where a long-term monitoring program for each sub-watershed is put in place to ensure complete sampling coverage of the watershed.

Due to the rapid release of fine materials from the Green Pit tailings pond at the Obed Mountain Coal Mine (Obed) near Hinton, Alberta on October 31st, 2013, water and sediment quality in Apetowun Creek, Plante Creek, and the Athabasca River have been monitored since the beginning of the spill and much of the data collected overlaps with the water and sediment data applicable to the current Phase 4 SOW report. Given the Phase 4 SOW only considers a data period between 2007 and 2012, data collected from the Obed spill should be included in future watershed assessments. Data and information on the Obed spill are publicly available on the AESRD website: http://esrd.alberta.ca/focus/obed-mountain-mine-release.aspx. External data and information is also available from Sherrit International: http://obed.ca/.

Coordination of monitoring between federal, provincial, and industry programs is necessary for measuring organic compounds in surface water and sediments and trace metals in sediments throughout the Athabasca watershed, particularly with respect to the specific analytes measured, analytical methods, and sampling frequency. Harmonization of monitoring programs and sampling methods among all parties can provide larger datasets and increase the chance of detecting any effects, thereby allowing watershed managers to more effectively assess the overall condition of the watershed. Ongoing integration of monitoring efforts through programs such as JOSM and the newly established Alberta Environmental Monitoring, Evaluation, and Reporting Agency (AEMERA) will help to reduce future knowledge gaps. Given AEMERA is anticipated to be in place in early 2014 to coordinate and integrate environmental monitoring activities throughout Alberta; it would be useful for the AWC-WPAC to inform AEMERA on the knowledge gaps and recommendations from the SOW phase 4 assessment for consideration in design of future integrated monitoring plans for the Athabasca watershed.

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1.0 INTRODUCTION

1.1 SCOPE OF ASSESSMENT

The Athabasca River is over 1,200 km in length and has a drainage area of approximately 100,000 km² (NRCan 2008). Its headwaters arise from the melting snow and ice of the Columbia Glacier in Jasper National Park. The Athabasca River then flows northeast across Alberta, through the Peace-Athabasca Delta, and into Lake Athabasca. The Athabasca watershed contains numerous industrial (i.e., oil and gas, mining) developments, human settlements with municipal wastewater treatment plants discharging into the Athabasca River, and forestry and agricultural activities that can affect the aquatic environment. Natural conditions within the watershed, such as surficial oil sands in the Lower Athabasca sub-watershed, also contribute to the water and sediment quality conditions in this river.

The Government of Alberta has committed to protecting and managing the water resources of Alberta pursuant to the *Water for Life (WFL) Strategy* and *Water for Life Action Plan* (AESRD 2003, 2008, 2009). Watershed Planning and Advisory Councils (WPACs) are designated in the *Water for Life Strategy* as multi-stakeholder, non-profit organizations responsible for assessing the condition of a watershed and developing a plan to address issues identified during the assessment. The Athabasca Watershed Council WPAC (AWC-WPAC) was formed in late 2009 and was mandated with the development of a State of the Watershed (SOW) Report for the Athabasca watershed to inform a future integrated watershed management plan for the watershed.

The AWC-WPAC initiated this process to determine the condition of the watershed in June 2010 with the State of the Watershed - Phase 1 Project, which included the identification and compilation of information and geospatial data relevant to the Athabasca watershed as well as development of suggested indicators for use in the Phase 2 SOW report, and a draft Terms of Reference document for Phase 2 (AWC-WPAC 2011). In 2012, the SOW Phase 2 report was completed and included the quantification and evaluation of a variety of pressure indicators which could potentially impact the health of the Athabasca Watershed (AWC-WPAC 2012). The SOW Phase 3 report was initiated by the AWC-WPAC in August 2012, and included an assessment of: water quantity throughout the watershed; water quality (i.e., physico-chemical properties and inorganic constituents) in the Athabasca River and major tributaries from 2007-2012, and benthic invertebrate community composition and abundance in the Athabasca River and a limited number of major tributaries (AWC-WPAC 2013). The Phase 3 report is still in draft form and currently under review by the AWC-WPAC. Although the Phase 3 SOW Report included examination of water quality in the Athabasca watershed, it focused on physico-chemical properties (i.e., pH, conductivity, temperature, etc.) and inorganic constituents in water (i.e., calcium, sodium, chloride, etc.) and did not include organic compounds present in surface waters of the Athabasca watershed. Therefore, the AWC-WPAC initiated a Phase 4 report in August 2013 with a scope of work that included a current (i.e., 2007 to 2012) assessment of the water and sediment quality of the Athabasca watershed in relation to organic compounds in surface waters and sediments and trace metals in sediments. Hatfield Consultants was retained by the AWC-WPAC to complete these Phase 4 tasks.

Specifically, the scope of the Phase 4 report includes the following components:

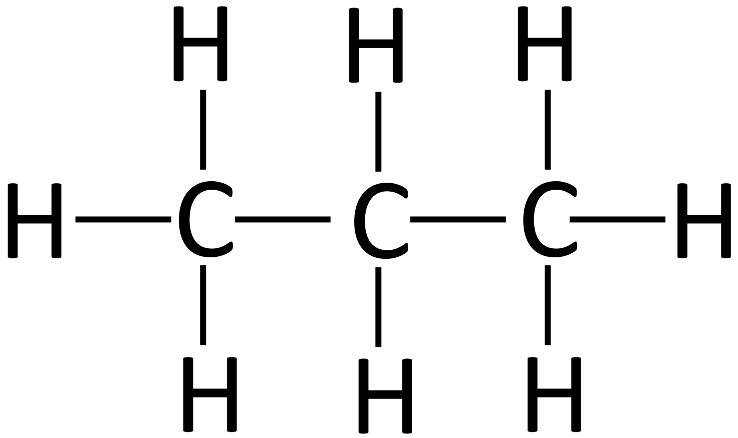
1. A compilation and analysis of existing and available data from 2007 to 2012 on organic compounds in surface water and sediments, and trace metals in sediments in the Athabasca watershed;
2. An assessment of surface water and sediment condition within the watershed through comparison of concentrations of organic compounds in surface water and sediments, and trace metals in sediments to Alberta's draft guidelines for the protection of aquatic life (AESRD 2013a), Canadian Council of Ministers of the Environment (CCME) guidelines for the protection of aquatic life (CCME 2011), and British Columbia's guidelines for the protection of aquatic life (BC 2006);
3. For stations with long-term datasets, an assessment of historical trends in organic compounds in surface water and sediments, and trace metals in sediments in the Athabasca watershed; and
4. A data and knowledge gap analysis, to identify information that is currently lacking or unavailable for use in developing a robust Phase 4 SOW report.

1.2 ORGANIC COMPOUNDS

This assessment focuses on aquatic environmental conditions in surface waters and sediments in the Athabasca watershed, to provide a current assessment of the organic compounds that are measured and detectable in the watershed.

Organic compounds generally consist of carbon chains that vary in length and shape and commonly have hydrogen, nitrogen, or oxygen atoms attached to the carbon atoms (Figure 1). Surface waters including rivers, streams, lakes, and wetlands, and their associated sediments naturally contain a variety of organic compounds, including hydrocarbons, whose concentrations can be influenced by a wide range of factors, including geology and river flows. For example, certain surface waters and sediments in the Athabasca oil sands region naturally contain petrogenic (petroleum-derived) polycyclic aromatic hydrocarbons (PAHs) due to the bituminous geological formations in the region (Brua et al. 2003, Headley et al. 2001). Surface waters and sediments can also contain organic compounds which have been introduced into aquatic ecosystems from municipal wastewater or industrial effluent discharge, urban and agricultural runoff, and atmospheric deposition. Organic compounds vary in their physical, chemical, and toxicological properties, their sources and behaviour, and their fate in the aquatic environment. Examples of organic compounds in the aquatic environment include hydrocarbons, phenols, pesticides, organochlorines, polychlorinated biphenyls, resin and fatty acids, and naphthenic acids. Some organic compounds found in aquatic environments are solely of human origin, such as specific pesticides and herbicides, and polychlorinated biphenyls (PCBs).

Figure 1 Structural formula of the organic compound propane (C_3H_8).



Certain organic compounds associated with surface waters and sediments can cause toxic effects on plants and animals, and can accumulate in the tissue of aquatic organisms, including benthic invertebrates and the fish that prey on them. Many organic compounds adsorb (in basic terms, adhere to) strongly to sediments, depending on the oxidation state, hydrophobicity, chain length, and molecular structure of the compound (McCarthy et al. 1997), and can adsorb to sediments from the water column. Concentrations of some organic compounds can be found in sediments even when they are non-detectable in surface waters, and monitoring sediment quality can provide an “early warning” of potential environmental effects (Sanderson et al. 1997).

Although many organic compounds are found everywhere in aquatic environments, the main focus of this SOW Phase 4 assessment is on specific organic compounds of concern in surface waters and sediments that have potential to negatively affect aquatic organisms. These groups of compounds are listed in Table 1 below. A description of the data sources and methods for compilation and assessment of the current data are provided in Section 2. Other organic compounds measured in surface water and sediments (i.e., pharmaceuticals and their metabolites) and constituents of sewage (i.e., Biochemical oxygen demand (BOD)) were not addressed in this assessment because they were not measured in recent years (i.e., pharmaceuticals and their metabolites in surface water), or they were beyond the scope of our assessment (i.e., BOD).

Table 1 Groups of organic compounds measured in surface waters and sediments relevant to the SOW Phase 4 Assessment.

Variable
Total Hydrocarbons
Polycyclic Aromatic Hydrocarbons (PAHs)
Other Aromatic Hydrocarbons
Pesticides (Fungicides, Herbicides, Insecticides)
Organic Acids (Naphthenic Acids, Oil sands Acid Extractable Organics, Resin and Fatty Acids, Total Phenols and Non-Chlorinated Phenols)
Organochlorines and Adsorbable Organic Halides (AOX)
Polychlorinated Biphenyls (PCBs)
Other Organic Compounds (Aliphatic Hydrocarbons, Flame Retardants, Nonylphenols, Phthalates
Trace Metals*

* Trace metals measured in sediments only (trace metals in surface water are reported in Phase 3)/

2.0 METHODOLOGY

2.1 DATA SOURCES AND ASSESSMENT

Information on organic compounds in surface waters and sediments and trace metals in sediments were obtained from numerous sources, including:

- Water and sediment quality data from Alberta Environment and Sustainable Resource Development (AESRD) and the oil sands Regional Aquatics Monitoring Program (RAMP);
- Publicly available data downloaded from government websites (e.g., Joint Canada-Alberta Oil Sands Environmental Monitoring [JOSM] Information Portal, AESRD);
- Municipal wastewater data from the municipalities of Athabasca, Edson, Fort McMurray, Hinton, Jasper, and Whitecourt;
- Dioxin and furan (TCDD/TCDF) information from West Fraser Timber Co.’s Hinton Pulp, and Alberta Pacific Forest Industries (AlPac);
- Government reports and documents;
- Reports and documents from various institutions, research programs, and other organizations (e.g., Northern Rivers Ecosystem Initiative, Northern River Basins Study, Regional Aquatics Monitoring Program, Slave River Environmental Quality Monitoring Program); and
- Academic publications.

To align with the SOW Phase 3 report, the SOW Phase 4 assessment considered a current data period of 2007 to 2012. Current surface water data were obtained from 35 AESRD stations, 64 RAMP stations, and 38 EC stations via the JOSM Information Portal (Table 2 and Figure 4). The majority of primary sediment quality data for the period of record were obtained from 30 RAMP stations, and five AESRD stations (Table 2 and Figure 5). Other, relevant information sources, such as academic publications and point-source effluent data (e.g., from pulp mills and municipalities) were incorporated into the report where possible; secondary sources are used to provide context and augment discussions in this assessment.

Water and sediment quality data in Microsoft Excel files were obtained for government-operated water and sediment quality stations from AESRD and Environment Canada via JOSM. Water and sediment quality data collected by RAMP were obtained from RAMP. Data were compiled into large Excel databases and standardized (e.g., analyte names, units) to facilitate data manipulation and processing. Data tables and graphs were created using Microsoft Excel and R (R Core Development Team 2013). AESRD data from 2012 were validated by AESRD staff, but not finalized, and were therefore treated as preliminary data.

Analyses and discussion focused on the groups of organic compounds and their associated analytes listed in Table 3 and Table 4, for surface waters and sediments, respectively. Some analytes fit into more than one category and were placed into categories that were most suitable for analysis and discussion. For example, 2,4-Dichlorophenol, which can be categorized as a herbicide or an organochlorine, was classified as a herbicide for this assessment. Given numerous analytes were measured within each group of organic compounds, many of which were detected infrequently, analysis and discussion focused primarily on those compounds that were present in detectable concentrations at each water quality station, and those compounds that exceeded published guidelines.

Maps showing the station locations for each group of organic compounds were used to display potential gaps in data availability throughout the ten sub-watersheds of the Athabasca watershed: Upper Athabasca, McLeod, Pembina, Lesser Slave, Upper Central Athabasca, Lower Central Athabasca, La Biche, Clearwater, Lower Athabasca, and Lake Athabasca.

2.1.1 Quality Assurance and Quality Control (QA/QC)

All monitoring programs contributing data for the SOW Phase 4 assessment have their own quality assurance and quality control (QA/QC) procedures and protocols to facilitate the collection of high quality data (e.g., Mitchell 2006, AESRD 2013b, Environment Canada 2013, RAMP 2013). Each monitoring program follows standardized methods for sample collection and monitoring, uses laboratories accredited by the Canadian Association for Laboratory Accreditation or the Standards Council of Canada, and performs additional QA/QC procedures upon receipt of data from the laboratories to further validate the data and follow up on unusual values. Given comparison between multiple data sources is a necessity of this assessment, it was assumed that each contributing data source followed its QA/QC protocols and appropriately screened and validated all data prior to release.

2.1.2 Detection Limits

Based on the laboratories and analytical techniques used to conduct analyses, detection limits can vary significantly between data sources and also between and within datasets. For example, both RAMP and AESRD utilize laboratories that analyse PAHs in water through gas chromatography/mass spectrometry (GC/MS) techniques; however, RAMP data is analyzed by AXYS Analytical Ltd. (AXYS) where high resolution GC/MS allows for much lower detection limits (typically 1,000-10,000 fold lower) than those provided in the AESRD data. To account for varying detection limits amongst multiple data sources, the highest detection limit was used as the 'common detection limit' and all results were adjusted to this value. This approach allowed meaningful comparison between multiple data sources. Although AESRD detection limits generally were higher than the RAMP detection limits, most remained below published water quality and sediment quality guidelines. Where common detection limits were higher than published guidelines, analytes were flagged and any samples with concentrations greater than the guideline were highlighted in red. Common detection limits were not used for historical trend analysis (see Section 2.1.6), or for analysis of certain analytes that were only present in one data source.

If the concentration of an organic compound is above the detection limit, or "detected", this may or may not indicate a cause for concern for resource managers depending on the source of the organic compound in the aquatic ecosystem. Some organic compounds (e.g., PAHs) can occur naturally in the environment and are not necessarily a concern unless they exceed thresholds known to cause adverse effects (e.g., CCME or AESRD guidelines); other organic compounds (e.g., pesticides, PCBs) are not found naturally in the environment and therefore are clear indicators of human influence if they are detected at all; and some groups of organic compounds (e.g., dioxins/furans) are found at very low levels in nature, but some specific examples of that group (e.g., 2,3,7,8-TCDD, the most toxic dioxin) are typically not detectable if there is not a human source. For all organic compounds, regardless of source, guidelines exist because there is a threshold concentration below which adverse effects are not expected, and above which adverse effects are a possibility based on existing data.

2.1.3 Comparison with Published Guidelines

The suitability of current water and sediment data to support aquatic life was assessed through comparison of data to the most recent AESRD draft Environmental Quality Guidelines for Alberta Surface Waters (specifically guidelines for the protection of aquatic life) (AESRD 2013a) along with Canadian Council of the Ministers of the Environment (CCME) guidelines for the protection of aquatic life in surface waters and sediments (CCME 2011). Data were also compared against the British Columbia guidelines for the protection of aquatic life, where AESRD or CCME guidelines did not exist.

Water quality guidelines provide protective condition thresholds and chemical concentration limits associated with the intended use of the water, whether it be for agricultural production, industrial inputs, drinking consumption, recreational or aesthetic use, or for the overall protection of aquatic life. Ideally, water quality guidelines for the protection of freshwater aquatic life are derived from recent, scientifically defensible toxicity studies, and are designed to protect all forms of aquatic life and all aspects of aquatic life cycles (CCME 1999a). Guidelines may differ between jurisdictions depending on specific needs and the scientific information and statistical methods used to derive guidelines. The CCME and AESRD have both established a set of water quality guidelines that can be used to assess water quality conditions in Alberta (CCME 2011, AESRD 2013a). The AESRD have recently updated and improved their surface water guidelines and released draft environmental quality guidelines for Alberta surface waters in September 2013 for public comment (AESRD 2013a).

In addition to general guidelines applicable across a jurisdiction, often site-specific water quality objectives are also developed to reflect local conditions and management objectives, including the protection of specific environmental values or water uses in the area. In northern Alberta, as part of the Lower Athabasca Regional Plan (LARP) for 2012-2022, specific water quality triggers and limits have been developed for the AESRD Long-term River Network (LTRN) station Athabasca River at Old Fort (Government of Alberta 2012). These triggers and limits were developed specifically based on surface water conditions at Old Fort and include general indicators (i.e., calcium and magnesium) and total and dissolved metals, but do not include any organic compounds and were therefore not used in this assessment.

Furthermore, work is being conducted within the JOSM Plan to develop a framework of tiers and interim triggers to be used as a step-by-step process to identify changes in the aquatic environment. Triggers for monitoring in the oil sands region are being developed based on existing data (e.g., RAMP). In 2014, further work will be conducted to define this framework, with the expectation that these triggers will be used across all environmental monitoring in the oil sands region (e.g., JOSMP, site-specific monitoring). This will include not only water quality based limits but also biologically based tiers and triggers. JOSM was initially established in 2012 as a joint plan between the Governments of Canada and Alberta to enhance existing monitoring activities within the oil sands region. JOSM is a three-year plan that will be fully implemented by 2015 and is committed to implementing a comprehensive, integrated, and transparent environmental monitoring plan for the oil sands region with an open data management program (Government of Alberta 2012).

In addition to the guidelines, objectives and tiers and triggers mentioned above (i.e., benchmarks), it is important to understand that each industrial and municipal sector discharging treated effluent to the Athabasca River and its tributaries also contain chemical, toxicological and biological benchmarks for assessing compliance to release. For example, the pulp and paper mills on the Athabasca River each must comply with provincial and federal regulation for discharge. In the federal case, compliance with the Pulp and Paper Effluent Regulations under the Fisheries Act holds the mills to both effluent discharge criteria for water quality parameters as well as receiving water criteria that are biologically based (i.e., benthic invertebrates and fish).

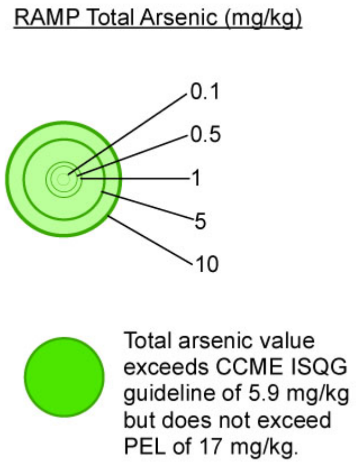
It is clear there are numerous benchmarks at play in the Athabasca watershed and the interplay amongst these various benchmarks by various agencies and programs must be considered to determine the state of the Athabasca watershed. Of greater consideration is the potential for misalignment of the benchmarks (i.e., different benchmarks for the same parameter or use of biological benchmarks in one application and water quality benchmarks in another). Core, consistent application of benchmarks in play in the watershed is essential for clear articulations of watershed state.

Sediment quality guidelines have been developed by the CCME to protect aquatic organisms living in or on bottom sediments (CCME 2001a). These guidelines were developed based on relationships between chemical concentrations and biological effects observed in the field, and on laboratory tests examining cause-effect relationships. CCME provides two guidelines per analyte: the interim sediment quality guideline (ISQG) which is equivalent to the threshold effect level (TEL) and represents the concentration below which adverse biological results are expected to occur only rarely, and the probable effects level (PEL), which represents the concentration above which adverse biological effects are expected to occur frequently (based on 50% of reviewed tests showing effect at that level) and is recommended as an additional tool to identify sediments where adverse biological effects are more likely (CCME 2001a). The ISQG and the PEL are used to define three ranges of chemical concentrations in sediments: (1) concentrations less than the ISQG represent the minimal effect range within which adverse effects rarely occur (i.e., less than 25% of adverse effects occur below the ISQG); (2) concentrations between the ISQG and the PEL represent the possible effect range within which adverse effects occasionally occur; and (3) concentrations above the PEL represent the probable effect range within which adverse biological effects frequently occur (i.e., more than 50% of adverse effects occur above the PEL). While CCME interim sediment quality guidelines are applicable nationwide, use of these guidelines to evaluate sediment quality at specific sites requires understanding the physical, chemical, and biological characteristics of the ecosystem and the behaviour of the specific chemical substance (CCME 1999b).

2.1.4 2012 Spatial Comparisons

Bubble maps were used to spatially compare fall 2012 data for selected organic compounds across stations within the Athabasca watershed. Each bubble, or circle, was proportional in size to the value of the selected organic compound at each station. Where applicable, data were screened against published CCME (2011), AESRD (2013), and BC (2006) guidelines for the protection of aquatic life. Stations with concentrations of selected compounds exceeding guidelines were shaded dark green. An example legend for the bubble maps is provided in Figure 2 below.

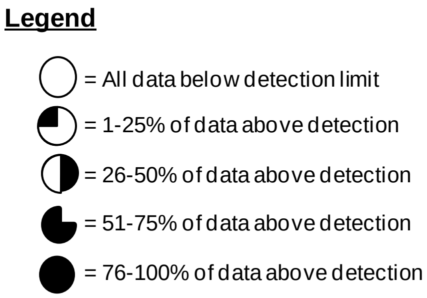
Figure 2 **Example of legend from total arsenic in sediments bubble map for 2012 spatial comparisons.**



2.1.5 Measles Tables

Measles tables were used to effectively compile, categorize, and present data for individual analytes sampled at least once between 2007 and 2012. These tables used shaded "measles", or circles, to show the number of samples that were above the detection limit for each species. For example, if the PAH anthracene at an AESRD station had 2 of 4 samples above detection limit, the corresponding circle would be half filled in; if no samples were detected, the circle would be empty. Because data from multiple sources may have differing detection limits, individual data from all stations were set to a common detection limit to allow comparison among stations; however, if individual data were only measured by one data source, they were screened against their given detection limits. Measles tables also were used to screen and indicate where analytes in surface water and sediment samples had exceeded published CCME (2011), AESRD (2013), and BC (2006) guidelines for the protection of aquatic life. Circles were presented in red if any measurement of a particular analyte exceeded a corresponding guideline. An example legend for the measles tables is provided in Figure 3 below.

Figure 3 Example of legend from measles tables.



2.1.6 Historical Trend Analysis

Concentrations of water and sediment quality variables were displayed graphically to allow for qualitative assessment of any temporal trends for stations with available and accessible long-term datasets and at least four years of data (including one year of data within the current period).

Statistical trend analysis was conducted on water and sediment quality measurement endpoints to determine if increasing/decreasing trends in the data were statistically significant. A non-parametric Mann-Kendall trend analysis was conducted on data from stations with at least seven years of data and no more than 50% non-detectable values using the program WQStat Plus (NIC 2004), using a level of significance of $\alpha=0.05$. Results of the statistical trend analysis were presented in the upper right hand corner of the corresponding historical figure.

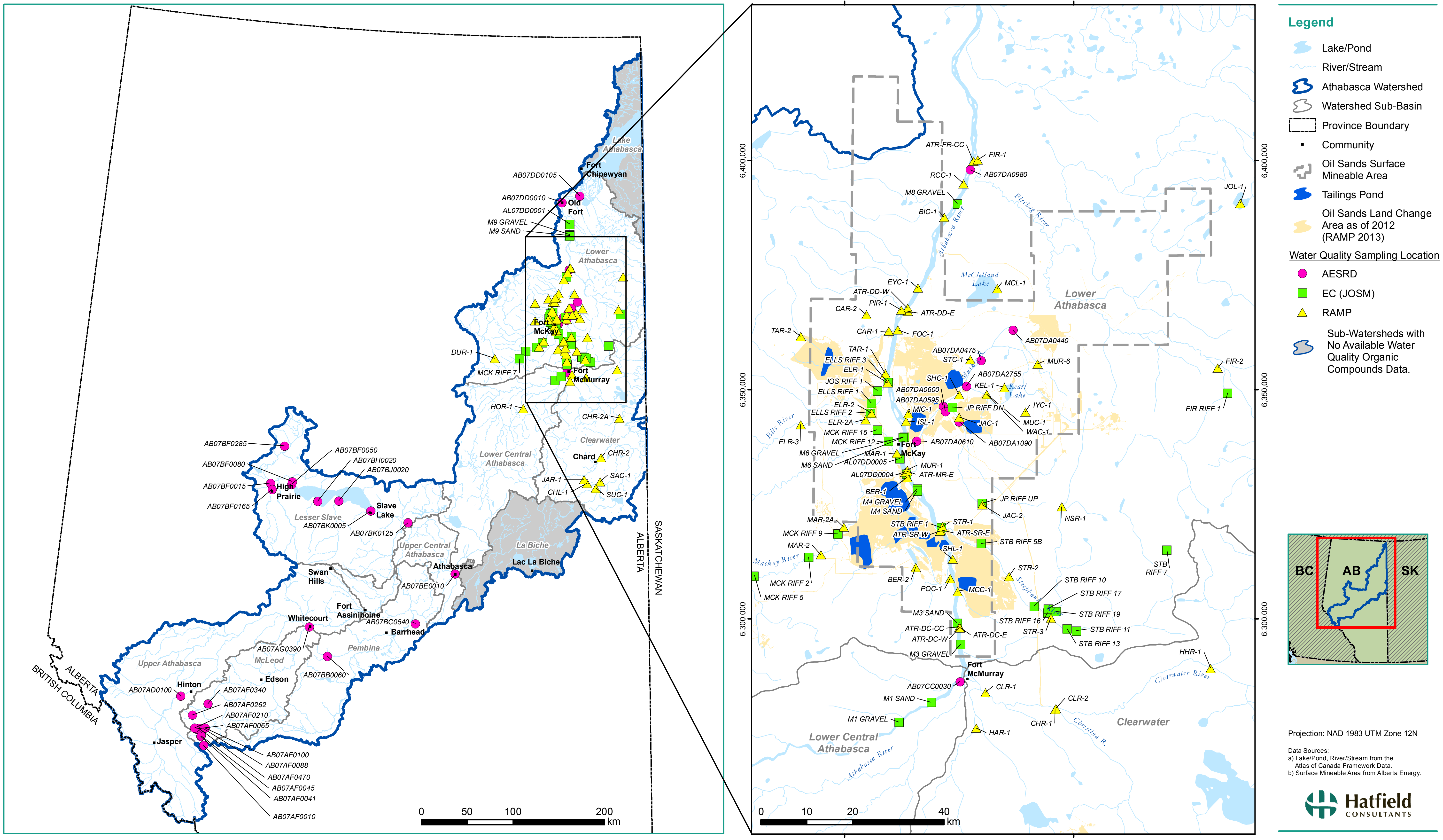
Table 2. All sampling station names and locations with accessible and available organic compounds data.

Station Number	Station Name	Latitude	Longitude	Source
AB07AD0100	ATHABASCA RIVER AT OLD ENTRANCE TOWN SITE - LEFT BANK	53.360	-117.723	AESRD
AB07AF0470	LUSCAR COAL LUSCAR CREEK SETTLING POND DISCHARGE	53.060	-117.376	AESRD
AB07AF0010	MCLEOD RIVER U/S OF MOUNTAIN PARK	52.899	-117.277	AESRD
AB07AF0041	MCLEOD RIVER 0.1 KM U/S OF CONFLUENCE WITH WHITEHORSE CREEK	52.984	-117.336	AESRD
AB07AF0045	MCLEOD RIVER 0.1 KM U/S OF CADOMIN CREEK	52.990	-117.333	AESRD
AB07AF0065	LUSCAR CREEK ABOVE LUSCAR VALLEY (CRC) MINE	53.052	-117.421	AESRD
AB07AF0088	LUSCAR CREEK IMMEDIATELY D/S HWY 40 BRIDGE	53.062	-117.301	AESRD
AB07AF0100	MCLEOD RIVER 3.5 KM D/S OF LUSCAR CREEK	53.071	-117.278	AESRD
AB07AF0210	GREGG RIVER ABOVE LUSCAR VALLEY (CRC) MINE	53.059	-117.451	AESRD
AB07AF0262	GREGG RIVER 9.5 D/S OF SPHINX CREEK AND 0.7 KM U/S OF DRINNAN CREEK	53.185	-117.506	AESRD
AB07AF0340	MCLEOD RIVER BELOW CONFLUENCE WITH GREGG RIVER	53.307	-117.268	AESRD
AB07AG0390	MCLEOD RIVER AT WHITECOURT - HIGHWAY #43 BRIDGE RIGHT BANK	54.136	-115.696	AESRD
AB07BB0060	PADDLE RIVER AT BRIDGE (NEAR ANSELMO)	53.858	-115.363	AESRD
AB07BC0540	WABASH CREEK NEAR PIBROCH NW OF WESTLOCK	54.224	-113.924	AESRD
AB07BE0010	ATHABASCA RIVER AT TOWN OF ATHABASCA	54.722	-113.286	AESRD
AB07BF0015	SOUTH HEART RIVER U/S CONFLUENCE WITH WEST PRAIRIE RIVER	55.509	-116.526	AESRD
AB07BF0050	GROUARD CHANNEL AT HWY #750 BRIDGE CENTRE OF RIVER	55.514	-116.165	AESRD
AB07BF0080	BUFFALO BAY OUTFLOW AT GROUARD	55.539	-116.158	AESRD
AB07BF0165	WEST PRAIRIE RIVER NEAR HIGH PRAIRIE WSC GAUGE	55.448	-116.493	AESRD
AB07BF0285	EAST PRAIRIE RIVER AT HWY 2 BRIDGE	55.882	-116.339	AESRD
AB07BH0020	DRIFTPILE RIVER NEAR CONFLUENCE WITH LESSER SLAVE LAKE	55.367	-115.694	AESRD
AB07BJ0020	SWAN RIVER NEAR CONFLUENCE WITH LESSER SLAVE LAKE	55.383	-115.332	AESRD
AB07BK0005	LESSER SLAVE RIVER NEAR TOWN WATER INTAKE (AT THE HEADWATERS)	55.306	-114.771	AESRD
AB07BK0125	LESSER SLAVE RIVER 9.5 KM U/S OF ATHABASCA RIVER CONFLUENCE	55.207	-114.123	AESRD
AB07CC0030	ATHABASCA RIVER U/S FORT MCMURRAY, 100 M ABOVE THE CONFLUENCE WITH HORSE RIVER - LEFT BANK	56.720	-111.406	AESRD
AB07DA0440	MUSKEG RIVER 11 KM U/S STANLEY CREEK	57.410	-111.221	AESRD
AB07DA0475	MUSKEG RIVER U/S STANLEY CREEK (RAMP S5)	57.350	-111.336	AESRD
AB07DA0595	MUSKEG RIVER U/S OF JACKPINE (HARTLEY) CREEK	57.260	-111.473	AESRD
AB07DA0600	JACKPINE (HARTLEY) CREEK 0.4 KM ABOVE CONFLUENCE WITH MUSKEG RIVER	57.250	-111.465	AESRD
AB07DA0610	MUSKEG RIVER AT WSC GAUGE D/S OF KEARL LAKE ROAD	57.192	-111.568	AESRD
AB07DA0980	ATHABASCA RIVER TRANSECT ABOVE THE FIREBAG RIVER	57.724	-111.379	AESRD
AB07DA1090	HARTLEY (JACKPINE) CREEK AT CANTERRA RD - 2 MILES ABOVE CONFLUENCE WITH MUSKEG RIVER	57.230	-111.415	AESRD
AB07DA2755	MUSKEG CREEK AT CONFLUENCE WITH MUSKEG RIVER	57.300	-111.389	AESRD
AB07DD0010	ATHABASCA RIVER AT OLD FORT - RIGHT BANK	58.383	-111.518	AESRD
AB07DD0105	ATHABASCA RIVER D/S OF DEVILS ELBOW AT WINTER ROAD CROSSING	58.447	-111.186	AESRD
AL07DD0001	ATHABASCA RIVER AT 27 BASELINE	58.172	-111.370	EC (JOSM)
AL07DD0004	ATHABASCA RIVER OIL SANDS LONGTERM WQ MONITORING	57.127	-111.602	EC (JOSM)
AL07DD0005	ATHABASCA RIVER OIL SANDS LONGTERM WQ MONITORING	57.157	-111.628	EC (JOSM)
ELLS RIFF 1	ELLS RIVER OIL SANDS BIOMONITORING STUDIES	57.265	-111.733	EC (JOSM)
ELLS RIFF 2	ELLS RIVER OIL SANDS BIOMONITORING STUDIES	57.245	-111.737	EC (JOSM)
ELLS RIFF 3	ELLS RIVER OIL SANDS BIOMONITORING STUDIES	57.305	-111.673	EC (JOSM)
FIR RIFF 1	FIREBAG RIVER OIL SANDS BIOMONITORING STUDIES	57.286	-110.442	EC (JOSM)
JOS RIFF 1	JOSLYN CREEK OIL SANDS BIOMONITORING STUDIES	57.290	-111.711	EC (JOSM)
JP RIFF DN	JACKPINE CREEK OIL SANDS BIOMONITORING STUDIES	57.259	-111.439	EC (JOSM)
JP RIFF UP	JACKPINE CREEK OIL SANDS BIOMONITORING STUDIES	57.070	-111.331	EC (JOSM)
M1 GRAVEL	ATHABASCA RIVER OIL SANDS BIOMONITORING STUDIES	56.641	-111.623	EC (JOSM)
M1 SAND	ATHABASCA RIVER OIL SANDS BIOMONITORING STUDIES	56.680	-111.508	EC (JOSM)
M3 GRAVEL	ATHABASCA RIVER OIL SANDS BIOMONITORING STUDIES	56.794	-111.404	EC (JOSM)
M3 SAND	ATHABASCA RIVER OIL SANDS BIOMONITORING STUDIES	56.835	-111.417	EC (JOSM)
M4 GRAVEL	ATHABASCA RIVER OIL SANDS BIOMONITORING STUDIES	57.098	-111.565	EC (JOSM)
M4 SAND	ATHABASCA RIVER OIL SANDS BIOMONITORING STUDIES	57.093	-111.565	EC (JOSM)
M6 GRAVEL	ATHABASCA RIVER OIL SANDS BIOMONITORING STUDIES	57.199	-111.612	EC (JOSM)
M6 SAND	ATHABASCA RIVER OIL SANDS BIOMONITORING STUDIES	57.198	-111.618	EC (JOSM)
M8 GRAVEL	ATHABASCA RIVER OIL SANDS BIOMONITORING STUDIES	57.657	-111.426	EC (JOSM)
M9 GRAVEL	ATHABASCA RIVER OIL SANDS BIOMONITORING STUDIES	58.067	-111.368	EC (JOSM)
M9 SAND	ATHABASCA RIVER OIL SANDS BIOMONITORING STUDIES	58.057	-111.371	EC (JOSM)
MCK RIFF 12	MACKAY RIVER OIL SANDS BIOMONITORING STUDIES	57.191	-111.671	EC (JOSM)
MCK RIFF 15	MACKAY RIVER OIL SANDS BIOMONITORING STUDIES	57.213	-111.710	EC (JOSM)
MCK RIFF 2	MACKAY RIVER OIL SANDS BIOMONITORING STUDIES	56.961	-111.952	EC (JOSM)
MCK RIFF 5	MACKAY RIVER OIL SANDS BIOMONITORING STUDIES	56.923	-112.149	EC (JOSM)
MCK RIFF 7	MACKAY RIVER OIL SANDS BIOMONITORING STUDIES	56.847	-112.257	EC (JOSM)
MCK RIFF 9	MACKAY RIVER OIL SANDS BIOMONITORING STUDIES	57.008	-111.848	EC (JOSM)
STB RIFF 1	STEEPBANK RIVER OIL SANDS BIOMONITORING STUDIES	57.022	-111.477	EC (JOSM)
STB RIFF 10	STEEPBANK RIVER OIL SANDS BIOMONITORING STUDIES	56.869	-111.142	EC (JOSM)
STB RIFF 11	STEEPBANK RIVER OIL SANDS BIOMONITORING STUDIES	56.821	-110.991	EC (JOSM)
STB RIFF 13	STEEPBANK RIVER OIL SANDS BIOMONITORING STUDIES	56.825	-111.024	EC (JOSM)
STB RIFF 16	STEEPBANK RIVER OIL SANDS BIOMONITORING STUDIES	56.856	-111.093	EC (JOSM)
STB RIFF 17	STEEPBANK RIVER OIL SANDS BIOMONITORING STUDIES	56.864	-111.092	EC (JOSM)
STB RIFF 19	STEEPBANK RIVER OIL SANDS BIOMONITORING STUDIES	56.858	-111.063	EC (JOSM)
STB RIFF 4	STEEPBANK RIVER OIL SANDS BIOMONITORING STUDIES	56.990	111.369	EC (JOSM)
STB RIFF 5A	STEEPBANK RIVER OIL SANDS BIOMONITORING STUDIES	56.991	111.342	EC (JOSM)

Table 2 (Cont'd.)

Station Number	Station Name	Latitude	Longitude	Source
STB RIFF 5B	STEEPBANK RIVER OIL SANDS BIOMONITORING STUDIES	56.992	-111.334	EC (JOSM)
STB RIFF 7	STEEPBANK RIVER OIL SANDS BIOMONITORING STUDIES	56.979	-110.664	EC (JOSM)
ATR-DC-CC	ATHABASCA RIVER UPSTREAM OF DONALD CREEK (CROSS CHANNEL)	56.828	-111.410	RAMP
ATR-DC-E	ATHABASCA RIVER UPSTREAM OF DONALD CREEK (EAST BANK)	56.827	-111.408	RAMP
ATR-DC-W	ATHABASCA RIVER UPSTREAM OF DONALD CREEK (WEST BANK)	56.827	-111.408	RAMP
ATR-DD-E	ATHABASCA RIVER DOWNSTREAM OF DEVELOPMENT (EAST BANK)	57.446	-111.605	RAMP
ATR-DD-W	ATHABASCA RIVER DOWNSTREAM OF DEVELOPMENT (WEST BANK)	57.452	-111.605	RAMP
ATR-ER	ATHABASCA RIVER UPSTREAM OF EMBARRAS RIVER	58.354	-111.546	RAMP
ATR-FR-CC	ATHABASCA RIVER UPSTREAM OF MOUTH OF FIREBAG RIVER (CROSS CHANNEL)	57.741	-111.368	RAMP
ATR-MR-E	ATHABASCA RIVER UPSTREAM OF MUSKEG RIVER (EAST BANK)	57.132	-111.603	RAMP
ATR-MR-W	ATHABASCA RIVER UPSTREAM OF MUSKEG RIVER (WEST BANK)	57.131	-111.608	RAMP
ATR-SR-E	ATHABASCA RIVER UPSTREAM OF STEEPBANK RIVER (EAST BANK)	57.018	-111.479	RAMP
ATR-SR-W	ATHABASCA RIVER UPSTREAM OF STEEPBANK RIVER (WEST BANK)	57.015	-111.481	RAMP
BER-1	BEAVER RIVER (MOUTH)	57.120	-111.600	RAMP
BER-2/BER-D2	BEAVER RIVER (UPPER)	56.944	-111.567	RAMP
BIC-1	BIG CREEK (MOUTH)	57.631	-111.474	RAMP
BPC-1	BIG POINT CHANNEL	58.589	-110.793	RAMP
CAR-1/CAR-D1	CALUMET RIVER (MOUTH)	57.406	-111.673	RAMP
CAR-2/CAR-D2	CALUMET RIVER (UPSTREAM OF CANADIAN NATURAL HORIZON)	57.438	-111.754	RAMP
CHL-1	CHRISTINA LAKE	55.632	-111.044	RAMP
CHR-1/CHR-D1	CHRISTINA RIVER (UPSTREAM OF FORT MCMURRAY)	56.667	-111.066	RAMP
CHR-2/CHR-D2	CHRISTINA RIVER (UPSTREAM OF JANVIER)	55.886	-110.802	RAMP
CHR-2A	CHRISTINA RIVER (MID)	56.271	-110.479	RAMP
CLR-1/CLR-D1	CLEARWATER RIVER (UPSTREAM OF FORT MCMURRAY)	56.700	-111.315	RAMP
CLR-2/CLR-D2	CLEARWATER RIVER (UPSTREAM OF CHRISTINA RIVER)	56.669	-111.064	RAMP
DUR-1	DUNKIRK RIVER	56.847	-112.701	RAMP
ELR-1/ELR-D1	ELLS RIVER (MOUTH)	57.305	-111.675	RAMP
ELR-2	ELLS RIVER (UPSTREAM OF TOTAL JOSLYN MINE)	57.245	-111.733	RAMP
ELR-2A	ELLS RIVER (UPSTREAM OF FORT MACKAY WATER INTAKE)	57.233	-111.754	RAMP
ELR-3	ELLS RIVER (UPSTREAM OF DEVELOPMENT)	57.221	-111.988	RAMP
EMR-1	EMBARRAS RIVER (UPPER)	58.390	-111.540	RAMP
EMR-2	EMBARRAS RIVER (LOWER)	58.568	-111.092	RAMP
EYC-1	EYMUNDSON CREEK (MOUTH)	57.491	-111.568	RAMP
FIR-1/FIR-D1	FIREBAG RIVER (MOUTH)	57.743	-111.352	RAMP
FIR-2	FIREBAG RIVER (UPSTREAM OF SUNCOR FIREBAG)	57.335	-110.476	RAMP
FLC-1	FLETCHER CHANNEL	58.565	-111.061	RAMP
FOC-1/FOC-D1	FORT CREEK (MOUTH)	57.409	-111.640	RAMP
GIC-1	GOOSE ISLAND CHANNEL	58.588	-110.835	RAMP
HAR-1	HANGINGSTONE RIVER	56.630	-111.348	RAMP
HHR-1	HIGH HILLS RIVER (MOUTH)	56.747	-110.510	RAMP
HOR-1	HORSE RIVER	56.362	-112.175	RAMP
ISL-1	ISADORE'S LAKE	57.230	-111.607	RAMP
IYC-1	IYINMIN CREEK (MOUTH)	57.250	-111.175	RAMP
JAC-1/JAC-D1	JACKPINE CREEK (MOUTH)	57.239	-111.414	RAMP
JAC-2/JAC-D2	JACKPINE CREEK (UPPER)	57.067	-111.329	RAMP
JAR-1	JACKFISH RIVER (OUTLET OF CHRISTINA LAKE)	55.672	-111.099	RAMP
JOL-1	JOHNSON LAKE	57.657	-110.389	RAMP
KEL-1	KEARL LAKE	57.298	-111.251	RAMP
MAR-1	MACKAY RIVER (MOUTH)	57.168	-111.640	RAMP
MAR-2	MACKAY RIVER (UPSTREAM OF SUNCOR MACKAY)	56.967	-111.909	RAMP
MAR-2A	MACKAY RIVER (MID-RIVER, UPSTREAM OF SUNCOR DOVER)	57.021	-111.828	RAMP
MCC-1	MCLEAN CREEK (MOUTH)	56.897	-111.416	RAMP
MCL-1	MCCLELLAND LAKE	57.491	-111.278	RAMP
MIC-1	MILLS CREEK	57.246	-111.599	RAMP
MUC-1	MUSKEG CREEK (MOUTH)	57.284	-111.316	RAMP
MUR-1	MUSKEG RIVER (MOUTH)	57.134	-111.601	RAMP
MUR-D2	MUSKEG RIVER (MIDDLE REACH)	57.197	-111.558	RAMP
MUR-D3	MUSKEG RIVER (UPPER REACH)	57.377	-111.302	RAMP
MUR-6	MUSKEG RIVER (UPSTREAM OF WAPASU CREEK)	57.344	-111.131	RAMP
NSR-1	NORTH STEEPBANK RIVER (UPSTREAM OF SUNCOR LEWIS)	57.064	-111.043	RAMP
PIR-1	PIERRE RIVER (MOUTH)	57.448	-111.628	RAMP
POC-1/POC-D1	POPLAR CREEK (MOUTH)	56.922	-111.444	RAMP
RCC-1	RED CLAY CREEK (MOUTH)	57.697	-111.405	RAMP
SAC-1/SAC-D1	SAWBONES CREEK (INLET TO CHRISTINA LAKE)	55.650	-110.818	RAMP
SHC-1	SHELLEY CREEK	57.284	-111.415	RAMP
SHL-1	SHIPYARD LAKE	56.961	-111.435	RAMP
STC-1	STANLEY CREEK (MOUTH)	57.352	-111.376	RAMP
STR-1	STEEPBANK RIVER (MOUTH)	57.024	-111.472	RAMP
STR-2	STEEPBANK RIVER (UPSTREAM OF PROJECT MILLENIUM)	56.927	-111.233	RAMP
STR-3	STEEPBANK RIVER (UPSTREAM OF NORTH STEEPBANK)	56.846	-111.082	RAMP
SUC-1/SUC-D1	SUNDAY CREEK (INLET TO CHRISTINA LAKE)	55.584	-110.893	RAMP
TAR-1/TAR-D1	TAR RIVER (MOUTH)	57.323	-111.683	RAMP
TAR-2	TAR RIVER (UPSTREAM OF CANADIAN NATURAL HORIZON)	57.394	-111.992	RAMP
WAC-1	WAPASU CREEK (CANTERRA ROAD CROSSING)	57.284	-111.316	RAMP

Figure 4 All water quality sampling locations with accessible and available organic compounds data.



Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Lake/Pond, River/Stream from the Atlas of Canada Framework Data.
b) Surface Mineable Area from Alberta Energy.

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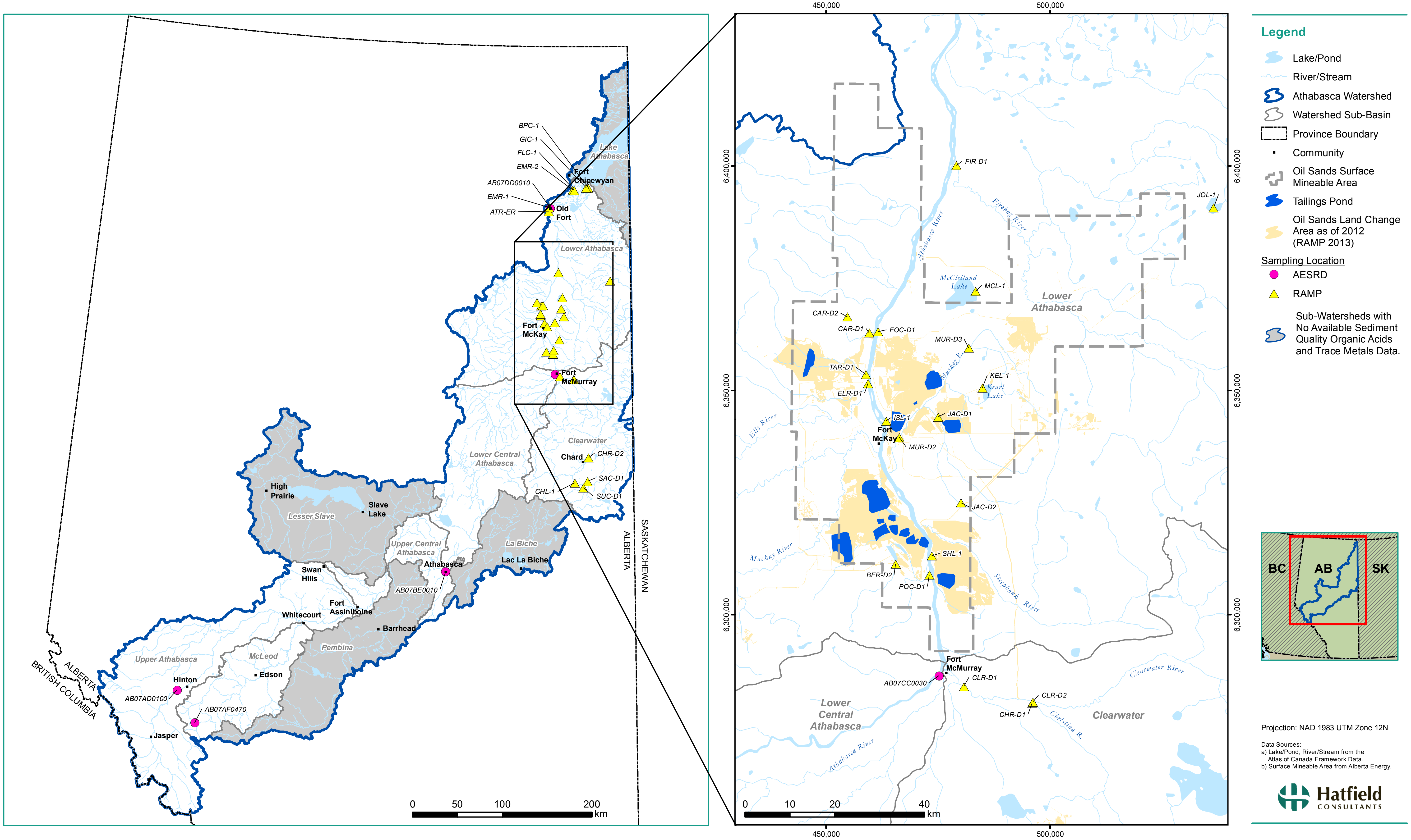
Figure 5 All sediment quality sampling locations with accessible and available organic compounds and trace metals data.



Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Lake/Pond, River/Stream from the
Atlas of Canada Framework Data.
b) Surface Mineable Area from Alberta Energy.

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Table 3 Water quality variables measured within each group of organic compounds.

Group	Water Quality Variable	
Total Hydrocarbons	Benzene	Ethylbenzene
	CCME Fraction 1 (C6-C10)	m+p-xylene
	CCME Fraction 1 (BTEX)	O-xylene
	CCME Fraction 2 (C10-C16)	Toluene
	CCME Fraction 3 (C16-C34)	Total Recoverable Hydrocarbons
	CCME Fraction 4 (C34-C50)	Xylene
PAHs	1-methylnaphthalene	C2-Dibenzothiophenes
	1,2,3,4-tetrahydronaphthalene	C2-Fluoranthenes/Pyrenes
	2-chloronaphthalene	C2-Fluorenes
	2-methylnaphthalene	C2-Naphthalenes
	3-methylcholanthrene	C2-Phenanthrenes/Anthracenes
	7,12-Dimethylbenz[a]anthracene	C3-Chrysene
	Acenaphthene	C3-Dibenzothiophenes
	Acenaphthylene	C3-Fluoranthenes/Pyrenes
	Acridine	C3-Fluorenes
	Anthracene	C3-Naphthalenes
	Benz[a]anthracene	C3-Phenanthrenes/Anthracenes
	Benzo[a]pyrene	C4-Chrysene
	Benzo[b,j,k]fluoranthene	C4-Dibenzothiophenes
	Benzo[b]fluoranthene	C4-Fluoranthene/Pyrene
	Benzo[c]phenanthrene	C4-Fluorene
	Benzo[e]pyrene	C4-Naphthalenes
	Benzo[g,h,i]perylene	C4-Phenanthrenes/Anthracenes
	Benzo[k]fluoranthene	Chrysene
	Biphenyl	Dibenz[a,h]anthracene
	C1-Acenaphthenes	Dibenzo[a,h]pyrene
	C1-Benzo[a]anthracenes/Chrysenes	Dibenzo[a,i]pyrene
	C1-Benzofluoranthenes/Benzopyrenes	Dibenzo[a,l]pyrene
	C1-Biphenyls	Dibenzothiophene
	C1-Chrysene	Fluoranthene
	C1-Dibenzothiophenes	Fluorene
	C1-Fluoranthenes/Pyrenes	Indene
	C1-Fluorenes	Indeno[1,2,3-c,d]-pyrene
	C1-Naphthalenes	Naphthalene
	C1-Phenanthrenes/Anthracenes	Perylene
	C2-Benzo[a]anthracenes/Chrysenes	Phenanthrene
	C2-Benzofluoranthenes/Benzopyrenes	Pyrene
	C2-Biphenyls	Retene
	C2-Chrysene	
Other Aromatic Hydrocarbons	1,2.4-trimethylbenzene	N-butylbenzene
	1.2-diphenylhydrazine	Nitrobenzene
	1,3,5-trimethylbenzene	N-propylbenzene
	2,4-dinitrotoluene	P-isopropyltoluene
	2,6-dinitrotoluene	Sec-butylbenzene

Table 3 (Cont'd.)

Group	Water Quality Variable	
Other Aromatic Hydrocarbons (Cont'd.)	4-bromophenyl phenyl ether	Styrene
	Benzidine	Tert-butylbenzene
	Bromobenzene	N-nitrosodiphenylamine
	Isopropylbenzene	
Pesticides		
Fungicides	Carbathiin (Carboxin)	Metalaxyl-M
	Chlorothalonil	Oxycarboxin
	Hexaconazole	Propiconazole
	Iprodione	Vinclozolin
Herbicides	2,4 & 2,5-Dichlorophenol	Fenoxaprop-p-ethyl
	2,4-D (dichlorophenoxyacetic acid)	Fluazifop
	2,4-DB	Fluroxypyr
	2,4-Dichlorophenol	Glufosinate
	4-Chloro-2-methylphenol	Glyphosate (Roundup)
	Aminomethyl phosphonic acid	Guthion (Azinphos methyl) (azinphos ethyl)
	Aminopyralid	Imazamethabenz-methyl
	Atrazine	Imazamox
	Bentazon	Imazethapyr
	Bromacil	Linuron
	Bromoxynil	MCPA
	Clodinafop acid metabolite	MCPB
	Clodinafop-propargyl	MCPP (Mecoprop)
	Clopyralid (Lontrel)	Metolachlor
	Cyanazine	Metribuzin
	Desethyl Atrazine	Napropamide
	Desisopropyl Atrazine	Picloram (Tordon)
	Dicamba (Banvel)	Quinclorac
	Dichlorprop (2,4-DP)	Quizalofop
	Diclofop-methyl (Hoegrass)	Simazine
	Diuron	Triallate (Avadex bw)
	Ethalfluralin (Edge)	Triclopyr
	Ethofumesate	Trifluralin (Treflan)
Insecticides	Aldicarb	Gamma-benzenehexachloride (Lindane)
	Aldrin	Malathion
	Alpha-benzenehexachloride (BHC)	Methomyl
	Alpha-endosulfan	Methoxychlor (P,P'-methoxychlor)
	Chlorpyrifos-ethyl (Dursban)	Parathion
	Diazinon	Pentachlorophenol
	Dieldrin	Phorate (Thimet)
	Dimethoate (Cygon)	Pyridaben
	Disulfoton (Di-Syston)	Terbufos
	Ethion	Thiamethoxam

Table 3 (Cont'd.)

Group	Water Quality Variable	
Organic Acids		
Naphthenic Acids	Naphthenic Acids	
Oilsands Acid Extractable Organics	Oilsands Acid Extractable	
Resin and Fatty Acids	Arachnidic Acid	Dehydroabietic acid
	Linoleic Acid	Isopimaric Acid
	Linolenic Acid	Levopimaric Acid
	Myristic Acid	Neoabietic Acid
	Oleic Acid	Palustric Acid
	Palmitic Acid	Pimaric Acid
	Stearic Acid	Sandaracopimaric Acid
	Abietic Acid	
Non-chlorinated and total phenols	2,4-dimethylphenol	4-nitrophenol
	2,4-dinitrophenol	Phenol
	2-methyl-4,6-dinitrophenol	Total Phenolics
	2-nitrophenol	
Organochlorines and AOX	1,1,1,2-tetrachloroethane	4,5-dichloroveratrole
	1,1,1-trichloroethane	4,6-dichloroguaiacol
	1,1,2,2-tetrachloroethane	4-chloro-3-methylphenol
	1,1,2-trichloroethane	4-chlorocatechol
	1,1-dichloroethane	4-chloroguaiacol
	1,1-dichloroethylene	4-chlorophenol
	1,1-dichloropropylene	4-chlorophenyl phenyl ether
	1,2,3-trichlorobenzene	4-chlorotoluene
	1,2,3-trichloropropane	5,6-dichlorovanillin
	1,2,4-trichlorobenzene	5-chlorovanillin
	1,2-dibromo-3-chloropropane	6-chlorovanillin
	1,2-dibromoethane	9,10-dichlorostearic acid
	1,2-dichlorobenzene	Adsorbable Organic Halides (AOX)
	1,2-dichloroethane	Bis(2-chloroethoxy)methane
	1,2-dichloropropane	Bis(2-chloroethyl)ether
	1,3-dichlorobenzene	Bis(2-chloroisopropyl)ether
	1,3-dichloropropane	Bromoform
	1,4-dichlorobenzene	Bromomethane
	12,14-dichlorodehydroabietic acid	Carbon tetrachloride
	12-chlorodehydroaibetic acid	chlorobenzene
	14-chlorodehydroaibetic acid	chloroethane
	2,2-dichloropropane	Chloroform
	2,3,4,6-tetrachlorophenol	chloromethane
	2,3,6-trichlorophenol	cis-1,2-dichloroethene
	2,4,5-trichlorophenol	cis-1,3-dichloropropene
	2,4,6-trichlorophenol	Dibromochloromethane
	2,6-dichlorophenol	Dibromomethane
	2,6-dichlorosyringaldehyde	Dichlorobromomethane

Table 3 (Cont'd.)

Group	Water Quality Variable	
Organochlorines and AOX (Cont'd.)	2-chloroethylvinylether	hexachlorobenzene
	2-chlorophenol	hexachlorobutadiene
	2-chlorosyringaldehyde	hexachlorocyclopentadiene
	2-chlorotoluene	hexachloroethane
	3,4,5-trichlorocatecol	Methylene chloride (Dichloromethane)
	3,4,5-trichloroguaiacol	tetrachlorocatecol
	3,4,5-trichloroveratrol	tetrachloroethylene
	3,4,6-trichlorocatechol	tetrachlorguaiacol
	3,4,6-trichloroguaiacol	tetrachloroveratrol
	3,4-dichlorocatechol	trans-1,2-dichloroethene
	3,4-dichloroguaiacol	trans-1,3-dichloropropene
	3,5-dichlorocatechol	trichloroethylene
	3,6-dichlorocatechol	Trichlorofluoromethane
	4,5,6-trichloroguaiacol	Trichloromethoxybenzene
	4,5,6-trichlorosyringol	Trihalomethanes
	4,5-dichlorocatechol	vinyl chloride
	4,5-dichloroguaiacol	
PCBs	No current data available	
Other Organic Compounds		
Aliphatic Hydrocarbons	Isophorone	N-Nitroso-Di-N-Propylamine
	Methyl Tertiary Butyl Ether (MTBE)	
Flame Retardants	No current data available	
Nonylphenols	No current data available	
Phthalates	Bis (2-ethylhexyl) phthalate	Dimethyl phthalate
	Butylbenzyl phthalate	Di-n-butyl phalate
	Diethyl phthalate	Di-n-octyl phthalate

Table 4 Sediment quality variables measured within each group of organic compounds and trace metals.

Group	Sediment Quality Variable	
Total Hydrocarbons	Benzene	CCME Total hydrocarbons (C6-C50)
	CCME Fraction 1 (BTEX)	Ethylbenzene
	CCME Fraction 1 (C2-C10)	m+p-xylene
	CCME Fraction 2 (C10-C16)	O-xylene
	CCME Fraction 3 (C16-C34)	Toluene
	CCME Fraction 4 (C34-C50)	Xylene
PAHs	3-methylcholanthrene	C2-Dibenzothiophenes
	7, 12-Dimethylbenz[a]anthracene	C2-Fluoranthenes/Pyrenes
	2-Chloronapthalene	C2-Fluorenes
	Acenaphthene	C2-Naphthalenes
	Acenaphthylene	C2-Phenanthrenes/Anthracenes
	Acridine	C3-Dibenzothiophenes
	Anthracene	C3-Fluoranthenes/Pyrenes
	Benz[a]anthracene	C3-Fluorenes
	Benzo[a]pyrene	C3-Naphthalenes
	Benzo[b]flouranthene	C3-Phenanthrenes/Anthracenes
	Benzo[b,j,k]fluoranthene	C4-Dibenzothiophenes
	Benzo[c]phenanthrene	C4-Naphthalenes
	Benzo[e]pyrene	C4-Phenanthrenes/Anthracenes
	Benzo[g,h,i]perylene	Chrysene
	Benzo[k]fluoranthene	Dibenz[a,h]anthracene
	Biphenyl	Dibenz[a,h]pyrene
	C1-Acenaphthenes	Dibenz[a,i]pyrene
	C1-Benzo[a]anthracenes/Chrysenes	Dibenz[a,l]pyrene
	C1-Benzofluoranthenes/Benzopyrenes	Dibenzothiophene
	C1-Biphenyls	Fluoranthene
	C1-Dibenzothiophenes	Fluorene
	C1-Fluoranthenes/Pyrenes	Indeno[1,2,3-c,d]-pyrene
	C1-Fluorenes	Naphthalene
	C1-Naphthalenes	Perylene
	C1-Phenanthrenes/Anthracenes	Phenanthrene
	C2-Benzo[a]anthracenes/Chrysenes	Pyrene
	C2-Benzofluoranthenes/Benzopyrenes	Retene
	C2-Biphenyls	
Other Aromatic Hydrocarbons	1,2-diphenylhydrazine	Benzidine
	2,4-dinitrotoluene	Nitrobenzene
	2,6-dinitrotoluene	N-nitrosodiphenylamine
	4-bromophenyl phenyl ether	
Pesticides		
Fungicides	Carbathiin (Carboxin)	Metalaxyl-M
	Chlorothalonil	Oxycarboxin
	Hexaconazole	Propiconazole
	Iprodione	Vinclozolin

Table 4 (Cont'd.)

Group	Sediment Quality Variable	
Herbicides	2,4-D (Dichlorophenoxyacetic Acid)	Fenoxaprop-p-ethyl
	2,4-DB	Fluazifop
	2,4-Dichlorophenol	Fluroxypyr
	Alachlor	Guthion (Azinphos methyl)
	Atrazine	Imazamethabenz-methyl
	Bentazon	Imazamox
	Bromacil	Imazethapyr
	Bromoxynil	Linuron
	Chlodinafop Acid Metabolite	MCPA
	Chlodinafop-propargyl	MCPB
	Clopyralid (Lontrel)	MCPP (Mecoprop)
	Cyanazine	Metolachlor
	Desethyl atrazine	Metribuzin
	Desisopropyl atrazine	Picloram (Tordon)
	Dicamba (Banvel)	Quinclorac
	Dichlorprop (2,4-DP)	Quinzalofop
	Diclofop-methyl (Hoegrass)	Simazine
	Diuron	Triallate (Avadex BW)
	Ethalfluralin (Edge)	Triclopyr
	Ethofumesate	Trifluralin (Treflan)
Insecticides	Aldicarb	Malathion
	Aldrin	Methoxychlor (P,P'-Methoxychlor)
	Alpha BHC	N,N-Diethyl-M-Toluamide (DEET)
	Alpha-chlordane	O,P'-DDD
	Alpha-endosulfan	O,P'-DDE
	Beta-endosulfan	O,P'-DDT
	Chlorpyrifos-ethyl (Dursban)	P,P'-DDD (TDP)
	Diazinon	P,P'-DDE
	Dieldrin	P,P'-DDT
	Dimethoate (Cygon)	Parathion
	Disulfoton (Di-syston)	Pentachlorophenol
	Ethion	Phorate (Thimet)
	Gamma-Benzenehexachloride (Lindane)	Pyridaben
	Gamma-chlordane	Terbufos
	Heptachlor	Thiamethoxam
	Heptachlor Epoxide	
Organic Acids		
Naphthenic Acids	Naphthenic acids	
Oilsands Acid Extractable Organics	No current data available	
Resin and Fatty Acids	No current data available	
Non-chlorinated and total phenols	2,4-dimethylphenol	2-nitrophenol
	2,4-dinitrophenol	4-nitrophenol
	2-methyl-4,6-dinitrophenol	Phenol

Table 4 (Cont'd.)

Group	Sediment Quality Variable	
Organochlorines and AOX	1,2,4-trichlorobenzene	Bis(2-chloroethyl)ether
	2,3,4,6-tetrachlorophenol	Bis(2-chloroisopropyl)ether
	2,4,6-trichlorophenol	Hexachlorobenzene
	2-chlorophenol	Hexachlorobutadiene
	4-chloro-3-methylphenol	Hexachlorocyclopentadiene
	4-chlorophenyl phenyl ether	Hexachloroethane
	Bis(2-chloroethoxy)methane	
PCBs	Total PCBs	
Trace Metals	Total Aluminum (Al)	Total Manganese (Mn)
	Total Antimony (Sb)	Total Mercury (Hg)
	Total Arsenic (As)	Total Molybdenum (Mo)
	Total Barium (Ba)	Total Nickel (Ni)
	Total Beryllium (Be)	Total Selenium (Se)
	Total Bismuth (Bi)	Total Silver (Ag)
	Total Boron (B)	Total Strontium (Sr)
	Total Cadmium (Cd)	Total Thallium (Tl)
	Total Chromium (Cr)	Total Tin (Sn)
	Total Cobalt (Co)	Total Titanium (Ti)
	Total Copper (Cu)	Total Uranium (U)
	Total Iron (Fe)	Total Vanadium (V)
	Total Lead (Pb)	Total Zinc (Zn)
	Total Lithium (Li)	
Other Organic Compounds		
Aliphatic Hydrocarbons	Isophorone	N-Nitroso-Di-N-Propylamine
Flame Retardants	BDE-17	BDE-100
	BDE-28	BDE-138
	BDE-47	BDE-153
	BDE-66	BDE-154
	BDE-71	BDE-183
	BDE-85	BDE-190
	BDE-99	
Nonylphenols	Bisphenol A	Nonylphenol Tetraethoxylate
	Nonylphenol	Nonylphenol-Diethoxylate
	Nonylphenol Pentaethoxylate	Nonylphenol-Triethoxylate
Phthalates	Bis (2-ethylhexyl) phthalate	Di-n-butyl phthalate
	Butylbenzyl phthalate	Di-n-octyl phthalate
	Diethyl phthalate	

3.0 RESULTS

This section provides results of water and sediment quality analyses of each group of organic compounds in the Athabasca watershed. Given the large number of analytes within each group of organic compounds, results will describe each group of compounds as a whole.

3.1 TOTAL HYDROCARBONS

Total hydrocarbons in water and sediment were represented by CCME Total Petroleum Hydrocarbons (TPH), which consist of four molecular-size fractions of total hydrocarbons including: F1 (6 to 10 carbon atoms); F2 (C10-C16); F3 (C16-34); and F4 (C34-50) as well as a fraction specifically measuring the volatile hydrocarbons benzene, toluene, ethylbenzene, and xylenes, collectively known as BTEX. Fractions F1 and F2 are composed of lighter, more volatile hydrocarbons and correlate roughly with gasoline and diesel, whereas F3 and F4 are composed of less volatile, heavier alkylated hydrocarbons and correlate roughly with lubricant and heavy lubricant (CCME 2008). Total Recoverable Hydrocarbons (TRH) are also used to measure total hydrocarbons in water and provide a gross estimate of total hydrocarbons from petroleum or non-petroleum sources.

Total hydrocarbons represent a mixture of organic compounds which contain only carbon and hydrogen atoms and originate from geological sources such as oil, bitumen, and coal. These hydrocarbons can also be released into freshwater ecosystems through various pathways including gasoline, crude oil, and jet fuel (CCME 2008). Once released into the environment, these compounds undergo physical, chemical, and biological changes known as weathering (Williams et al. 2006). Total hydrocarbons can be of potential concern when released to the environment due to the following characteristics:

- volatility - which poses a risk of fire, explosion, and future chemical reactions;
- toxicity - which poses a risk to aquatic life;
- mobility - where lighter hydrocarbons can travel to areas that are a significant distance from the original source via water, air, or ground transport; and
- persistence in the environment – which can be attributed to the presence of larger, branched chains (CCME 2008).

3.1.1 Data Availability

3.1.1.1 Water Quality

Total hydrocarbons data for surface waters were obtained from two sources: AESRD, and RAMP (Figure 6). AESRD provided current data for 14 stations within the Athabasca watershed, and RAMP provided total hydrocarbons data for 64 stations within the Lower Athabasca and Clearwater sub-watersheds. No data were available for total hydrocarbons in surface water for the McLeod, Pembina, La Biche, or Lake Athabasca sub-watersheds.

Following a decision by the RAMP Technical Committee in April 2011, both TRH and TPH were adopted as target variables for RAMP water quality monitoring programs. The purpose of this potential change in method analysis was to provide more detailed information regarding hydrocarbon concentrations in water in the RAMP focal study area, as well as to align with AESRD sampling programs, which were also beginning to shift to CCME TPH (See RAMP 2011 Technical Report (RAMP 2012) for more information).

3.1.1.2 Sediment Quality

Sediment total hydrocarbons data were obtained from 30 RAMP stations (Figure 6). Of the ten sub-watersheds in the Athabasca River watershed, sediment total hydrocarbons data were only available for only two: the Lower Athabasca and Clearwater.

3.1.2 Total Hydrocarbons in Water

3.1.2.1 2012 Spatial Comparisons

Given all 2012 data for total recoverable hydrocarbons in surface waters were below detection (i.e., <0.1 mg/L) for all stations, spatial comparisons were not conducted.

3.1.2.2 Compilation of Current Total Hydrocarbons in Water and Comparison with Guidelines

In surface water, the majority of total hydrocarbons samples were below common detection limits (i.e., <0.5 to 1000 µg/L) at both AESRD and RAMP stations (Table 5 and Table 6).

Concentrations of toluene exceeded guidelines (0.5 µg/L) in one sample at six RAMP stations (ATR-DC-W, one sample from 2012; BIC-1, one sample from 2011; EYC-1, one sample from 2011; MAR-2A, one sample from 2012; RCC-1, one sample from 2011; and STR-1, one sample from 2012) and three AESRD stations (AB07DA0980, one sample from 2010; AB07DD0010, one sample from 2011; and AB07DD0105, one sample from 2007), all located in the lower Athabasca sub-watershed. For a CCME guideline value of 0.5 µg/L, the magnitude of exceedance at the six RAMP stations ranged from approximately 1.2 times greater than the guideline at Big Creek (BIC-1) to 9.3 times greater than the guideline at the Athabasca River upstream of Donald Creek (ATR-DC-W). The magnitude of exceedance at the three AESRD stations ranged from approximately 1.4 times greater than the guideline at the Athabasca River downstream of Devil's Elbow winter road crossing (AB07DD0105) to 3 times greater than the guideline at the Athabasca River at Old Fort (AB07DD0010). Of the six RAMP stations, four (ATR-DC-W, BIC-1, EYC-1, RCC-1) were defined by RAMP as "baseline" stations unaffected by oilsands development and two (STR-1 and MAR-1) were defined as "test" stations downstream of oilsands development. The high concentration of toluene in "baseline" stations may indicate higher levels of naturally occurring toluene in these watercourses.

3.1.2.3 Historical Trend Analysis

Historical trend analysis was conducted on total recoverable hydrocarbons in surface water for the current data period. Sixteen RAMP stations had less than four years of data and therefore were excluded from both qualitative and quantitative trend analysis. Historical total recoverable hydrocarbon concentrations for the remaining 48 RAMP stations were plotted, but were excluded from statistical trend analysis because these stations either had less than seven years of data, or had greater than 50% non-detectable values (Figure 7). The majority of total recoverable hydrocarbon samples were below detection at all RAMP stations over all years of data. After 2005, detection limits for RAMP total hydrocarbons water quality data increased from 0.5 mg/L to 1 mg/L due to a change in analytical laboratories from Envirotest Laboratories to ALS Environmental Laboratories.

3.1.3 Total Hydrocarbons in Sediment

3.1.3.1 2012 Spatial Comparisons

Given that the only sediment data available for fall 2012 was from RAMP, spatial comparisons were conducted among RAMP stations only (Figure 8). If total hydrocarbons concentrations were below detection, half of the station marker was shaded black.

Detectable CCME Total hydrocarbon concentrations ranged from 22 mg/kg at upper Beaver River (BER-2) to 4750 mg/kg at lower Fort Creek (FOC-D1) (Figure 8). Total hydrocarbon concentrations were generally lowest at stations upstream of Fort McMurray and further downstream of major oil sands developments. Concentrations of total hydrocarbons were generally highest downstream of Fort McKay around the lower Ells River and Fort Creek stations.

3.1.3.2 Compilation of Current Total Hydrocarbons in Sediment and Comparison with Guidelines

In sediment, CCME F3, F4, and CCME Total Hydrocarbons were detected (i.e., ≥410 mg/kg) in at least one sample at the majority of RAMP stations (Table 7). All other hydrocarbons were below detection in all samples at all stations with the exception of CCME F2 which was detected in at least one sample at one RAMP station (KEL-1, Kearl Lake), and ethylbenzene, which was detected in at least one sample at two RAMP lake stations (KEL-1 and SHL-1, Shipyard Lake). Concentrations of F3 and F4 hydrocarbons exhibited wide ranges of concentrations among stations, with sediments from RAMP baseline stations throughout the region showing concentrations of F3 hydrocarbons from non-detectable to 3,600 mg/kg, and of F4 hydrocarbons from non-detectable to 2,500 mg/kg).No guidelines were available for total hydrocarbons in sediments.

CCME F3 and F4 fractions are heavy hydrocarbons that correlate roughly with lubricant and heavy lubricants (CCME 2008). As such, these fractions generally have low solubility in water and are more likely to adsorb to sediments than the lighter, more soluble CCME F1 and F2 hydrocarbon fractions. From Figure 9, it is evident that the CCME F3 and F4 hydrocarbons in sediments are frequently above the detection limit, which may explain why these heavier fractions were mostly detectable in sediment stations, but not typically in water.

3.1.3.3 Historical Trend Analysis

Historical trend analysis was conducted on CCME total hydrocarbons in sediments for the current data period. Eight RAMP stations had less than four years of data and were therefore excluded from both qualitative and quantitative trend analysis. Historical total hydrocarbon concentrations for an additional eight RAMP stations were plotted, but were excluded from statistical trend analysis because these stations had less than seven years of data (Figure 10). After 2008, detection limits for RAMP total hydrocarbons sediment quality data increased from 5 mg/kg to a detection limit that varies with the moisture content in the sediment due to a change in analytical laboratories from Envirotest Laboratories to ALS Environmental Laboratories. Concentrations of CCME total hydrocarbons in sediments of Shipyard Lake (SHL-1) showed a statistically significant increase since RAMP sampling began in 2001, although the 2012 concentration still fell within the range of concentrations found in unaffected lakes sampled by RAMP since 1999, and these hydrocarbon fractions were detectable in water. All other stations showed no significant trends over time (Figure 10).

3.1.4 Overall Assessment: Total Hydrocarbons

- Most surface water total hydrocarbons data were obtained from the Lower Athabasca watershed, indicating a general gap in sampling total hydrocarbons in surface water throughout the rest of the Athabasca watershed.
- All sediment total hydrocarbons data were obtained from RAMP stations in the lower Athabasca and Clearwater sub-watersheds indicating a general gap in sampling of total hydrocarbons in sediments throughout the rest of the Athabasca watershed.
- The majority of total hydrocarbons surface water samples were below common detection limits at both AESRD and RAMP stations.
- Concentrations of toluene—an aromatic hydrocarbon with a common odour of paint thinner—exceeded guidelines in one sample at six RAMP stations upstream and downstream of oil sands developments and three AESRD stations. The magnitude of exceedance at the six RAMP stations ranged from approximately 1.2 to 9.3 times greater than the guideline. The magnitude of exceedance at the three AESRD stations ranged from approximately 1.4 to 3 times greater than the guideline.
- Qualitative trend analysis indicated that the majority of total recoverable hydrocarbon surface water samples were below detection at all stations over all years of data.
- The majority of measurable total hydrocarbons in sediments at RAMP stations were heavier CCME F3, F4 fractions.
- No significant trends were observed in total hydrocarbons at RAMP sediment stations except for station SHL-1 on the Shipyard Lake which showed an increasing trend in total hydrocarbons from 2004 to 2012.

Figure 6 Sampling locations for total hydrocarbons in water and sediment.

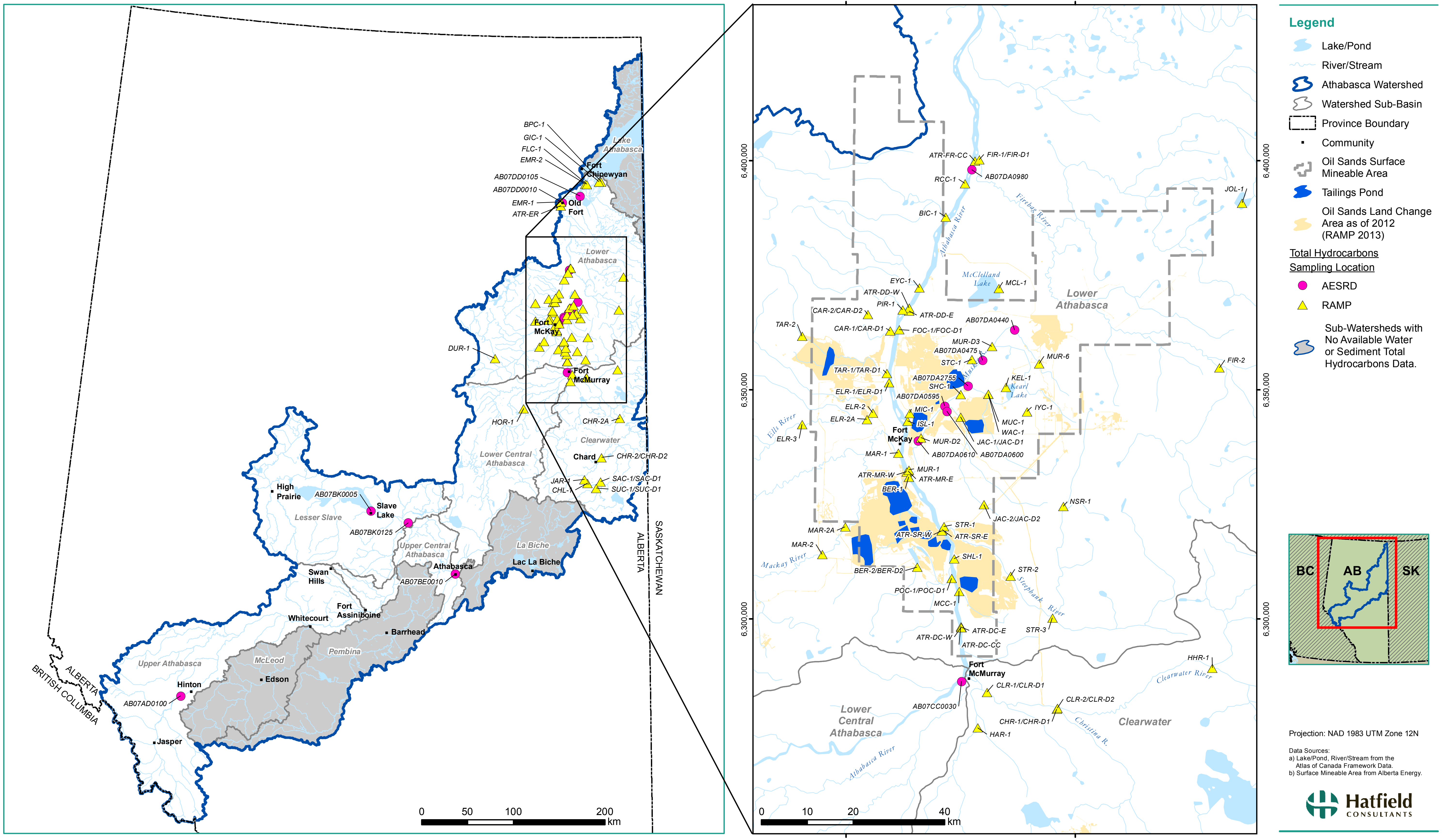

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Table 5 Total hydrocarbons in surface water at AESRD stations with at least one year of current data available.

Analyte	Guideline (µg/L)			Common Detection Limit (µg/L)	Stations and Sub-watersheds													
					Upper Athabasca	Upper Central Athabasca	Lesser Slave		Lower Central Athabasca	Lower Athabasca								
	AESRD (2013)	CCME	BC		AB07AD0100	AB07BE0010	AB07BK0005	AB07BK0125	AB07CC0030	AB07DA0440	AB07DA0475	AB07DA0595	AB07DA0600	AB07DA0610	AB07DA0980	AB07DA2755	AB07DD0010	AB07DD0105
Benzene	40	370	40	0.5	n=3 ○	n=12 ○	n=1 ○	n=2 ○	n=37 ○	n=10 ○	n=10 ○	n=10 ○	n=10 ○	n=57 ○	n=36 ○	n=7 ○	n=22 ◔	n=15 ○
CCME Fraction 1 (C6-C10)	-	-	-	100	-	n=9 ○	-	-	n=34 ○	n=10 ○	n=10 ○	n=10 ○	n=10 ○	n=57 ○	n=36 ○	n=7 ○	n=22 ○	n=12 ○
CCME Fraction 2 (C10-C16)	-	-	-	250	-	n=9 ○	-	-	n=33 ○	n=10 ○	n=10 ○	n=10 ○	n=10 ○	n=56 ○	n=36 ○	n=7 ○	n=22 ○	n=11 ○
CCME Fraction 3 (C16-C34)	-	-	-	250	-	n=9 ○	-	-	n=33 ◔	n=10 ◔	n=10 ◔	n=10 ○	n=10 ◔	n=56 ◔	n=36 ○	n=7 ○	n=22 ◔	n=11 ○
CCME Fraction 4 (C34-C50)	-	-	-	250	-	n=9 ○	-	-	n=30 ○	-	-	-	-	n=21 ○	n=19 ○	-	n=19 ◔	n=9 ○
Ethylbenzene	90	90	-	0.5	n=3 ○	n=12 ○	n=1 ○	n=2 ○	n=37 ○	n=10 ○	n=10 ○	n=10 ○	n=10 ○	n=57 ○	n=36 ○	n=7 ○	n=22 ○	n=15 ○
m+p-xylene	-	-	-	0.5	n=3 ○	n=12 ○	n=1 ○	n=2 ○	n=37 ○	n=10 ○	n=10 ○	n=10 ○	n=10 ○	n=57 ◔	n=36 ◔	n=7 ○	n=22 ◔	n=15 ◔
O-xylene	-	-	-	0.5	n=3 ○	n=12 ○	n=1 ○	n=2 ○	n=37 ○	n=10 ○	n=10 ○	n=10 ○	n=10 ○	n=57 ○	n=36 ◔	n=7 ○	n=22 ○	n=15 ◔
Toluene	-	0.5	-	0.5	n=3 ○	n=12 ○	n=1 ○	n=2 ○	n=37 ○	n=10 ○	n=10 ○	n=10 ○	n=10 ○	n=57 ○	n=36 ◔	n=7 ○	n=22 ◔	n=15 ◔
Xylene	30	-	30	0.71	n=3 ○	n=3 ○	n=1 ○	n=2 ○	n=3 ○	-	-	-	-	-	-	-	-	n=3 ◑

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes.

Legend

○ = All data below detection limit
◔ = 1-25% of data above detection
◑ = 26-50% of data above detection
◕ = 51-75% of data above detection
● = 76-100% of data above detection

Red highlighting indicates guideline exceedence.

Table 6 Total hydrocarbons in surface water at RAMP stations with at least one year of current data available.

Analyte	Guideline (µg/L)			Common Detection Limit (µg/L)	Station																			
	AESRD (2013)	CCME	BC		ATR-DC-CC	ATR-DC-E	ATR-DC-W	ATR-DD-E	ATR-DD-W	ATR-FR-CC	ATR-MR-E	ATR-MR-W	ATR-SR-E	ATR-SR-W	BER-1	BER-2	BIC-1	CAR-1	CAR-2	CHL-1	CHR-1	CHR-2	CHR-2A	CLR-1
Benzene	40	370	40	0.5	-	n=7 ○	n=7 ◔	n=7 ○	n=7 ○	-	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	-	n=2 ○
CCME Fraction 1 (C6-C10)	-	-	-	100	-	n=7 ○	n=7 ○	n=7 ○	n=7 ○	-	n=2 ○	n=2 ○	n=2 ◑	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	-	n=2 ○
CCME Fraction 1 (BTEX)	-	-	-	100	-	n=7 ○	n=7 ○	n=7 ○	n=7 ○	-	n=2 ○	n=2 ○	n=2 ◑	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	-	n=2 ○
CCME Fraction 2 (C10-C16)	-	-	-	250	-	n=7 ○	n=7 ○	n=7 ○	n=7 ○	-	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	-	n=2 ○
CCME Fraction 3 (C16-C34)	-	-	-	250	-	n=7 ○	n=7 ○	n=7 ○	n=7 ○	-	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ◑	n=2 ◑	n=3 ○	n=2 ○	n=2 ○	-	n=2 ○
CCME Fraction 4 (C34-C50)	-	-	-	250	-	n=7 ○	n=7 ○	n=7 ○	n=7 ○	-	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ◑	n=3 ○	n=2 ○	n=2 ○	-	n=2 ○
Ethylbenzene	90	90	-	0.5	-	n=7 ○	n=7 ◔	n=7 ○	n=7 ○	-	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	-	n=2 ○
m+p-xylene	-	-	-	0.5	-	n=7 ○	n=7 ◔	n=7 ○	n=7 ○	-	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	-	n=2 ○
O-xylene	-	-	-	0.5	-	n=7 ○	n=7 ◔	n=7 ○	n=7 ○	-	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	-	n=2 ○
Toluene	-	0.5	-	0.5	-	n=7 ○	n=7 ◔	n=7 ○	n=7 ○	-	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ◔	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	-	n=2 ○
Total recoverable hydrocarbons	-	-	-	1000	n=1 ○	n=17 ○	n=17 ○	n=24 ◔	n=24 ○	n=4 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=13 ○	n=6 ○	n=6 ○	n=9 ○	n=3 ○	n=7 ○	n=7 ○	n=2 ○	n=8 ○
Xylene	30	-	30	0.71	-	n=7 ○	n=7 ◔	n=7 ○	n=7 ○	-	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	-	n=2 ○

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes.

Legend

○ = All data below detection limit
◔ = 1-25% of data above detection
◑ = 26-50% of data above detection
◕ = 51-75% of data above detection
● = 76-100% of data above detection

Red highlighting indicates guideline exceedence.

Table 6 (Cont'd.)

Analyte	Guideline (µg/L)			Common Detection Limit (µg/L)	Station																			
	AESRD (2013)	CCME	BC		CLR-2	DUR-1	ELR-1	ELR-2	ELR-2A	ELR-3	EYC-1	FIR-1	FIR-2	FOC-1	HAR-1	HHR-1	HOR-1	ISL-1	IYC-1	JAC-1	JAC-2	JAR-1	JOL-1	KEL-1
Benzene	40	370	40	0.5	n=2 ○	-	n=2 ○	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	-	n=6 ○	-	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○
CCME Fraction 1 (C6-C10)	-	-	-	100	n=2 ○	-	n=2 ○	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	-	n=6 ○	-	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○
CCME Fraction 1 (BTEX)	-	-	-	100	n=2 ○	-	n=2 ○	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	-	n=6 ○	-	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○
CCME Fraction 2 (C10-C16)	-	-	-	250	n=2 ○	-	n=2 ○	n=2 ○	n=4 ◔	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	-	n=6 ○	-	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○
CCME Fraction 3 (C16-C34)	-	-	-	250	n=2 ○	-	n=2 ○	n=2 ○	n=4 ◔	n=2 ○	n=7 ◔	n=2 ○	n=2 ○	n=2 ○	-	n=6 ○	-	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○
CCME Fraction 4 (C34-C50)	-	-	-	250	n=2 ○	-	n=2 ○	n=2 ○	n=4 ◔	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	-	n=6 ○	-	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○
Ethylbenzene	90	90	-	0.5	n=2 ○	-	n=2 ○	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	-	n=6 ○	-	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○
m+p-xylene	-	-	-	0.5	n=2 ○	-	n=2 ○	n=2 ○	n=4 ○	n=2 ○	n=7 ◔	n=2 ○	n=2 ○	n=2 ○	-	n=6 ○	-	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○
O-xylene	-	-	-	0.5	n=2 ○	-	n=2 ○	n=2 ○	n=4 ○	n=2 ○	n=7 ◔	n=2 ○	n=2 ○	n=2 ○	-	n=6 ○	-	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○
Toluene	-	0.5	-	0.5	n=2 ○	-	n=2 ○	n=2 ○	n=4 ○	n=2 ○	n=7 ◔	n=2 ○	n=2 ○	n=2 ○	-	n=6 ○	-	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○
Total recoverable hydrocarbons	-	-	-	1000	n=6 ○	n=1 ○	n=6 ○	n=8 ○	n=6 ○	n=2 ○	n=7 ○	n=6 ○	n=6 ○	n=6 ○	n=4 ○	n=6 ○	n=1 ○	n=8 ○	n=6 ○	n=6 ○	n=5 ○	n=3 ○	n=6 ○	n=7 ○
Xylene	30	-	30	0.71	n=2 ○	-	n=2 ○	n=2 ○	n=4 ○	n=2 ○	n=7 ◔	n=2 ○	n=2 ○	n=2 ○	-	n=6 ○		n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes.

Legend

○ = All data below detection limit
◔ = 1-25% of data above detection
◑ = 26-50% of data above detection
◕ = 51-75% of data above detection
● = 76-100% of data above detection

Red highlighting indicates guideline exceedence.

Table 6 (Cont'd.)

Analyte	Guideline (µg/L)			Common Detection Limit (µg/L)	Station																			
	AESRD (2013)	CCME	BC		MAR-1	MAR-2	MAR-2A	MCC-1	MCL-1	MIC-1	MUC-1	MUR-1	MUR-6	NSR-1	PIR-1	POC-1	RCC-1	SAC-1	SHC-1	SHL-1	STC-1	STR-1	STR-2	STR-3
Benzene	40	370	40	0.5	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	-	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○
CCME Fraction 1 (C6-C10)	-	-	-	100	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	-	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○
CCME Fraction 1 (BTEX)	-	-	-	100	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	-	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○
CCME Fraction 2 (C10-C16)	-	-	-	250	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	-	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○
CCME Fraction 3 (C16-C34)	-	-	-	250	n=2 ○	n=2 ○	n=6 ○	n=2 ◑	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	-	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○
CCME Fraction 4 (C34-C50)	-	-	-	250	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ◔	n=3 ○	-	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○
Ethylbenzene	90	90	-	0.5	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	-	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○
m+p-xylene	-	-	-	0.5	n=2 ○	n=2 ○	n=6 ◔	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ◔	n=3 ○	-	n=2 ○	n=2 ○	n=3 ◑	n=2 ○	n=2 ○
O-xylene	-	-	-	0.5	n=2 ○	n=2 ○	n=6 ◔	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	-	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○
Toluene	-	0.5	-	0.5	n=2 ○	n=2 ○	n=6 ◔	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ◔	n=3 ○	-	n=2 ○	n=2 ○	n=3 ◑	n=2 ○	n=2 ○
Total recoverable hydrocarbons	-	-	-	1000	n=11 ○	n=11 ○	n=13 ○	n=6 ○	n=6 ○	n=3 ○	n=7 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=3 ○	n=2 ○	n=8 ○	n=6 ○	n=11 ○	n=6 ○	n=8 ○
Xylene	30	-	30	0.71	n=2 ○	n=2 ○	n=6 ◔	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	-	n=2 ○	n=2 ○	n=3 ◑	n=2 ○	n=2 ○

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes.

Legend

○ = All data below detection limit
◔ = 1-25% of data above detection
◑ = 26-50% of data above detection
◕ = 51-75% of data above detection
● = 76-100% of data above detection

Red highlighting indicates guideline exceedence.

Table 6 (Cont'd.)

Analyte	Guideline (µg/L)			Common Detection Limit (µg/L)	Station			
	AESRD (2013)	CCME	BC		SUC-1	TAR-1	TAR-2	WAC-1
Benzene	40	370	40	0.5	n=3 ○	n=2 ○	n=2 ○	n=2 ○
CCME Fraction 1 (C6-C10)	-	-	-	100	n=3 ○	n=2 ○	n=2 ○	n=2 ○
CCME Fraction 1 (BTEX)	-	-	-	100	n=3 ○	n=2 ○	n=2 ○	n=2 ○
CCME Fraction 2 (C10-C16)	-	-	-	250	n=3 ○	n=2 ○	n=2 ○	n=2 ○
CCME Fraction 3 (C16-C34)	-	-	-	250	n=3 ○	n=2 ○	n=2 ○	n=2 ○
CCME Fraction 4 (C34-C50)	-	-	-	250	n=3 ○	n=2 ○	n=2 ○	n=2 ○
Ethylbenzene	90	90	-	0.5	n=3 ○	n=2 ○	n=2 ○	n=2 ○
m+p-xylene	-	-	-	0.5	n=3 ○	n=2 ○	n=2 ○	n=2 ○
O-xylene	-	-	-	0.5	n=3 ○	n=2 ○	n=2 ○	n=2 ○
Toluene	-	0.5	-	0.5	n=3 ○	n=2 ○	n=2 ○	n=2 ○
Total recoverable hydrocarbons	-	-	-	1000	n=3 ○	n=8 ○	n=10 ○	n=6 ○
Xylene	30	-	30	0.71	n=3 ○	n=2 ○	n=2 ○	n=2 ○

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes.

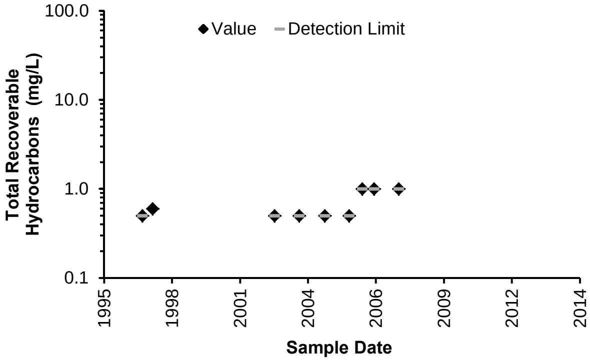
Legend

○ = All data below detection limit
◔ = 1-25% of data above detection
◑ = 26-50% of data above detection
◕ = 51-75% of data above detection
● = 76-100% of data above detection

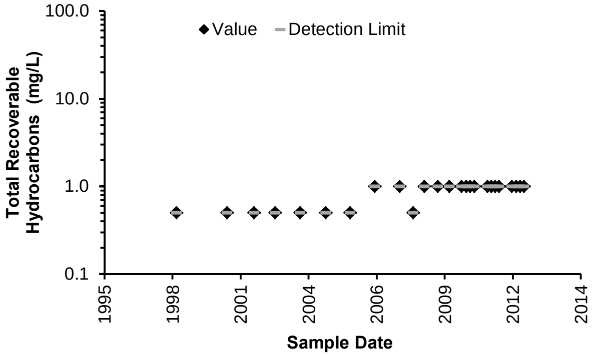
Red highlighting indicates guideline exceedence.

Figure 7 **Total Recoverable Hydrocarbons (Log Scale) in surface water at RAMP stations with historical datasets.**

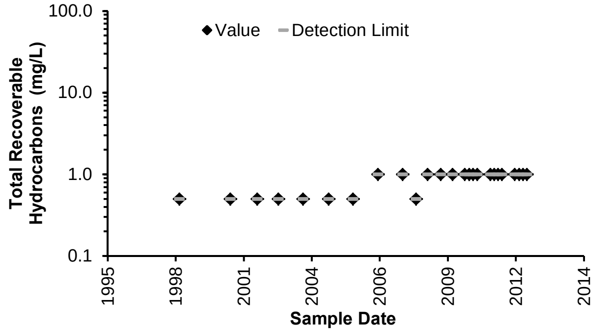
ATR-DC-CC (Athabasca River Upstream of Donald Creek (cross channel))



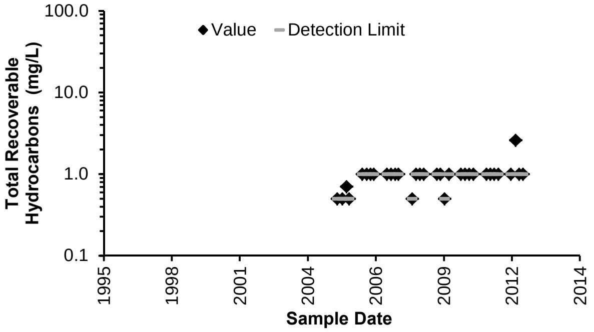
ATR-DC-E (Athabasca River Upstream of Donald Creek (east bank))



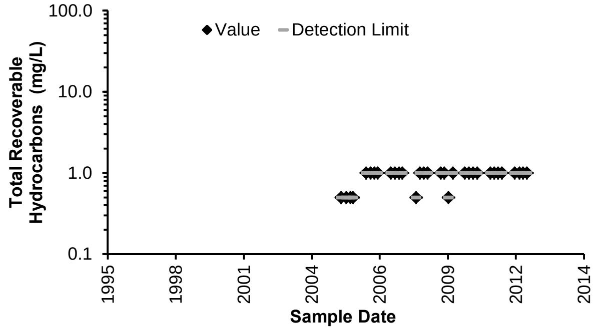
ATR-DC-W (Athabasca River Upstream of Donald Creek (west bank))



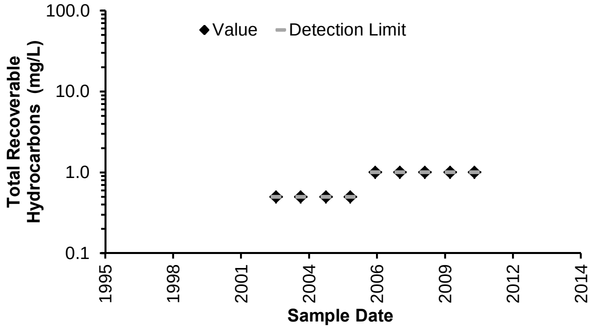
ATR-DD-E (Athabasca River Downstream of Development (east bank))



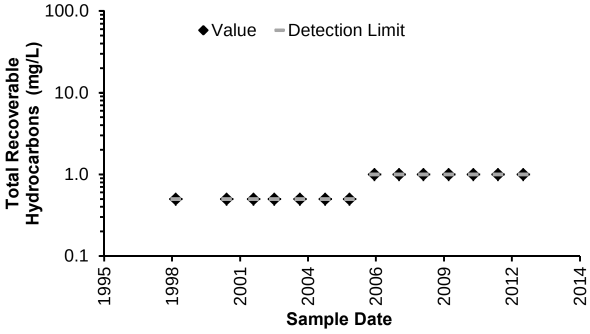
ATR-DD-W (Athabasca River Downstream of Development (west bank))



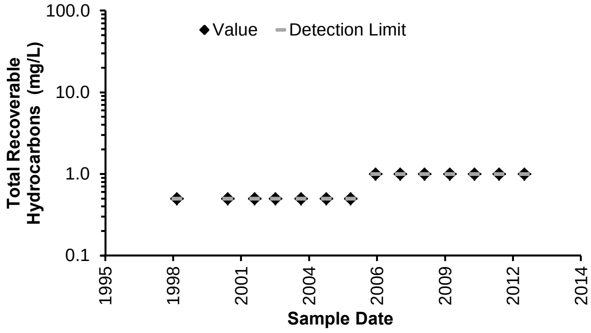
ATR-FR-CC (Athabasca River Upstream of Mouth of Firebag River (cross channel))



ATR-MR-E (Athabasca River Upstream of Muskeg River (east bank))



ATR-MR-W (Athabasca River Upstream of Muskeg River (west bank))



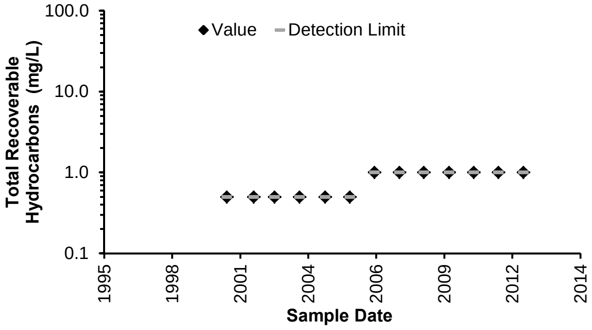
Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

Note: Detection limits are indicated by a grey dash, absence of a grey dash indicates that detection limits were not provided for these data points.

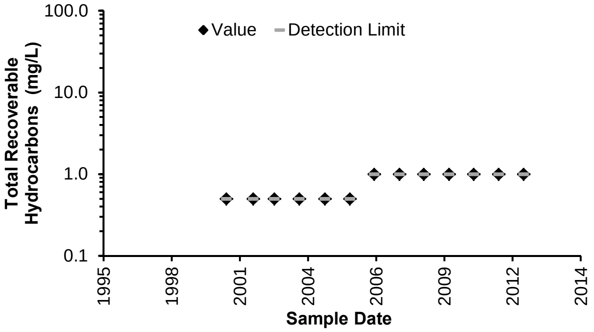
No guideline available for Total Recoverable Hydrocarbons in surface water.

Figure 7 (Cont'd.)

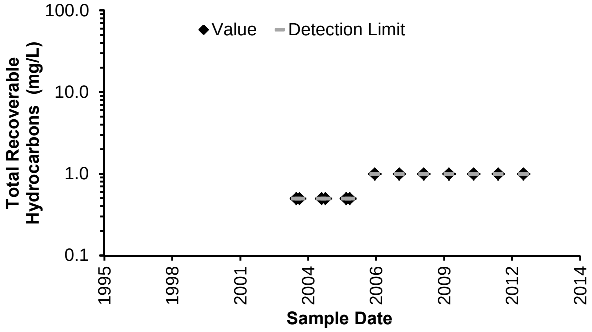
ATR-SR-E (Athabasca River Upstream of Steepbank River (east bank))



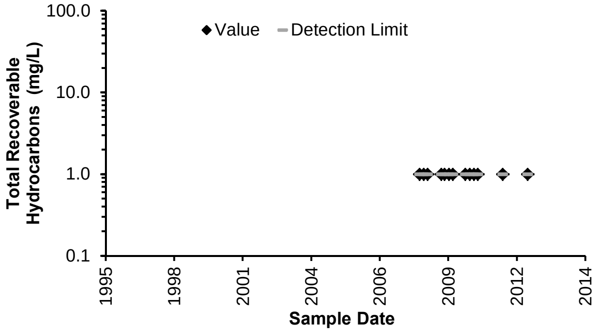
ATR-SR-W (Athabasca River Upstream of Steepbank River (west bank))



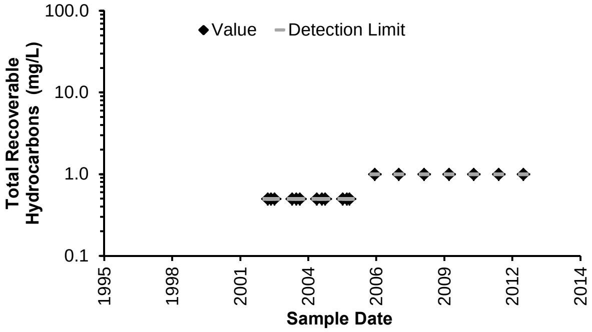
BER-1 (Beaver River)



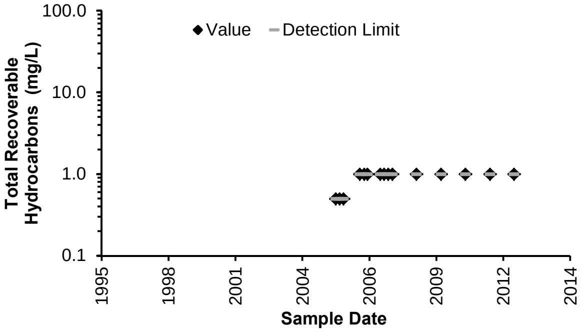
BER-2 (Beaver River)



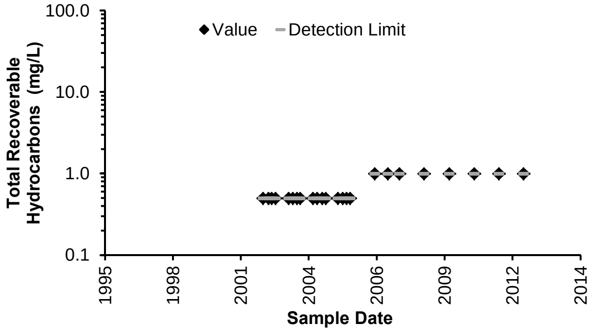
CAR-1 (Calumet River)



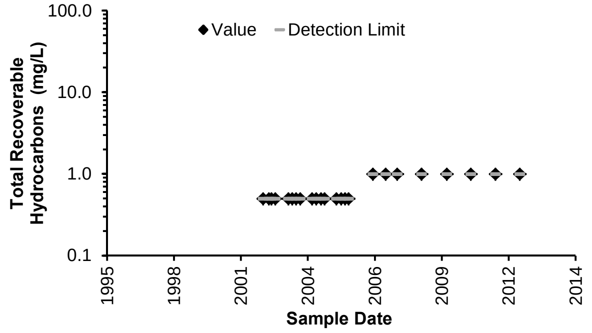
CAR-2 (Calumet River)



CHR-1 (Christina River)



CHR-2 (Christina River)



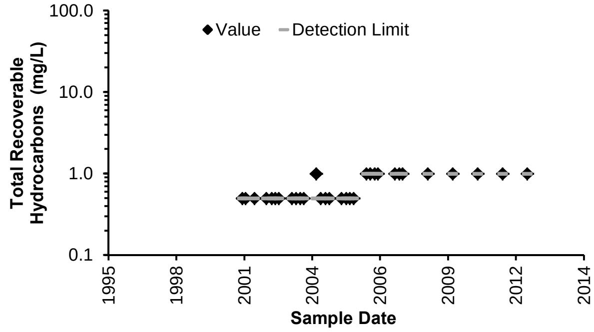
Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

Note: Detection limits are indicated by a grey dash, absence of a grey dash indicates that detection limits were not provided for these data points.

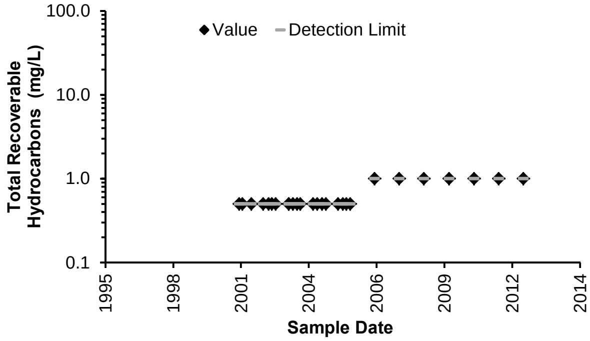
No guideline available for Total Recoverable Hydrocarbons in surface water.

Figure 7 (Cont'd.)

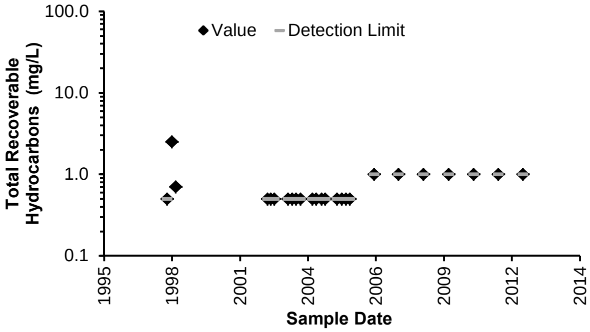
CLR-1 (Clearwater River)



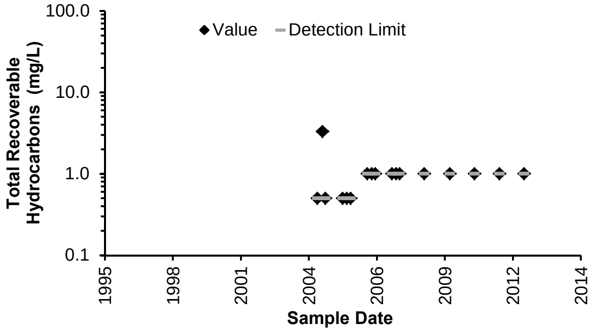
CLR-2 (Clearwater River)



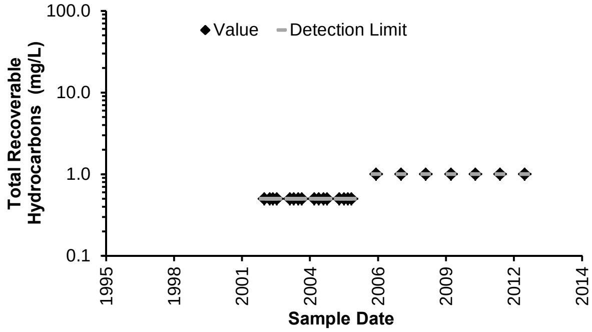
ELR-1 (Ells River)



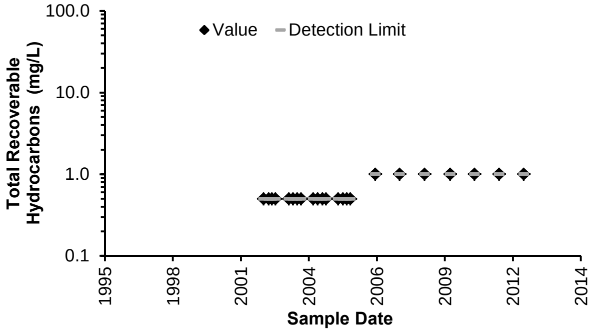
ELR-2 (Ells River)



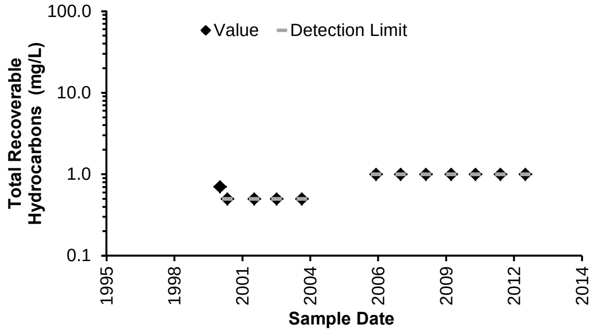
FIR-1 (Firebag River)



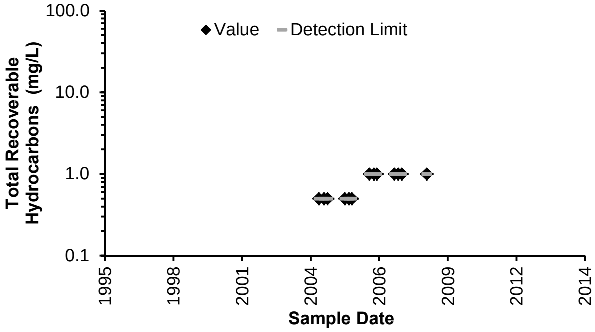
FIR-2 (Firebag River)



FOC-1 (Fort Creek)



HAR-1 (Hangingstone River)



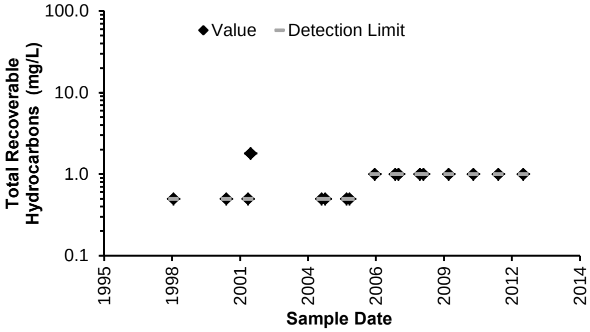
Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

Note: Detection limits are indicated by a grey dash, absence of a grey dash indicates that detection limits were not provided for these data points.

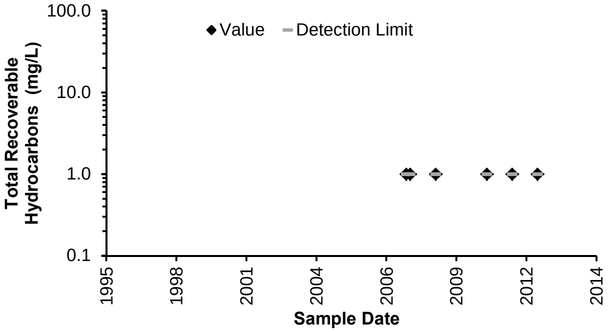
No guideline available for Total Recoverable Hydrocarbons in surface water.

Figure 7 (Cont'd.)

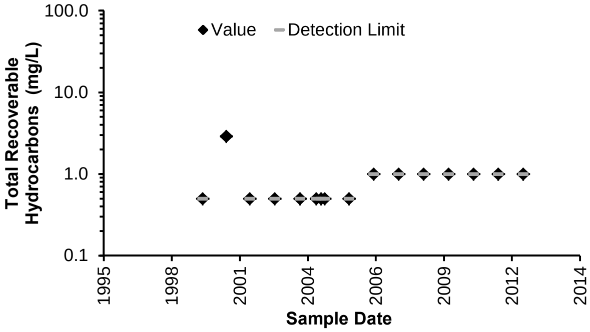
ISL-1 (Isadore's Lake)



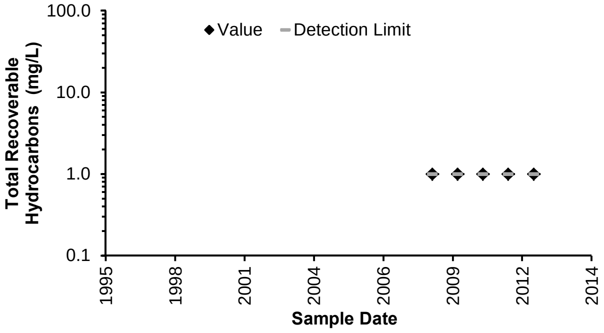
IYC-1 (Lyinimin Creek)



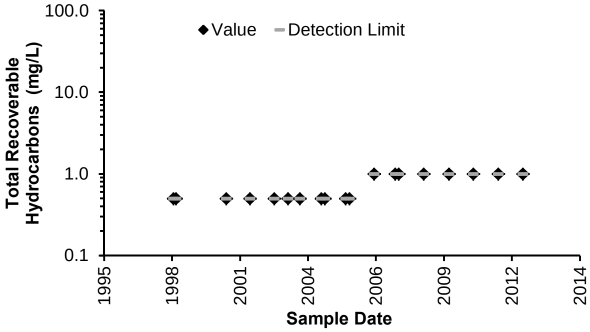
JAC-1 (Jackpine Creek)



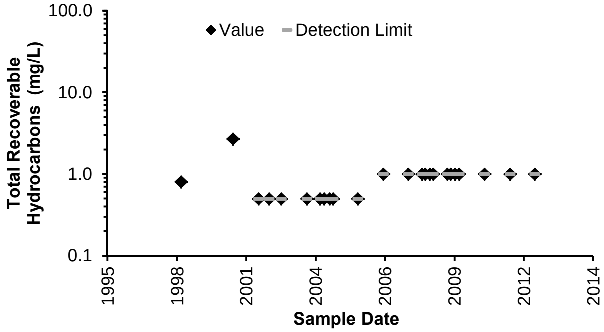
JAC-2 (Jackpine Creek)



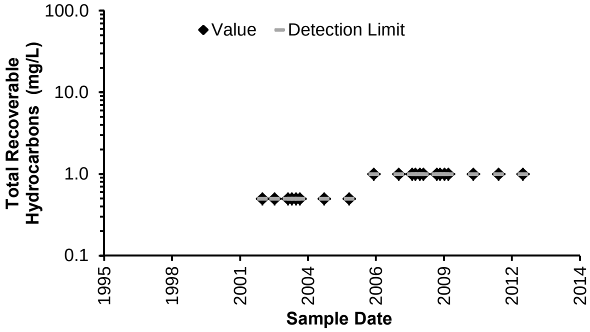
KEL-1 (Kearl Lake)



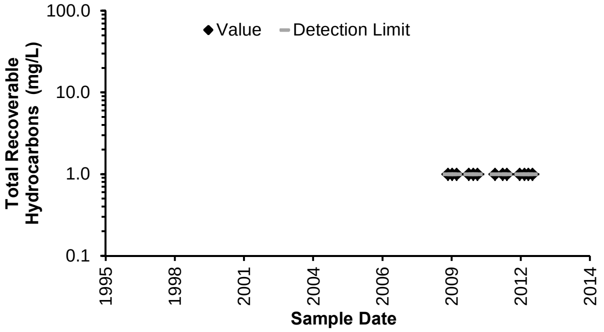
MAR-1 (Mackay River)



MAR-2 (Mackay River)



MAR-2A (Mackay River)

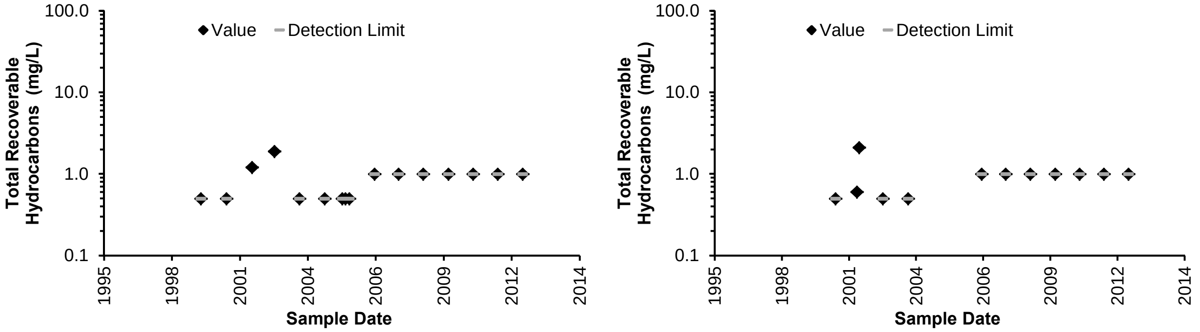


Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

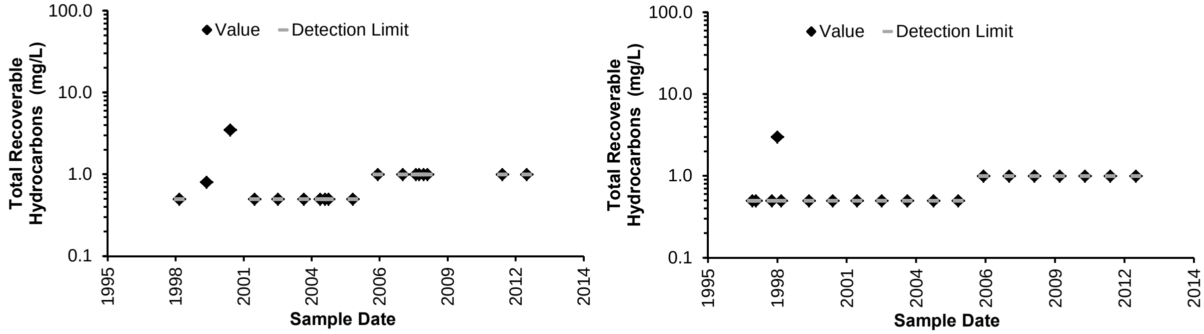
Note: Detection limits are indicated by a grey dash, absence of a grey dash indicates that detection limits were not provided for these data points.

No guideline available for Total Recoverable Hydrocarbons in surface water.

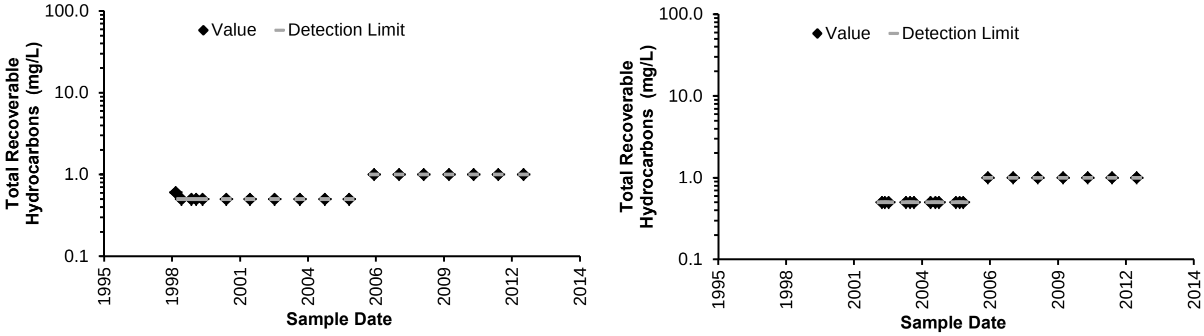
Figure 7 (Cont'd.)


MCC-1 (McLean Creek)

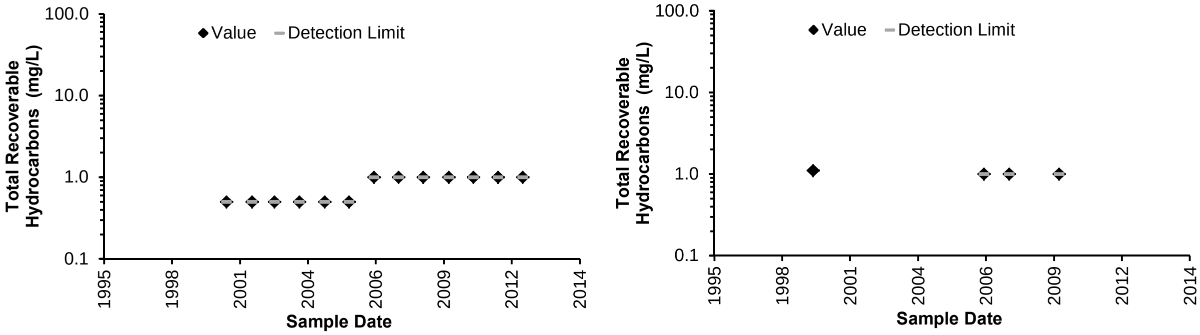
MCL-1 (McClelland Lake)


MUC-1 (Muskeg Creek)

MUR-1 (Muskeg River)


MUR-6 (Muskeg River)

NSR-1 (North Steepbank River)


POC-1 (Poplar Creek)

SHC-1 (Shelley Creek)

Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

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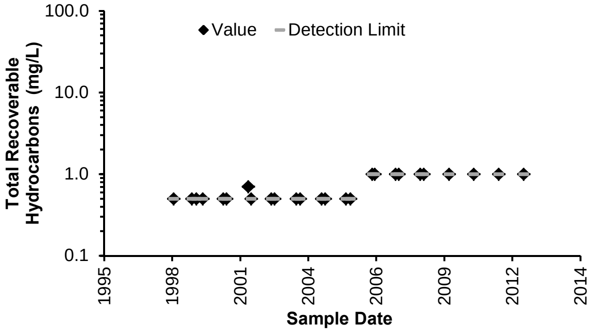
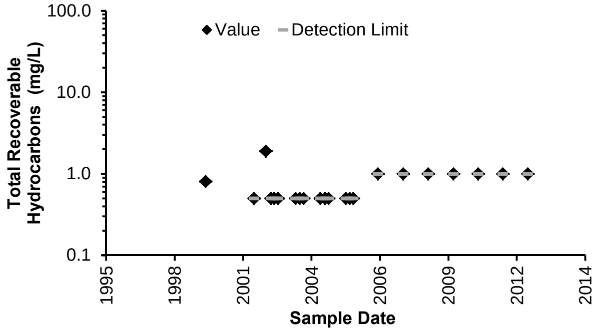
No guideline available for Total Recoverable Hydrocarbons in surface water.

Figure 7 (Cont'd.)

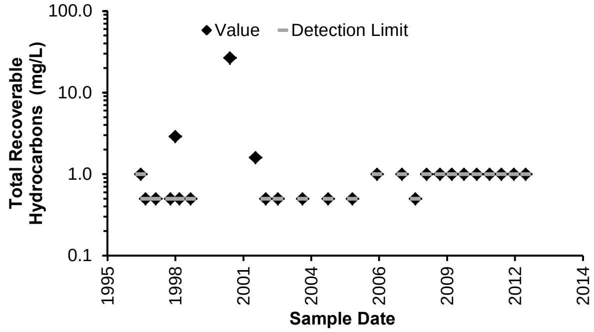
SHL-1 (Shipyard Lake)



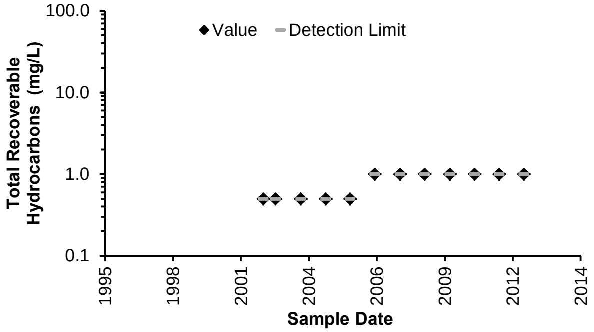
STC-1 (Stanley Creek)



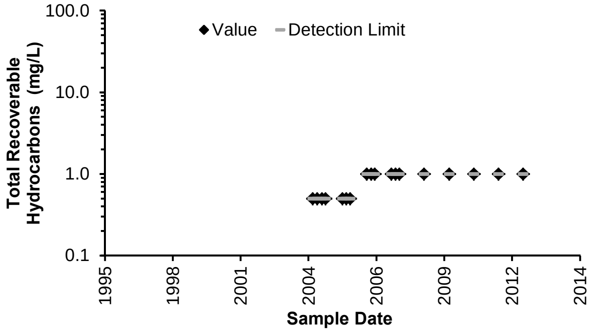
STR-1 (Steepbank River)



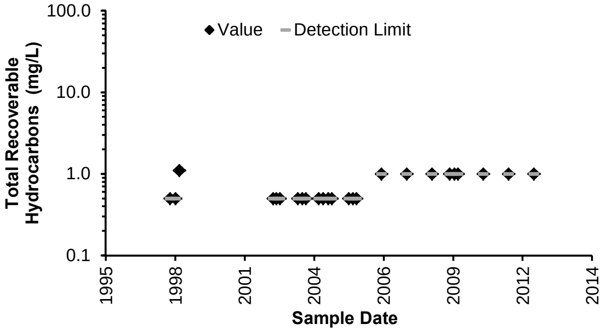
STR-2 (Steepbank River)



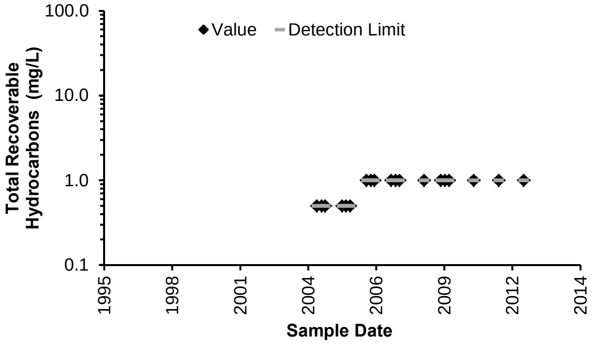
STR-3 (Steepbank River)



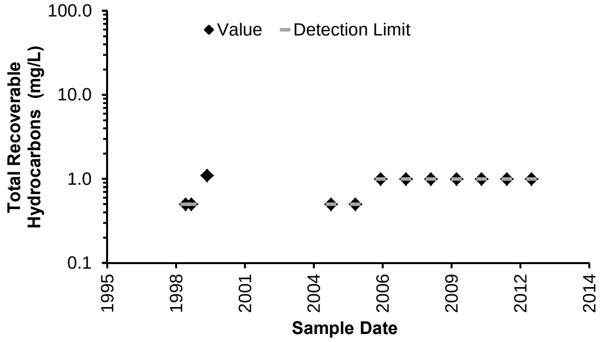
TAR-1 (Tar River)



TAR-2 (Tar River)



WAC-1 (Wapasu Creek)



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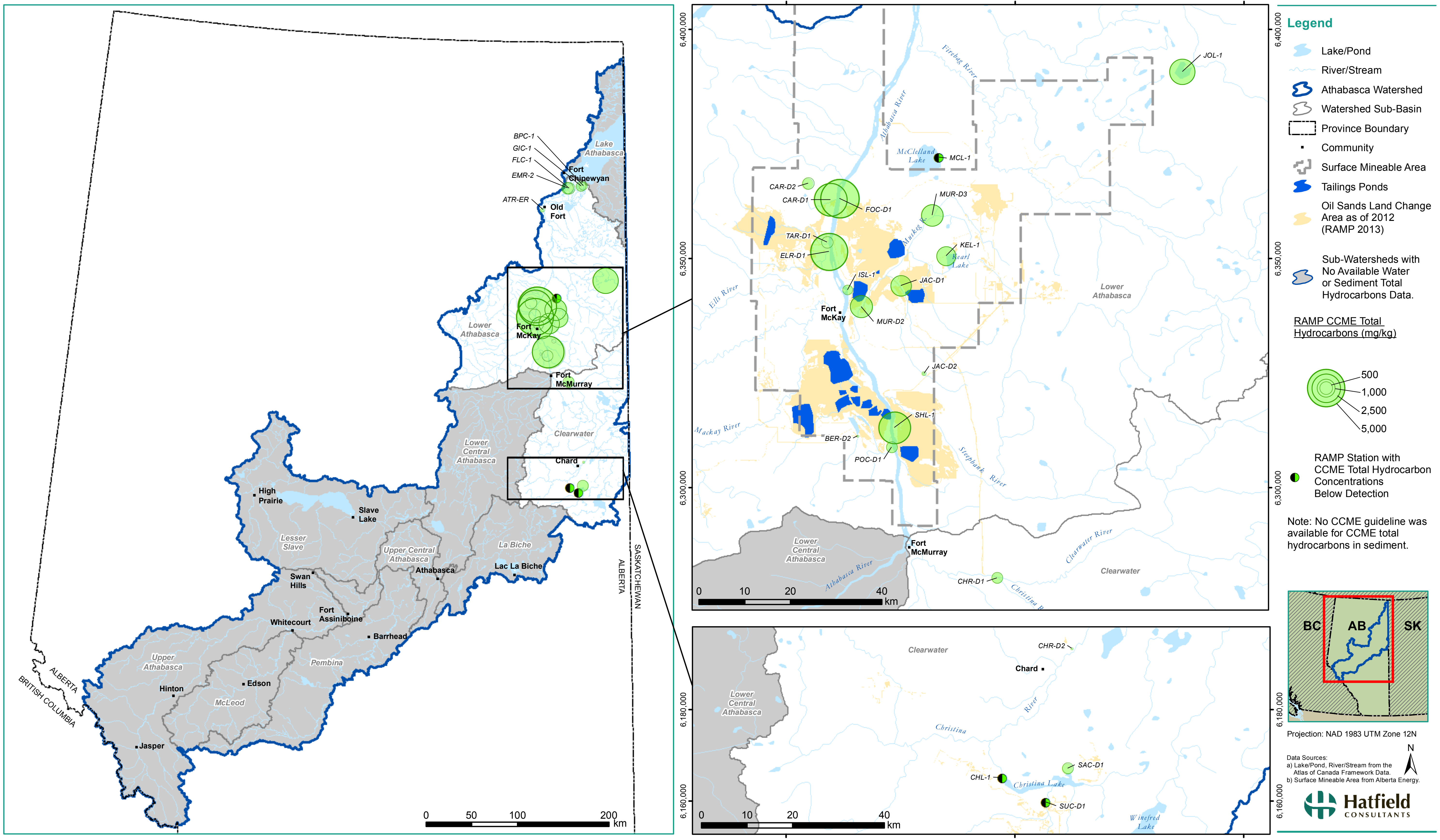
No guideline available for Total Recoverable Hydrocarbons in surface water.

Figure 8 CCME total hydrocarbons in sediment (mg/kg), fall 2012.



Note: No CCME guideline was available for CCME total hydrocarbons in sediment.

Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Lake/Pond, River/Stream from the Atlas of Canada Framework Data.
b) Surface Mineable Area from Alberta Energy.

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Table 7 Total hydrocarbons in sediments at RAMP stations with at least one year of current data available.

Analyte	Guideline		Common Detection	Station														
	CCME - ISQG	CCME - PEL	Limit (mg/kg)	ATR-ER	BER-D2	BPC-1	CAR-D1	CAR-D2	CHL-1	CHR-D1	CHR-D2	CLR-D1	CLR-D2	ELR-D1	EMR-1	EMR-2	FIR-D1	FLC-1
Benzene	-	-	0.2	n=6 ○	n=5 ○	n=6 ○	n=2 ○	n=2 ○	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ○	n=1 ○	n=2 ○	n=2 ○	n=6 ○
CCME Fraction 1 (BTEX)	-	-	240	n=6 ○	n=4 ○	n=6 ○	n=2 ○	n=2 ○	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ○	n=1 ○	n=2 ○	n=2 ○	n=6 ○
CCME Fraction 1 (C2-C10)	-	-	240	n=6 ○	n=4 ○	n=6 ○	n=2 ○	n=2 ○	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ○	n=1 ○	n=2 ○	n=2 ○	n=6 ○
CCME Fraction 2 (C10-C16)	-	-	410	n=6 ○	n=4 ○	n=6 ○	n=2 ○	n=2 ○	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ○	n=1 ○	n=2 ○	n=2 ○	n=6 ○
CCME Fraction 3 (C16-C34)	-	-	410	n=6 ◔	n=4 ○	n=6 ○	n=2 ●	n=2 ○	n=1 ○	n=3 ◑	n=2 ○	n=2 ○	n=2 ◑	n=4 ●	n=1 ○	n=2 ○	n=2 ◑	n=6 ○
CCME Fraction 4 (C34-C50)	-	-	410	n=6 ○	n=4 ○	n=6 ○	n=2 ●	n=2 ○	n=1 ○	n=3 ◑	n=2 ○	n=2 ○	n=2 ◑	n=4 ●	n=1 ○	n=2 ○	n=2 ◑	n=6 ○
CCME Total hydrocarbons (C6-C50)	-	-	410	n=6 ◑	n=4 ○	n=6 ◔	n=2 ●	n=2 ●	n=1 ○	n=3 ◕	n=2 ○	n=2 ○	n=2 ◑	n=4 ●	n=1 ○	n=2 ○	n=2 ◑	n=6 ◑
Ethylbenzene	-	-	0.36	n=6 ○	n=5 ○	n=6 ○	n=2 ○	n=2 ○	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ○	n=1 ○	n=2 ○	n=2 ○	n=6 ○
m+p-xylene	-	-	1.2	n=4 ○	n=4 ○	n=4 ○	n=2 ○	n=2 ○	n=1 ○	n=2 ○	n=2 ○	n=1 ○	n=1 ○	n=3 ○	n=1 ○	n=2 ○	n=1 ○	n=4 ○
o-xylene	-	-	1.2	n=4 ○	n=4 ○	n=4 ○	n=2 ○	n=2 ○	n=1 ○	n=2 ○	n=2 ○	n=1 ○	n=1 ○	n=3 ○	n=1 ○	n=2 ○	n=1 ○	n=4 ○
Toluene	-	-	1.2	n=6 ○	n=5 ○	n=6 ○	n=2 ○	n=2 ○	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ○	n=1 ○	n=2 ○	n=2 ○	n=6 ○
Xylene	-	-	2.4	n=6 ○	n=5 ○	n=6 ○	n=2 ○	n=2 ○	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ○	n=1 ○	n=2 ○	n=2 ○	n=6 ○

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes.

Legend

○ = All data below detection limit
◔ = 1-25% of data above detection
◑ = 26-50% of data above detection
◕ = 51-75% of data above detection
●

Red highlighting indicates guideline exceedence.

Table 7 (Cont'd.)

Analyte	Guideline		Common Detection Limit (mg/kg)	Station														
	CCME - ISQG	CCME - PEL		FOC-D1	GIC-1	ISL-1	JAC-D1	JAC-D2	JOL-1	KEL-1	MCL-1	MUR-D2	MUR-D3	POC-D1	SAC-D1	SHL-1	SUC-D1	TAR-D1
Benzene	-	-	0.2	n=4 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=2 ○	n=6 ○	n=5 ○	n=6 ○	n=6 ○	n=5 ○	n=1 ○	n=6 ○	n=1 ○	n=4 ○
CCME Fraction 1 (BTEX)	-	-	240	n=4 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=2 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=5 ○	n=1 ○	n=6 ○	n=1 ○	n=4 ○
CCME Fraction 1 (C2-C10)	-	-	240	n=4 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=2 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=5 ○	n=1 ○	n=6 ○	n=1 ○	n=4 ○
CCME Fraction 2 (C10-C16)	-	-	410	n=4 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=2 ○	n=6 ◔	n=6 ○	n=6 ○	n=6 ○	n=5 ○	n=1 ○	n=6 ○	n=1 ○	n=4 ○
CCME Fraction 3 (C16-C34)	-	-	410	n=4 ●	n=6 ○	n=6 ◑	n=6 ◕	n=6 ○	n=2 ◑	n=6 ●	n=6 ◕	n=6 ●	n=6 ●	n=5 ◑	n=1 ○	n=6 ●	n=1 ○	n=4 ◔
CCME Fraction 4 (C34-C50)	-	-	410	n=4 ●	n=6 ○	n=6 ◑	n=6 ◕	n=6 ○	n=2 ◑	n=6 ◑	n=6 ◑	n=6 ●	n=6 ◑	n=5 ◑	n=1 ○	n=6 ◕	n=1 ○	n=4 ◔
CCME Total hydrocarbons (C6-C50)	-	-	410	n=4 ●	n=6 ○	n=6 ●	n=6 ●	n=6 ○	n=2 ●	n=6 ●	n=6 ◕	n=6 ●	n=6 ●	n=5 ◑	n=1 ○	n=6 ●	n=1 ○	n=4 ◕
Ethylbenzene	-	-	0.36	n=4 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=2 ○	n=6 ○	n=5 ○	n=6 ○	n=6 ○	n=5 ○	n=1 ○	n=6 ◔	n=1 ○	n=4 ○
m+p-xylene	-	-	1.2	n=3 ○	n=4 ○	n=4 ○	n=4 ○	n=4 ○	n=2 ○	n=4 ○	n=4 ○	n=4 ○	n=4 ○	n=4 ○	n=1 ○	n=4 ○	n=1 ○	n=4 ○
o-xylene	-	-	1.2	n=3 ○	n=4 ○	n=4 ○	n=4 ○	n=4 ○	n=2 ○	n=4 ○	n=4 ○	n=4 ○	n=4 ○	n=4 ○	n=1 ○	n=4 ○	n=1 ○	n=4 ○
Toluene	-	-	1.2	n=4 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=2 ○	n=6 ○	n=5 ○	n=6 ○	n=6 ○	n=5 ○	n=1 ○	n=6 ○	n=1 ○	n=4 ○
Xylene	-	-	2.4	n=4 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=2 ○	n=6 ○	n=5 ○	n=6 ○	n=6 ○	n=5 ○	n=1 ○	n=6 ○	n=1 ○	n=4 ○

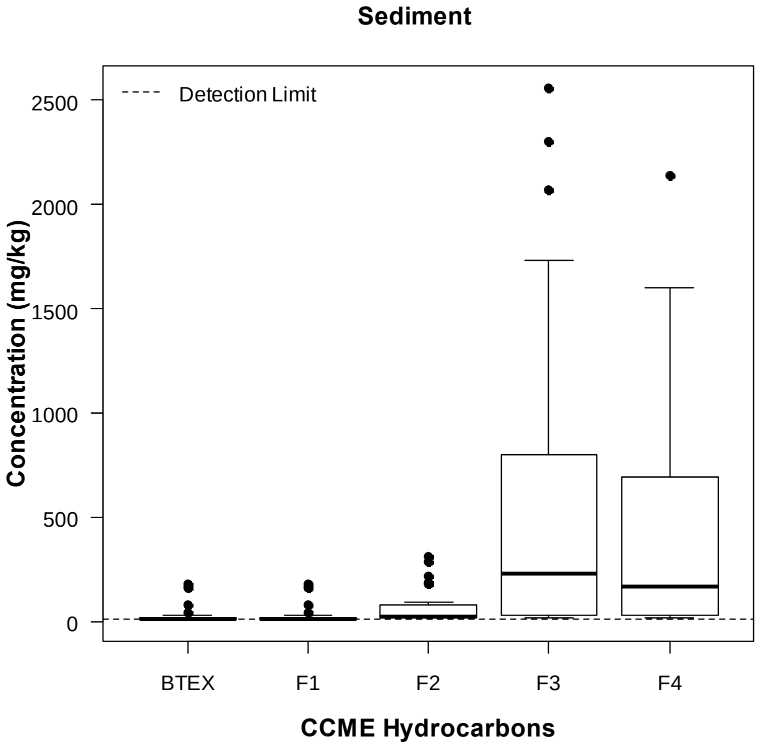
Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes.

Legend

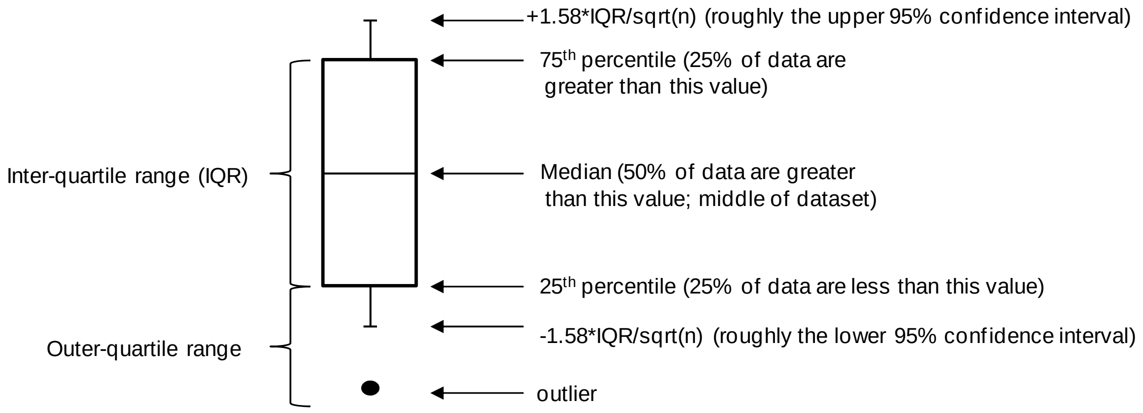
○ = All data below detection limit
◔ = 1-25% of data above detection
◑ = 26-50% of data above detection
◕ = 51-75% of data above detection
●

Red highlighting indicates guideline exceedence.

Figure 9 CCME total hydrocarbons (F1-F4 and BTEX) in sediments at all RAMP stations, fall 2012.



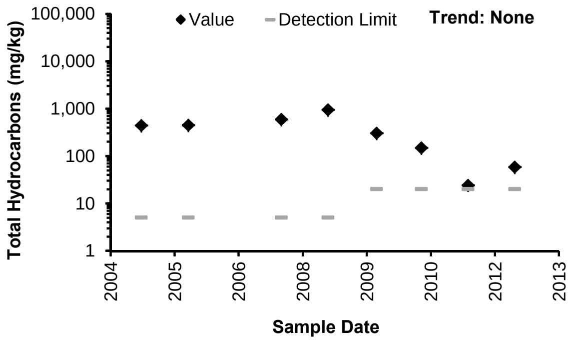
Legend



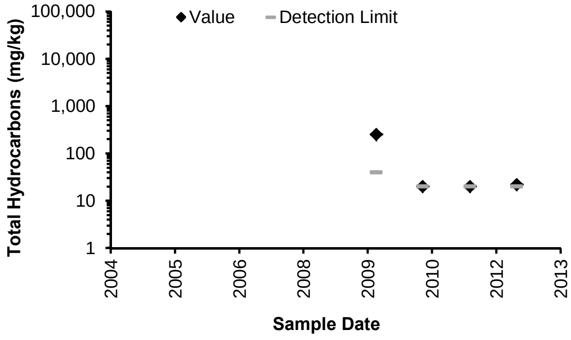
Note: The whiskers of the boxplots extend to +/-1.58*IQR/sqrt(n) based on Chambers et al. (1983), and represent roughly a 95% confidence interval for the difference in the two medians (R Development Core Team 2013).

Figure 10 Total Hydrocarbons (CCME C6-C50) (Log Scale) in sediments at RAMP stations with historical data.

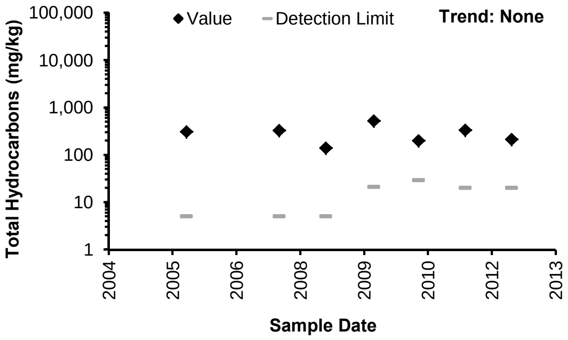
ATR-ER (Athabasca River)



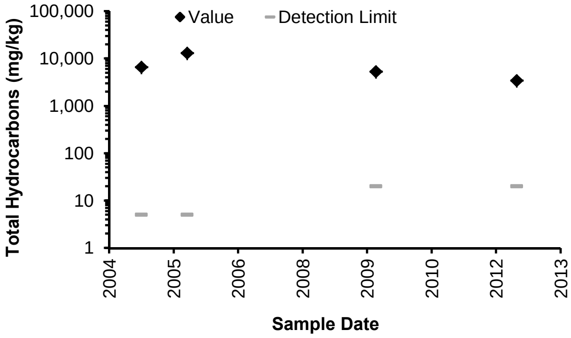
BER-D2 (Beaver River)



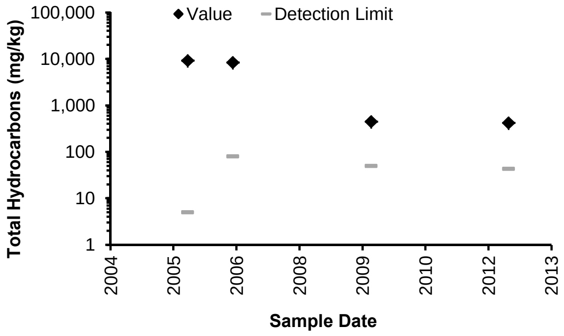
BPC-1 (Big Point Channel)



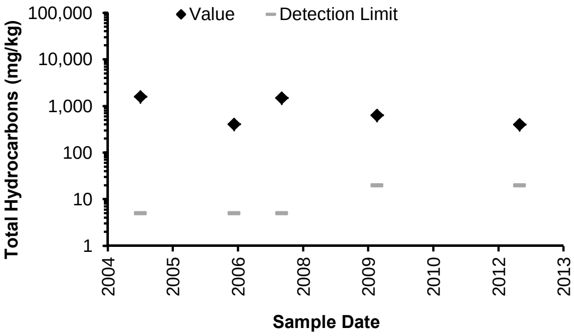
CAR-D1 (Calumet River)



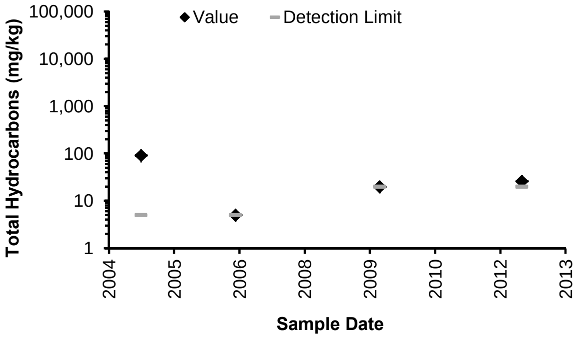
CAR-D2 (Calumet River)



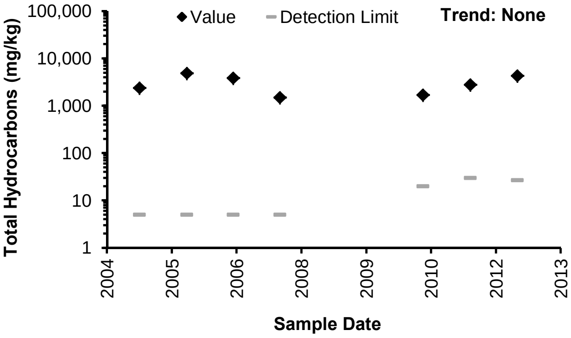
CHR-D1 (Christina River)



CHR-D2 (Christina River)



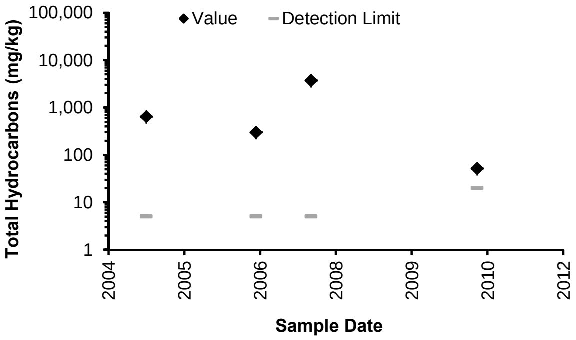
ELR-D1 (Ells River)

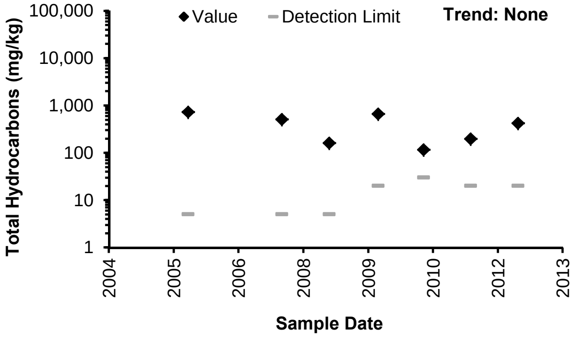


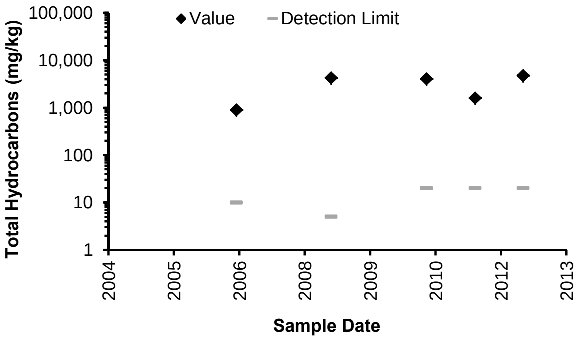
Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

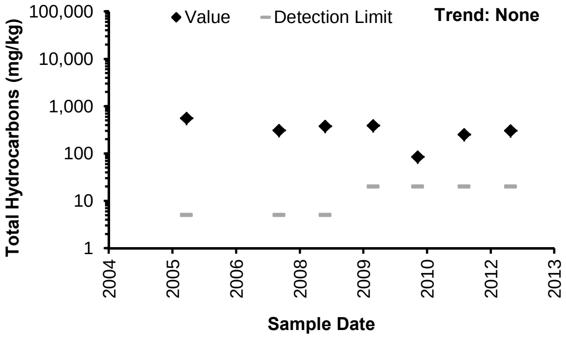
Note: For samples analysed after 2008, detection limits vary with the moisture content in the sediment. No guideline available for total hydrocarbons (CCME C6-C50) in sediment.

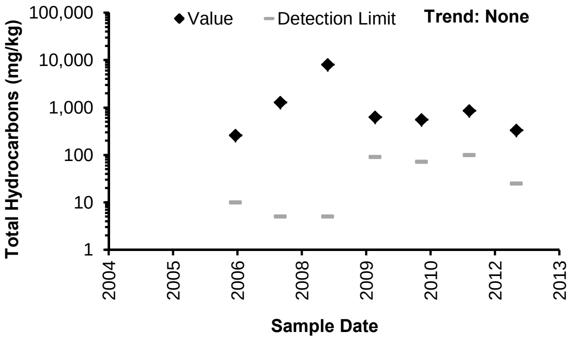
Figure 10 (Cont'd.)

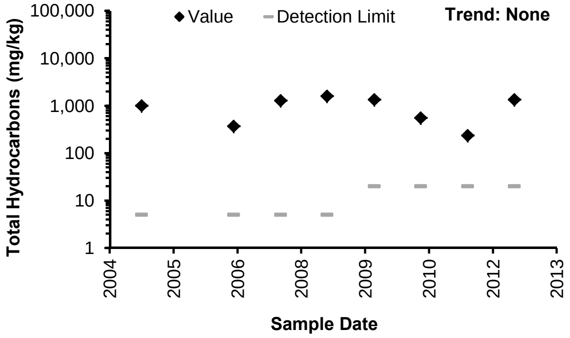

FIR-D1 (Firebag River)


FLC-1 (Fletcher Channel)

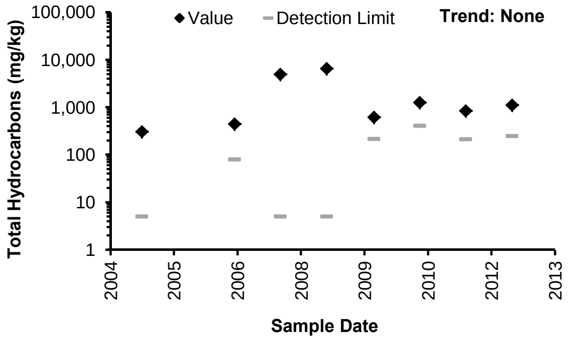

FOC-D1 (Fort Creek)


GIC-1 (Goose Island Channel)


ISL-1 (Isadore's Lake)


JAC-D1 (Jackpine Creek)


JAC-D2 (Jackpine Creek)

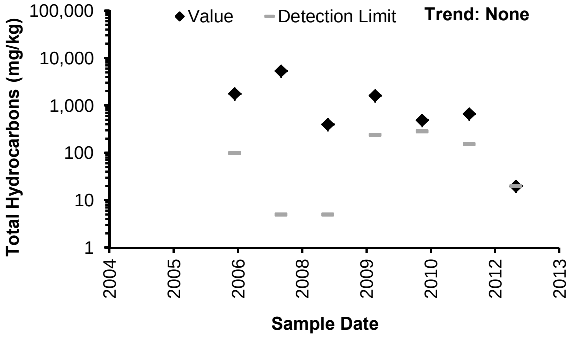

KEL-1 (Kearl Lake)

Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

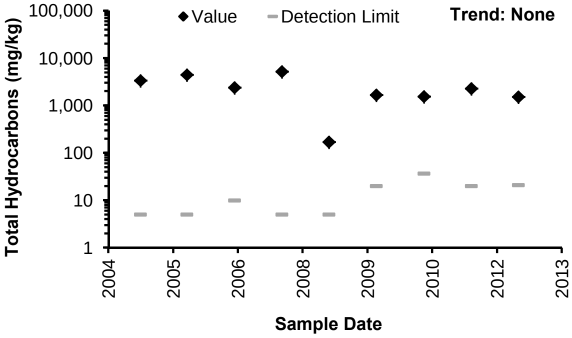
Note: For samples analysed after 2008, detection limits vary with the moisture content in the sediment. No guideline available for total hydrocarbons (CCME C6-C50) in sediment.

Figure 10 (Cont'd.)

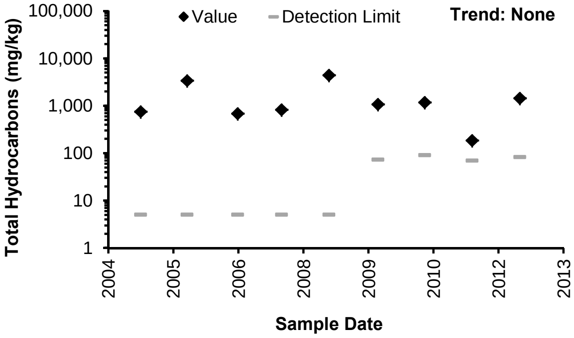
MCL-1 (McClelland Lake)



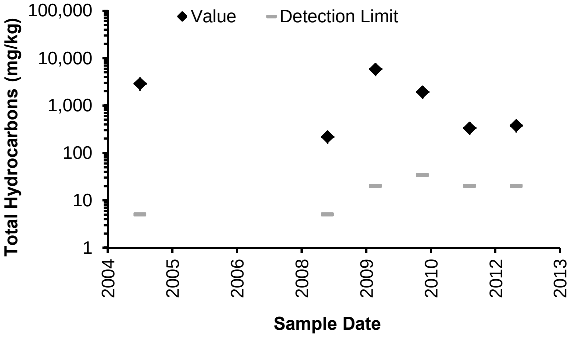
MUR-D2 (Muskeg River)



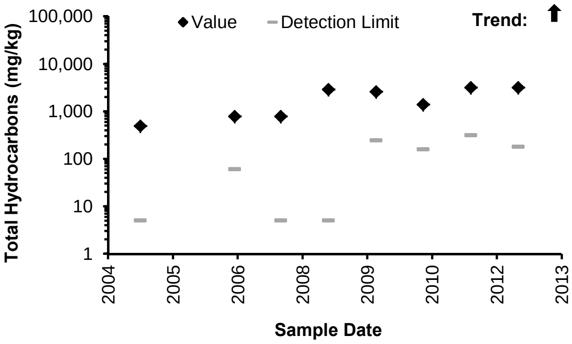
MUR-D3 (Muskeg River)



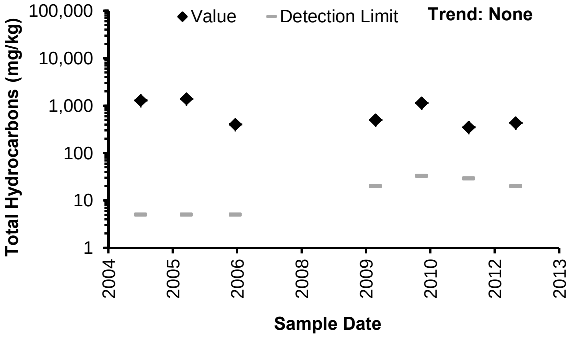
POC-D1 (Poplar Creek)



SHL-1 (Shipyard Lake)



TAR-D1 (Tar River)



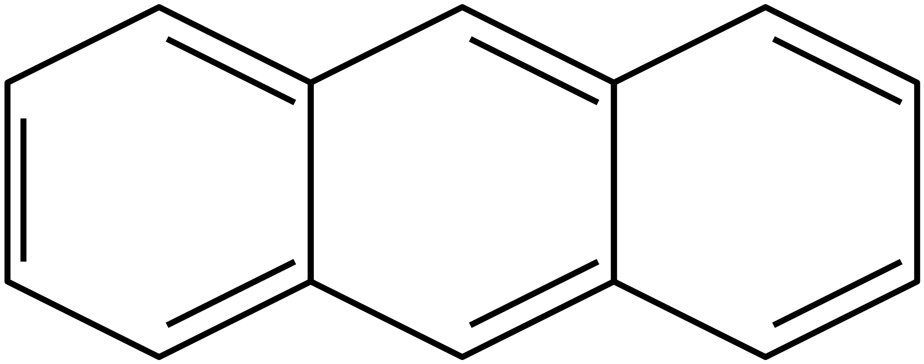
Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

Note: For samples analysed after 2008, detection limits vary with the moisture content in the sediment. No guideline available for total hydrocarbons (CCME C6-C50) in sediment.

3.2 POLYCYCLIC AROMATIC HYDROCARBONS

Polycyclic aromatic hydrocarbons (PAHs) are a group of organic compounds comprised of two or more fused, aromatic carbon rings (Figure 11). PAHs in the environment can originate from combustion of organic matter such as wood, grass, coal, and diesel (pyrogenic), erosion of bituminous geologic formations (petrogenic), or microbial degradation (diagenic) (Neff et al. 2005). In general, PAHs are hydrophobic (i.e., water-repelling) compounds and are typically present in lower concentrations in water than in other environmental compartments such as sediments.

Figure 11 Structural formula of the PAH anthracene.



PAHs are found everywhere in freshwater ecosystems and can take various pathways to reach these ecosystems. PAHs can be released through water and sediments via industrial and wastewater discharges, run-off of industrial or natural dust particles, and/or seepage or erosion of PAH-containing materials. Airborne releases of PAHs can be attributed to volcanic eruptions, forest fires, vehicle exhaust, and/or stack emissions.

Several recent studies in the Lower Athabasca region have raised concerns over the increased occurrence of PAHs in water and sediment from oil sands mining operations and their potential impacts on aquatic life (Colavecchia et al. 2004, Kelly et al. 2009; Kelly et al. 2010, Timoney & Lee 2011, Kurek et al. 2013). Anthropogenic sources of PAHs in the Lower Athabasca include evaporation of process water from tailings ponds, upgrading of bitumen to synthetic crude oil (emissions from upgrading bitumen to synthetic crude oil), and emissions from fleet vehicles (Birks et al. 2013). Natural sources of PAHs in the Lower Athabasca include erosion of bituminous geological formations in the Athabasca River and its tributaries (Headley et al. 2001), as well as forest fires in the region (Gabos et al. 2001).

PAHs are often summarized into Total PAHs, which include a sum of concentrations of non-alkylated (i.e., parent) and alkylated PAHs measured in a given sample. Typically, alkylated species comprise the majority of PAHs associated with bitumen.

3.2.1 Data Availability

3.2.1.1 Water Quality

PAH data for surface waters were obtained from three sources: AESRD, Environment Canada via the JOSM Information Portal, and RAMP (Figure 12). AESRD provided data for 25 stations within the Athabasca watershed, Environment Canada provided PAH data for two oil sands long-term water quality monitoring stations, 37 JOSM stations, and one other station within the Lower Athabasca sub-watershed. RAMP provided PAH data for 57 stations within the Lower Athabasca and Clearwater sub-watersheds. No data were available for PAHs in surface water for the Pembina, La Biche, or Lake Athabasca sub-watersheds.

3.2.1.2 Sediment Quality

Sediment PAH data were obtained from 30 RAMP stations and four AESRD stations (Figure 12). Of the ten sub-watersheds in the Athabasca River watershed, sediment PAH data were only available for only two: the Lower Athabasca and Clearwater.

Recent studies have also examined PAHs in sediments within and around the Lower Athabasca oil sands region:

- Evans et al. (2002) looked at PAHs in sediment cores collected from Lake Athabasca and the Athabasca delta in 1998. They found that concentrations of PAHs in sediments deposited in the late 1990s were similar to those in sediments deposited in the 1920s;
- Hall et al. (2012) collected sediment cores from three perched lakes in the Peace-Athabasca Delta. They compared concentrations of Polycyclic Aromatic Compounds (PACs, a term that primarily includes PAHs and generally is used synonymously in the oil-sands region) from a lake with high flood frequency since 1982 to its pre-1940 frequently flooded interval and found no measurable increase in the concentration and proportion of riverine-transported bitumen-associated PACs in the lake’s sediments since the onset of major oil sands development. They postulated that natural erosion of bitumen in the banks of the Athabasca River and tributaries is a key process in transport of PACs to the Athabasca River delta;
- Jautzy et al. (2013) collected sediment cores from two headwater lakes located 40 and 55 km east of the main area of oil sands mining operations, outside of the bitumen-containing McMurray Formation. They examined source apportionment of PAHs in lakes of the oil sands region with PAH diagnostic ratios showing an increasingly large input of petrogenic PAHs over the past 30 years, even though PAH levels in both lakes were low and below the CCME interim sediment quality guidelines for PAHs. They postulated that trends observed in sediment cores likely resulted from expansion of the surface mining area in the oil sands region, resulting in deposition of bitumen in dust particles associated with wind erosion from open pit mines.; and

- Kurek et al. (2013) collected sediment cores from five lakes within a 35 km radius of major oil sands activities, and one remote lake ~90 km northwest of upgrading facilities. They found significant increases in PAH concentrations and fluxes in lake sediments since the ~1960s and 1970s. Since the 1980s, certain PAH concentrations have exceeded CCME interim sediment quality guidelines at the most impacted lake, located near the Muskeg River (NE20). However, maximum concentrations and fluxes of unsubstituted PAHs from the six study lakes were within the range typical of remote lakes and substantially lower than lakes in urbanized catchments. They postulated that oil sands development has increased the delivery of PAHs to both near-field and remote lake ecosystems to above "natural" predevelopment levels. The authors attributed upgrading activities and/or bitumen in the form of dust particles from open pit mines as major sources of atmospheric deposition of PAHs in regional aquatic ecosystems.

3.2.2 PAHs in Water

3.2.2.1 2012 Spatial Comparisons

To facilitate comparison of the fall 2012 AESRD and RAMP datasets, a common set of 31 parent and alkylated PAH species were used to calculate total PAHs for each station (Figure 13). From Figure 13, it is apparent that almost all of the AESRD data for these 31 PAH species were below detection, and most of the RAMP data were well below the AESRD detection limits. Given AESRD detection limits were much higher than RAMP detection limits, common detection limits were not used in the 2012 spatial comparisons. For calculation of total PAHS, all 31 PAH species values were summed together and those PAH species with values below detection were set to zero. If total PAHs were below detection, half of the station marker was shaded black in the bubble map (Figure 14).

Total PAHs at RAMP stations ranged from 0.002 µg/L in the upper Tar River (TAR-2) to 4.367 µg/L in the lower Steepbank River (STR-1) (Figure 14). Total PAH concentrations were generally lowest in lakes and the upper reaches of major tributaries of the Athabasca River as well as upstream of Chard in the Clearwater sub-watershed. Total PAHs were highest upstream of Fort McKay around the Muskeg, Steepbank, and MacKay rivers (STR-1, ATR-SR-W, ATR-MR-E, MAR-1, MAR-2A) and downstream of Fort McKay at Fort Creek (FOC-1), but concentrations decreased further downstream of Fort Creek.

Total PAHs at the five AESRD stations with available 2012 data were all below detection except for one station located above the Firebag River which had one detectable PAH species for a Total PAH value of 0.03 µg/L.

Given that all of the common 31 PAHs used to calculate total PAHs were not measured at nine AESRD stations (AB07AF0010, AB07AF0041, AB07AF0045, AB07AF0065, AB07AF0088, AB07AF0100, AB07AF0210, AB07AF0262, AB07AF0340) located in the McLeod sub-watershed, these stations were not included in the 2012 spatial comparisons.

3.2.2.2 Compilation of Current PAHs in Water and Comparison with Guidelines

Given that most results were compared to common detection limits which were generally higher than RAMP detection limits, the majority of PAH species were below these adjusted detection limits (i.e., 0.001 to 0.5 µg/L) for all RAMP samples (Table 8). Concentrations of benzo(a)pyrene exceeded guidelines (0.015 µg/L) in one sample at ATR-SR-W (Athabasca River Upstream of Steepbank River) in 2012. Concentrations of naphthalene exceeded guidelines (1.0 µg/L) in one sample at MAR-2A in 2012 (MacKay River Upstream of Suncor Dover) and two samples at ATR-DC-W (Athabasca River Upstream of Donald Creek) in 2012, both areas upstream of most oil sands developments which may indicate higher levels of naturally occurring naphthalene in these watercourses (Table 8).

The majority of PAH species were below detection (i.e., <0.01 to <0.5 µg/L and <0.0051 to <0.5 µg/L) for all AESRD stations and EC stations, respectively (Table 9 and Table 10). No guidelines were exceeded for any PAH species at any AESRD or EC station.

3.2.2.3 Historical Trend Analysis

To qualitatively assess temporal trends in the data, a common set of 13 parent PAHs were used to calculate Total Parent PAHs from all available years of sampling for any stations with long-term datasets (Figure 15). Given that RAMP stations only have two years of PAH data within the current period, and most EC stations have only one or two years of data, qualitative trend analysis consisted solely of data from AESRD stations. For AESRD stations with long-term datasets, detection limits of most PAH species have decreased 100-fold from 1 µg/L in the 1980s and 1990s to 0.01 µg/L in the 2000s (Figure 15). These advancements in detection capabilities have increased the detections of PAHs in the environment which likely reflects a trend toward more targeted monitoring of these species rather than a trend in occurrence of these compounds in surface waters.

Regardless of the detection limit, Total Parent PAHs were below detection for almost all years at all stations (Figure 15). Seven AESRD stations (i.e., AB07BE0010, AB07CC0030, AB07DA0595, AB07DA0610, AB07DA0980, AB07DD0010, AB07DD0105) had at least one sample that was detectable, with naphthalene as the most common parent PAH species detected at these stations.

Statistical trend analysis was not conducted for RAMP or EC (JOSM) or long-term water quality monitoring stations, given only two years of PAH data were available. Trend analysis was not conducted on the one remaining EC station or any AESRD stations, given that the majority of PAH species were below detection limit; therefore a trend could not be determined at this time.

3.2.3 PAHs in Sediment

3.2.3.1 2012 Spatial Comparisons

Because only RAMP sediment data were available for fall 2012, spatial comparisons were conducted among RAMP stations only (Figure 16). Forty-two parent and alkylated PAH species were used to calculate Total PAHs for each

RAMP station. Total PAHs were normalized to 1% total organic carbon (TOC) to remove the variable influence of TOC levels on PAH values, given PAHs in sediments are associated with organic carbon. TOC concentrations in these sediments ranged from <0.1 to 27.3%.

Total PAHs normalized to 1% TOC ranged from 0.027 mg/kg in Kearl Lake to 10.495 mg/kg in the lower Ells River (Figure 16). Total PAHs were lowest in the lakes and the upper reaches of the major tributaries of the Athabasca River. Total PAHs were highest around the lower Ells and Calumet Rivers, but concentrations decreased further downstream in the Athabasca River delta. Previous research also has indicated that sediments from the Ells River contain regionally high levels of naturally-derived PAHs, likely released naturally from oil sands to riverine sediments (Headley et al. 2001).

3.2.3.2 Compilation of Current PAHs in Sediment and Comparison with Guidelines

The majority of detected PAH species were alkylated PAHs at RAMP stations (Table 11). Of the PAHs listed in Table 11, alkylated species C2-biphenyls to C4-Phenanthrenes/Anthracenes were detected (i.e., ≥ 0.0008 to ≥ 0.0751 mg/kg) in most RAMP samples. These alkylated PAH species were only analyzed at RAMP sediment stations and were therefore compared with RAMP detection limits rather than a common detection limit. Almost all other PAH species were found to be below detection (i.e., <0.001 to <5 mg/kg) at RAMP and AESRD stations (Table 12). Samples of six PAH species exceeded guidelines at RAMP sediment stations between 2007 and 2012. Benz(a)anthracene exceeded guidelines (0.0319 mg/kg) at three RAMP stations (ELR-D1, one sample from 2011; SHL-1, four samples from 2007, 2008, 2011, 2012; and TAR-D1, one sample from 2012). Benzo(a)pyrene exceeded guidelines (0.0317 mg/kg) at two RAMP stations (SHL-1, four samples from 2007, 2008, 2011, 2012; and TAR-D1, one sample from 2012). Chrysene exceeded guidelines (0.0571 mg/kg) at eight RAMP stations: CAR-D1, two samples from 2009, 2012; ELR-D1, four samples from 2007, 2010, 2011, 2012; FIR-D1, one sample from 2007; FOC-D1, four samples from 2008, 2010, 2011, 2012; MUR-D2, three samples from 2007, 2009, 2010; POC-D1, one sample from 2009; SHL-1, five samples from 2007, 2008, 2009, 2011, 2012; and TAR-D1, two samples from 2010, 2012. Dibenz[a,h]anthracene exceeded guidelines (0.00622 mg/kg) at eight RAMP stations: CAR-D1, two samples from 2009, 2012; ELR-D1, one sample from 2012; FIR-D1, one sample from 2007; FOC-D1, four samples from 2008, 2010, 2011, 2012; MUR-D2, one sample from 2011; POC-D1, one sample from 2009; SHL-1, five samples from 2007, 2008, 2010, 2011, 2012; and TAR-D1, three samples from 2010, 2011, 2012. Phenanthrene exceeded guidelines (0.0419 mg/kg) at four RAMP stations (ELR-D1, one sample from 2012; POC-D1, one sample from 2009; SHL-1, five samples from 2007, 2008, 2009, 2011, 2012; and TAR-D1, one sample in 2012). Pyrene exceeded guidelines (0.053 mg/kg) at three RAMP stations (CAR-D1, one sample from 2012; ELR-D1, one sample from 2012; and SHL-1, three samples from 2007, 2008, 2012).

3.2.3.3 Historical Trend Analysis

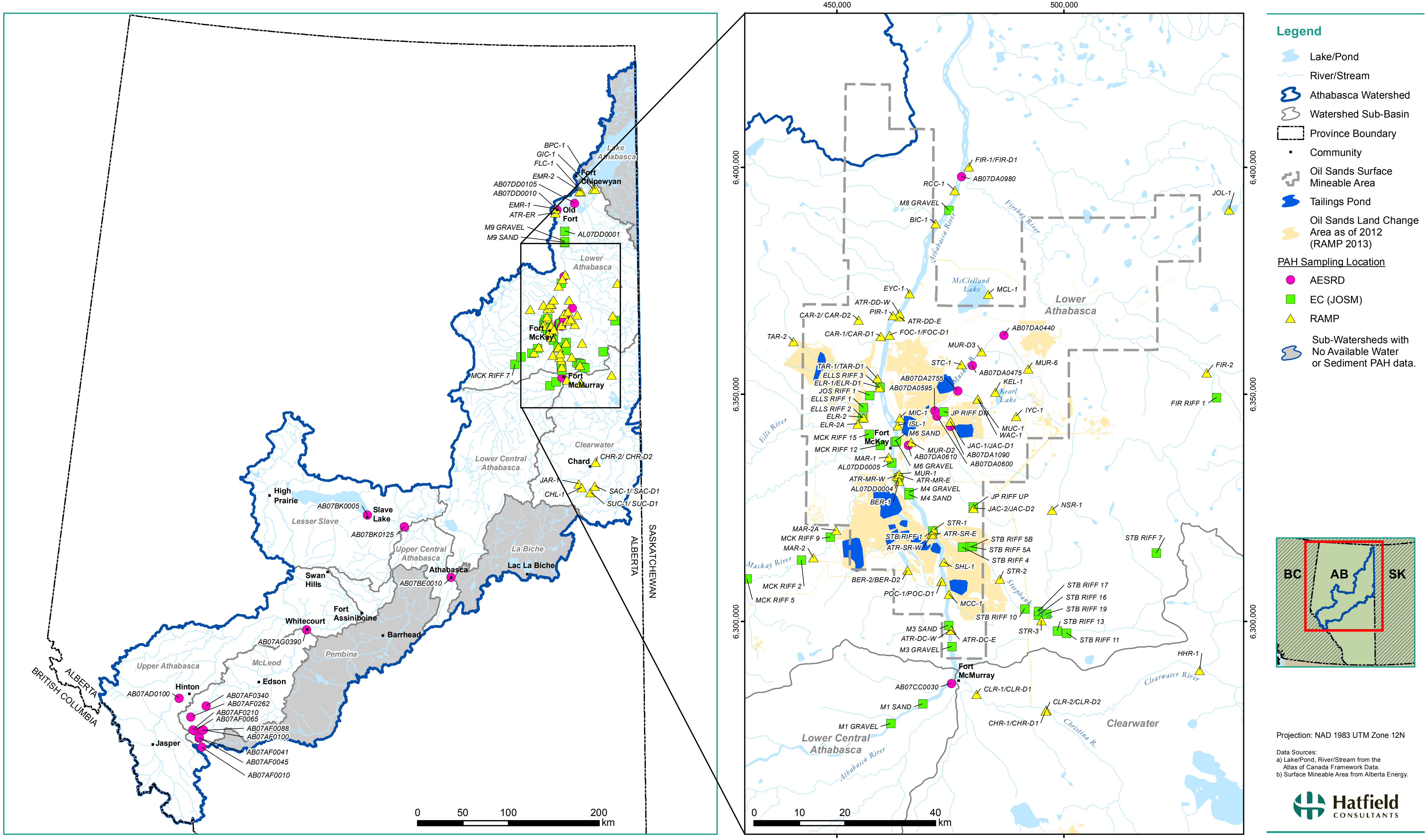
To qualitatively assess temporal trends in the data, Total PAHs normalized to 1% TOC were calculated for all available years of sampling for any stations with long-term datasets (Figure 17). AESRD stations had only one year of PAH sediment data available for assessment; therefore qualitative and quantitative trend analysis consisted solely of RAMP stations.

Statistical trend analysis was conducted on total PAHs in sediments normalized to 1% TOC at 16 RAMP sampling stations where there were at least seven years of sediment quality data. Concentrations of total PAHs normalized to 1% TOC at the lower Christina River (CHR-D1) decreased significantly over time; all other stations showed no significant trends over time (Figure 17). Changes in physical habitats (i.e., increases in particle size of sediments and decreases in TOC over time) sampled at this location may have influenced the result.

3.2.4 Overall Assessment: PAHs

- Most surface water and sediment PAH data were obtained from stations located in the Lower Athabasca and Clearwater sub-watersheds, indicating a general gap in sampling of PAHs throughout the rest of the Athabasca watershed.
- Sediment data were particularly sparse for PAHs in the Athabasca watershed and most alkylated species were not analyzed for the few AESRD stations where PAH data were available.
- When compared with common detection limits, the majority of PAH species in surface water were below detection for all RAMP, AESRD, and EC samples.
- Naphthalene—most commonly known publicly as the primary ingredient in moth balls—was the most common PAH detected in historical AESRD water quality samples and exceeded guidelines at two RAMP water quality stations in the lower Athabasca sub-watershed. Naphthalene is a volatile, low-molecular-weight PAH, which makes it more readily present in the water column in areas of erosion and exposure to petroleum hydrocarbons.
- The majority of measurable PAH species in sediments at RAMP stations were heavy, alkylated forms, indicating primarily a petrogenic (petroleum-related) origin of these PAHs, with the exception of C4 phenanthrenes (retene) which are of diagenic (biological) origin.
- Most parent PAHs were found to be below detection limits at both RAMP and AESRD sediment stations. Samples of six PAH species (benz(a)anthracene, benzo(a)pyrene, chrysene, dibenz[a,h]anthracene, phenanthrene, pyrene) exceeded guidelines at RAMP sediment stations between 2007 and 2012.
- No significant trends were observed in Total PAHs normalized to 1% TOC at RAMP sediment stations except for station CHR-D1 on the lower Christina River which showed a decreasing trend in Total PAHs over time.

Figure 12 Sampling locations for PAHs in water and sediment.



Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Lake/Pond, River/Stream from the Atlas of Canada Framework Data.
b) Surface Mineable Area from Alberta Energy.

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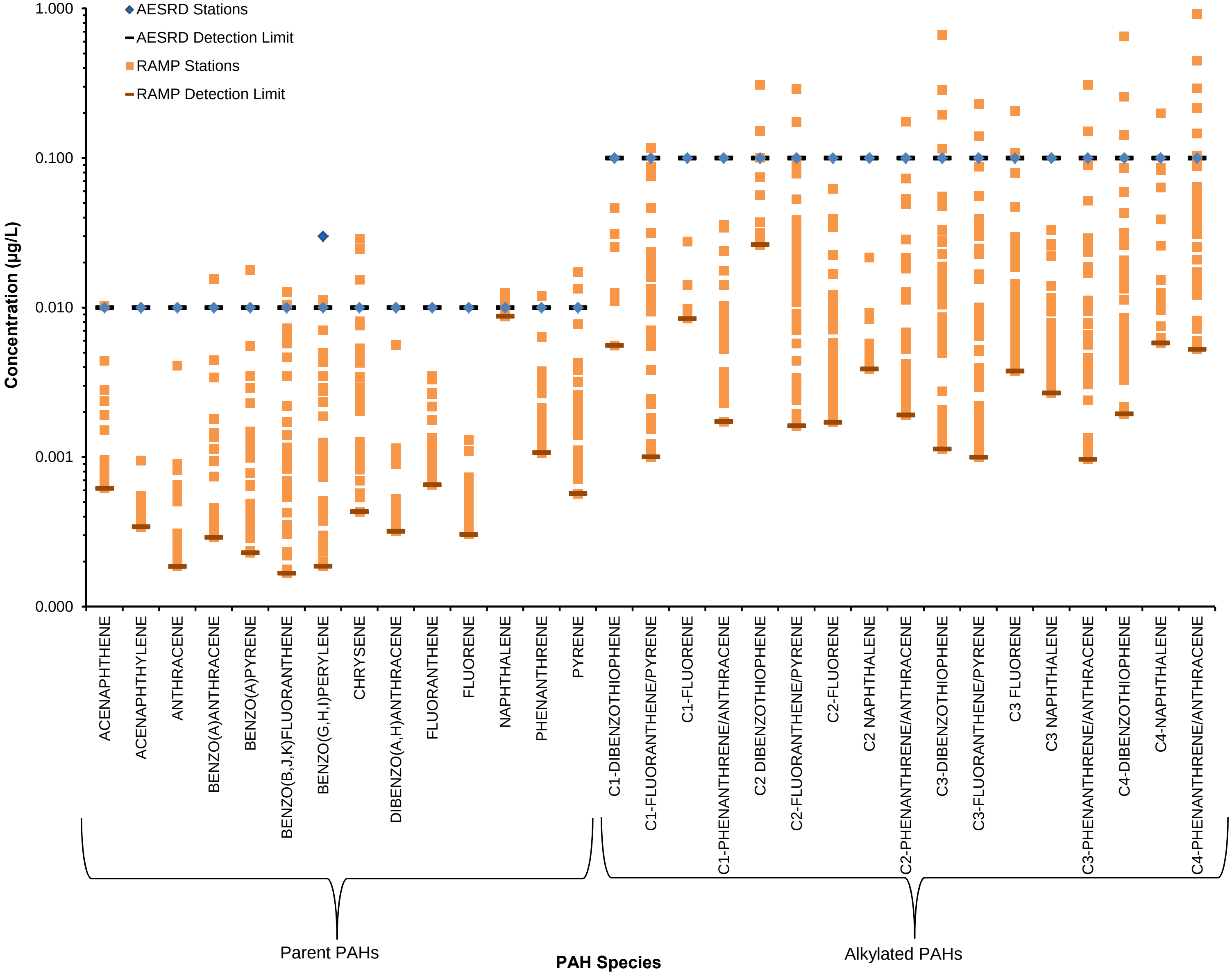
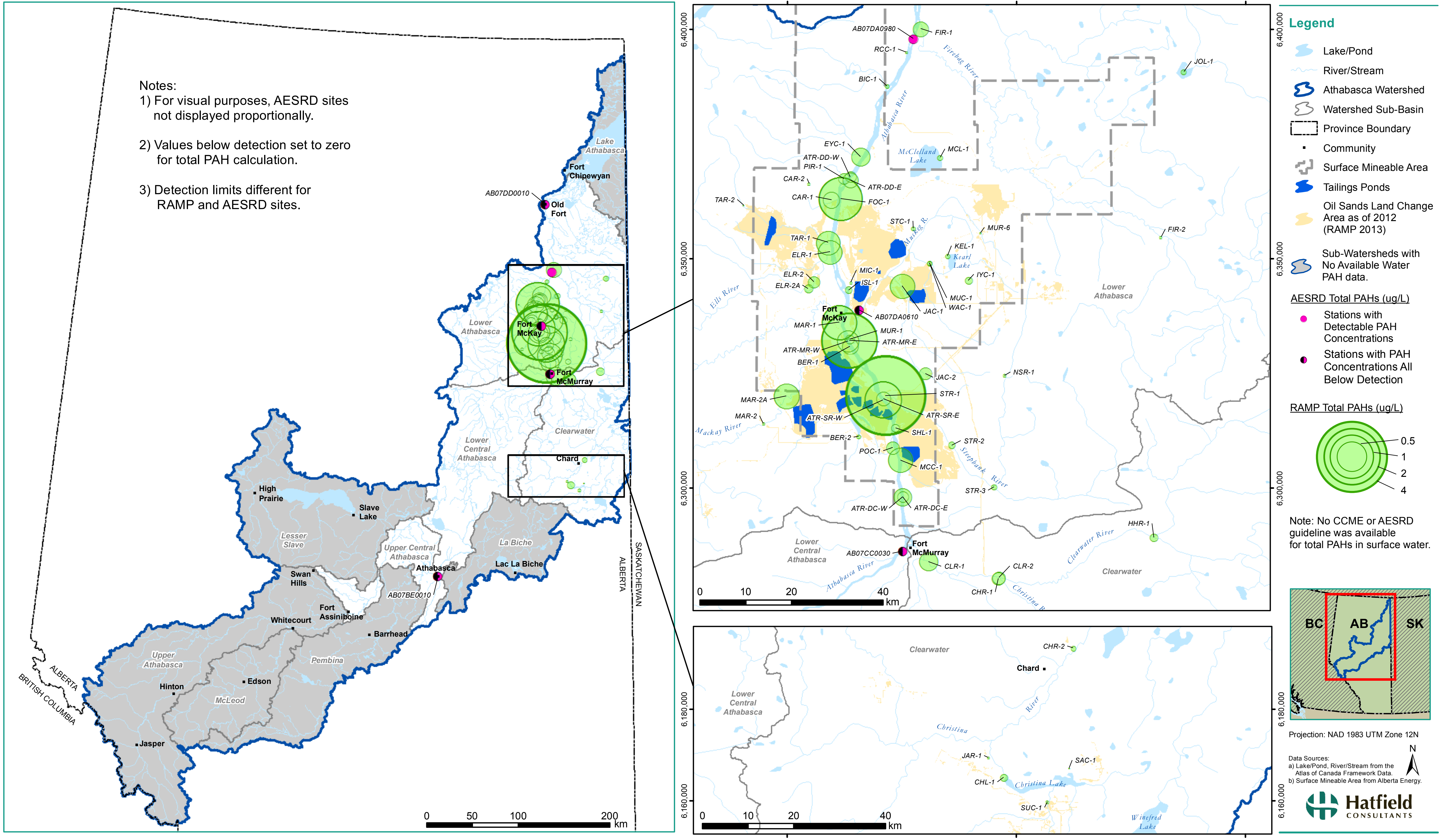
Figure 13 Concentrations (Log scale) of common PAH species in water at AESRD and RAMP stations, fall 2012.



Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

Figure 14 Total PAHs in surface water (ug/L), fall 2012.



Notes:
1) For visual purposes, AESRD sites not displayed proportionally.
2) Values below detection set to zero for total PAH calculation.
3) Detection limits different for RAMP and AESRD sites.

Note: No CCME or AESRD guideline was available for total PAHs in surface water.

Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Lake/Pond, River/Stream from the Atlas of Canada Framework Data.
b) Surface Mineable Area from Alberta Energy.

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Table 8 PAHs in surface water at RAMP Stations with at least one year of current data available.

Analyte	Guideline (µg/L)			Common Detection	Station																		
	AESRD (2013)	CCME	BC	Limit (µg/L)	ATR-DC-E	ATR-DC-W	ATR-DD-E	ATR-DD-W	ATR-MR-E	ATR-MR-W	ATR-SR-E	ATR-SR-W	BER-1	BER-2	BIC-1	CAR-1	CAR-2	CHL-1	CHR-1	CHR-2	CLR-1	CLR-2	ELR-1
Acenaphthene	5.8	5.8	6.0	0.1	n=7 ○	n=7 ○	n=7 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
Acenaphthylene	-	-	-	0.1	n=7 ○	n=7 ○	n=7 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
Anthracene	0.012	0.012	4.0	0.1*	n=7 ○	n=7 ○	n=7 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
Benz[a]anthracene	0.018	0.018	0.10	0.1*	n=7 ○	n=7 ○	n=7 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
Benzo[a]pyrene	0.015	0.015	0.01	0.1*	n=7 ○	n=7 ○	n=7 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ◑	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
Benzo[b,j,k]fluoranthene	-	-	-	0.01	n=7 ◔	n=7 ◔	n=7 ◔	n=7 ◔	n=2 ○	n=2 ○	n=2 ○	n=2 ◑	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
Benzo[g,h,i]perylene	-	-	-	0.2	n=7 ○	n=7 ○	n=7 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
Biphenyl	-	-	-	0.002	n=7 ◑	n=7 ◑	n=7 ◑	n=7 ◑	n=2 ○	n=2 ○	n=2 ○	n=2 ◑	n=2 ○	n=2 ◑	n=6 ◕	n=2 ◑	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
C1-Acenaphthenes	-	-	-	0.001	n=7 ○	n=7 ○	n=7 ○	n=7 ○	n=2 ◑	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
C1-Benzo[a]anthracenes/Chrysenes	-	-	-	0.006	n=7 ◕	n=7 ◕	n=7 ◕	n=7 ◕	n=2 ●	n=2 ◑	n=2 ◑	n=2 ●	n=2 ◑	n=2 ○	n=6 ○	n=2 ◑	n=2 ○	n=3 ○	n=2 ◑	n=2 ○	n=2 ○	n=2 ○	n=2 ○
C1-Benzofluoranthenes/Benzopyrenes	-	-	-	0.003	n=7 ●	n=7 ◕	n=7 ◕	n=7 ◕	n=2 ●	n=2 ●	n=2 ●	n=2 ●	n=2 ●	n=2 ○	n=6 ○	n=2 ●	n=2 ○	n=3 ○	n=2 ◑	n=2 ○	n=2 ◑	n=2 ◑	n=2 ○
C1-Biphenyls	-	-	-	0.019	n=7 ○	n=7 ○	n=7 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
C1-Dibenzothiophenes	-	-	-	0.1	n=7 ○	n=7 ○	n=7 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
C1-Fluoranthenes/Pyrenes	-	-	-	0.1	n=7 ○	n=7 ◔	n=7 ○	n=7 ◔	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
C1-Fluorenes	-	-	-	0.1	n=7 ○	n=7 ○	n=7 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
C1-Naphthalenes	-	-	-	0.012	n=7 ◔	n=7 ◑	n=7 ◑	n=7 ◑	n=2 ○	n=2 ○	n=2 ○	n=2 ◑	n=2 ◑	n=2 ○	n=6 ◔	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ◑	n=2 ◑	n=2 ○	n=2 ○
C1-Phenanthrenes/Anthracenes	-	-	-	0.1	n=7 ○	n=7 ○	n=7 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
C2-Benzo[a]anthracenes/Chrysenes	-	-	-	0.019	n=7 ◑	n=7 ◔	n=7 ◑	n=7 ◑	n=2 ◑	n=2 ○	n=2 ○	n=2 ●	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
C2-Benzofluoranthenes/Benzopyrenes	-	-	-	0.003	n=7 ◑	n=7 ◑	n=7 ◕	n=7 ◑	n=2 ◑	n=2 ◑	n=2 ◑	n=2 ●	n=2 ○	n=2 ○	n=6 ○	n=2 ●	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ◑	n=2 ◑	n=2 ○
C2-Biphenyls	-	-	-	0.086	n=7 ○	n=7 ◔	n=7 ○	n=7 ○	n=2 ○	n=2 ◑	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes

*All values were below the common detection limit, but common detection limit value is higher than published guideline. Samples with concentrations greater than the guideline are highlighted in r

Legend

○= All data below detection limit

◔= 0-25% of data above detection

◑= 26-50% of data above detection

◕= 51-75% of data above detection

●= 76-100% of data above detection

Red highlighting indicates guideline exceedence

Table 8 (Cont'd.)

Analyte	Guideline (µg/L)			Common Detection	Station																		
	AESRD (2013)	CCME	BC	Limit (µg/L)	ATR-DC-E	ATR-DC-W	ATR-DD-E	ATR-DD-W	ATR-MR-E	ATR-MR-W	ATR-SR-E	ATR-SR-W	BER-1	BER-2	BIC-1	CAR-1	CAR-2	CHL-1	CHR-1	CHR-2	CLR-1	CLR-2	ELR-1
C2-Dibenzothiophenes	-	-	-	0.1	n=7 ○	n=7 ○	n=7 ○	n=7 ○	n=2 ◑	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
C2-Fluoranthenes/Pyrenes	-	-	-	0.1	n=7 ◔	n=7 ◔	n=7 ◔	n=7 ◔	n=2 ◑	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
C2-Fluorenes	-	-	-	0.1	n=7 ○	n=7 ○	n=7 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
C2-Naphthalenes	-	-	-	0.1	n=7 ○	n=7 ◔	n=7 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
C2-Phenanthrenes/Anthracenes	-	-	-	0.1	n=7 ○	n=7 ○	n=7 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
C3-Dibenzothiophenes	-	-	-	0.1	n=7 ○	n=7 ◔	n=7 ◔	n=7 ○	n=2 ◑	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
C3-Fluoranthenes/Pyrenes	-	-	-	0.1	n=7 ○	n=7 ◔	n=7 ◔	n=7 ◔	n=2 ◑	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
C3-Fluorenes	-	-	-	0.1	n=7 ○	n=7 ◔	n=7 ○	n=7 ○	n=2 ◑	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
C3-Naphthalenes	-	-	-	0.1	n=7 ○	n=7 ○	n=7 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
C3-Phenanthrenes/Anthracenes	-	-	-	0.1	n=7 ○	n=7 ○	n=7 ○	n=7 ○	n=2 ◑	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
C4-Dibenzothiophenes	-	-	-	0.1	n=7 ○	n=7 ○	n=7 ○	n=7 ○	n=2 ◑	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
C4-Naphthalenes	-	-	-	0.1	n=7 ○	n=7 ◔	n=7 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
C4-Phenanthrenes/Anthracenes	-	-	-	0.1	n=7 ◑	n=7 ◔	n=7 ◑	n=7 ◑	n=2 ◑	n=2 ○	n=2 ○	n=2 ●	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
Chrysene	-	-	-	0.1	n=7 ○	n=7 ○	n=7 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
Dibenz[a,h]anthracene	-	-	-	0.5	n=7 ○	n=7 ○	n=7 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
Dibenzothiophene	-	-	-	0.008	n=7 ○	n=7 ○	n=7 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
Fluoranthene	0.04	0.04	4.0	0.1*	n=7 ○	n=7 ○	n=7 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
Fluorene	3.0	3.0	12	0.1	n=7 ○	n=7 ○	n=7 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
Indeno[1,2,3-c,d]-pyrene	-	-	-	0.1	n=7 ○	n=7 ○	n=7 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
Naphthalene	1.0	1.1	1.0	0.1	n=7 ○	n=7 ◔	n=7 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
Phenanthrene	0.4	0.4	0.3	0.1	n=7 ○	n=7 ○	n=7 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
Pyrene	0.025	0.025	-	0.1*	n=7 ○	n=7 ○	n=7 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○
Retene	-	-	-	0.021	n=7 ◔	n=7 ◑	n=7 ◑	n=7 ◑	n=2 ◑	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ◑	n=2 ○

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes

*All values were below the common detection limit, but common detection limit value is higher than published guideline. Samples with concentrations greater than the guideline are highlighted in r

Legend

○ = All data below detection limit
◔ = 0-25% of data above detection
◑ = 26-50% of data above detection
◕ = 51-75% of data above detection
● = 76-100% of data above detection

Red highlighting indicates guideline exceedence

Table 8 (Cont'd.)

Analyte	Guideline (µg/L)			Common Detection																					
	AESRD (2013	CCME	BC	Limit (µg/L)	ELR-2	ELR-2A	ELR-3	EYC-1	FIR-1	FIR-2	FOC-1	HHR-1	ISL-1	IYC-1	JAC-1	JAC-2	JAR-1	JOL-1	KEL-1	MAR-1	MAR-2	MAR-2A	MCC-1	MCL-1	MIC-1
Acenaphthene	5.8	5.8	6.0	0.1	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○
Acenaphthylene	-	-	-	0.1	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○
Anthracene	0.012	0.012	4.0	0.1*	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○
Benz[a]anthracene	0.018	0.018	0.10	0.1*	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○
Benzo[a]pyrene	0.015	0.015	0.01	0.1*	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○
Benzo[b,j,k]fluoranthene	-	-	-	0.01	n=2 ○	n=4 ○	n=2 ○	n=7 ◔	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ◔	n=2 ○	n=2 ○	n=2 ○
Benzo[g,h,i]perylene	-	-	-	0.2	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○
Biphenyl	-	-	-	0.002	n=2 ○	n=4 ○	n=2 ○	n=7 ◕	n=2 ○	n=2 ○	n=2 ○	n=6 ◔	n=2 ◑	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ◑	n=2 ○	n=2 ○	n=2 ○	n=6 ◔	n=2 ○	n=2 ○	n=2 ○
C1-Acenaphthenes	-	-	-	0.001	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○
C1-Benzo[a]anthracenes/Chrysenes	-	-	-	0.006	n=2 ○	n=4 ○	n=2 ○	n=7 ●	n=2 ○	n=2 ○	n=2 ◑	n=6 ○	n=2 ○	n=2 ○	n=2 ◑	n=2 ◑	n=3 ○	n=6 ○	n=2 ○	n=2 ◑	n=2 ○	n=6 ◔	n=2 ◑	n=2 ○	n=2 ○
C1-Benzofluoranthenes/Benzopyrenes	-	-	-	0.003	n=2 ○	n=4 ○	n=2 ○	n=7 ◕	n=2 ○	n=2 ○	n=2 ◑	n=6 ◔	n=2 ○	n=2 ○	n=2 ◑	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ◑	n=2 ○	n=6 ◔	n=2 ◑	n=2 ○	n=2 ○
C1-Biphenyls	-	-	-	0.019	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ●	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○
C1-Dibenzothiophenes	-	-	-	0.1	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○
C1-Fluoranthenes/Pyrenes	-	-	-	0.1	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○
C1-Fluorenes	-	-	-	0.1	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○
C1-Naphthalenes	-	-	-	0.012	n=2 ○	n=4 ◔	n=2 ○	n=7 ◑	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ◔	n=2 ○	n=2 ○	n=2 ○	n=6 ◔	n=2 ○	n=2 ○	n=2 ○
C1-Phenanthrenes/Anthracenes	-	-	-	0.1	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○
C2-Benzo[a]anthracenes/Chrysenes	-	-	-	0.019	n=2 ○	n=4 ○	n=2 ○	n=7 ◑	n=2 ○	n=2 ○	n=2 ◑	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ◔	n=2 ○	n=2 ○	n=2 ○
C2-Benzofluoranthenes/Benzopyrenes	-	-	-	0.003	n=2 ○	n=4 ○	n=2 ○	n=7 ◕	n=2 ◑	n=2 ○	n=2 ◑	n=6 ◔	n=2 ○	n=2 ○	n=2 ◑	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ◑	n=2 ○	n=6 ◔	n=2 ◑	n=2 ○	n=2 ○
C2-Biphenyls	-	-	-	0.086	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ◑	n=6 ○	n=2 ◑	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes

*All values were below the common detection limit, but common detection limit value is higher than published guideline. Samples with concentrations greater than the guideline are highlighted in r

Legend

○ = All data below detection limit
◔ = 0-25% of data above detection
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Red highlighting indicates guideline exceedence

Table 8 (Cont'd.)

Analyte	Guideline (µg/L)			Common Detection Limit (µg/L)																					
	AESRD (2013	CCME	BC		ELR-2	ELR-2A	ELR-3	EYC-1	FIR-1	FIR-2	FOC-1	HHR-1	ISL-1	IYC-1	JAC-1	JAC-2	JAR-1	JOL-1	KEL-1	MAR-1	MAR-2	MAR-2A	MCC-1	MCL-1	MIC-1
C2-Dibenzothiophenes	-	-	-	0.1	n=2 ○	n=4 ○	n=2 ○	n=7 ◔	n=2 ○	n=2 ○	n=2 ◑	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○
C2-Fluoranthenes/Pyrenes	-	-	-	0.1	n=2 ○	n=4 ○	n=2 ○	n=7 ◔	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○
C2-Fluorenes	-	-	-	0.1	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○
C2-Naphthalenes	-	-	-	0.1	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ◔	n=2 ○	n=2 ○	n=2 ○
C2-Phenanthrenes/Anthracenes	-	-	-	0.1	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○
C3-Dibenzothiophenes	-	-	-	0.1	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ◑	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ◑	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○
C3-Fluoranthenes/Pyrenes	-	-	-	0.1	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○
C3-Fluorenes	-	-	-	0.1	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○
C3-Naphthalenes	-	-	-	0.1	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○
C3-Phenanthrenes/Anthracenes	-	-	-	0.1	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○
C4-Dibenzothiophenes	-	-	-	0.1	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ◑	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○
C4-Naphthalenes	-	-	-	0.1	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○
C4-Phenanthrenes/Anthracenes	-	-	-	0.1	n=2 ○	n=4 ○	n=2 ○	n=7 ◑	n=2 ○	n=2 ○	n=2 ◑	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ◑	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○
Chrysene	-	-	-	0.1	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○
Dibenz[a,h]anthracene	-	-	-	0.5	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○
Dibenzothiophene	-	-	-	0.008	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○
Fluoranthene	0.04	0.04	4.0	0.1*	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○
Fluorene	3.0	3.0	12	0.1	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○
Indeno[1,2,3-c,d]-pyrene	-	-	-	0.1	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○
Naphthalene	1.0	1.1	1.0	0.1	n=2 ○	n=4 ○	n=2 ○	n=7 ◑	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ◔	n=2 ○	n=2 ○	n=2 ○
Phenanthrene	0.4	0.4	0.3	0.1	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○
Pyrene	0.025	0.025	-	0.1*	n=2 ○	n=4 ○	n=2 ○	n=7 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○
Retene	-	-	-	0.021	n=2 ○	n=4 ○	n=2 ○	n=7 ◑	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=6 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ◔	n=2 ○	n=2 ○	n=2 ○

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes

*All values were below the common detection limit, but common detection limit value is higher than published guideline. Samples with concentrations greater than the guideline are highlighted in r

Legend

○ = All data below detection limit
◔ = 0-25% of data above detection
◑ = 26-50% of data above detection
◕ = 51-75% of data above detection
●

Red highlighting indicates guideline exceedence

Table 8 (Cont'd.)

Analyte	Guideline (µg/L)			Common Detection	Station																
	AESRD (2013	CCME	BC	Limit (µg/L)	MUC-1	MUR-1	MUR-6	NSR-1	PIR-1	POC-1	RCC-1	SAC-1	SHL-1	STC-1	STR-1	STR-2	STR-3	SUC-1	TAR-1	TAR-2	WAC-1
Acenaphthene	5.8	5.8	6.0	0.1	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
Acenaphthylene	-	-	-	0.1	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
Anthracene	0.012	0.012	4.0	0.1*	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
Benz[a]anthracene	0.018	0.018	0.10	0.1*	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
Benzo[a]pyrene	0.015	0.015	0.01	0.1*	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
Benzo[b,j,k]fluoranthene	-	-	-	0.01	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
Benzo[g,h,i]perylene	-	-	-	0.2	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
Biphenyl	-	-	-	0.002	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ◑	n=2 ○	n=6 ◔	n=3 ○	n=3 ○	n=2 ○	n=3 ◑	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
C1-Acenaphthenes	-	-	-	0.001	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ◔	n=3 ○	n=3 ○	n=2 ○	n=3 ◑	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
C1-Benzo[a]anthracenes/Chrysenes	-	-	-	0.006	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ●	n=2 ○	n=2 ○	n=3 ○	n=2 ●	n=2 ○	n=2 ○
C1-Benzofluoranthenes/Benzopyrenes	-	-	-	0.003	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ◔	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ●	n=2 ○	n=2 ○	n=3 ○	n=2 ●	n=2 ○	n=2 ○
C1-Biphenyls	-	-	-	0.019	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ◔	n=3 ○	n=3 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
C1-Dibenzothiophenes	-	-	-	0.1	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
C1-Fluoranthenes/Pyrenes	-	-	-	0.1	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ◑	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
C1-Fluorenes	-	-	-	0.1	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
C1-Naphthalenes	-	-	-	0.012	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ◔	n=2 ○	n=6 ◔	n=3 ○	n=3 ○	n=2 ○	n=3 ◑	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
C1-Phenanthrenes/Anthracenes	-	-	-	0.1	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
C2-Benzo[a]anthracenes/Chrysenes	-	-	-	0.019	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ◕	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
C2-Benzofluoranthenes/Benzopyrenes	-	-	-	0.003	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ◔	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ●	n=2 ○	n=2 ○	n=3 ○	n=2 ●	n=2 ○	n=2 ◑
C2-Biphenyls	-	-	-	0.086	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ◔	n=3 ○	n=3 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes

*All values were below the common detection limit, but common detection limit value is higher than published guideline. Samples with concentrations greater than the guideline are highlighted in r

Legend

○ = All data below detection limit
◔ = 0-25% of data above detection
◑ = 26-50% of data above detection
◕ = 51-75% of data above detection
● = 76-100% of data above detection

Red highlighting indicates guideline exceedence

Table 8 (Cont'd.)

Analyte	Guideline (µg/L)			Common Detection	Station																
	AESRD (2013	CCME	BC	Limit (µg/L)	MUC-1	MUR-1	MUR-6	NSR-1	PIR-1	POC-1	RCC-1	SAC-1	SHL-1	STC-1	STR-1	STR-2	STR-3	SUC-1	TAR-1	TAR-2	WAC-1
C2-Dibenzothiophenes	-	-	-	0.1	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ◑	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
C2-Fluoranthenes/Pyrenes	-	-	-	0.1	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ◑	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
C2-Fluorenes	-	-	-	0.1	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
C2-Naphthalenes	-	-	-	0.1	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ◑	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
C2-Phenanthrenes/Anthracenes	-	-	-	0.1	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ◑	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
C3-Dibenzothiophenes	-	-	-	0.1	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ◑	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
C3-Fluoranthenes/Pyrenes	-	-	-	0.1	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ◑	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
C3-Fluorenes	-	-	-	0.1	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ◑	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
C3-Naphthalenes	-	-	-	0.1	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
C3-Phenanthrenes/Anthracenes	-	-	-	0.1	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ◑	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
C4-Dibenzothiophenes	-	-	-	0.1	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ◑	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
C4-Naphthalenes	-	-	-	0.1	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ◑	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
C4-Phenanthrenes/Anthracenes	-	-	-	0.1	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ◕	n=2 ○	n=2 ○	n=3 ○	n=2 ◑	n=2 ○	n=2 ○
Chrysene	-	-	-	0.1	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
Dibenz[a,h]anthracene	-	-	-	0.5	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
Dibenzothiophene	-	-	-	0.008	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
Fluoranthene	0.04	0.04	4.0	0.1*	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
Fluorene	3.0	3.0	12	0.1	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
Indeno[1,2,3-c,d]-pyrene	-	-	-	0.1	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
Naphthalene	1.0	1.1	1.0	0.1	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ◑	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
Phenanthrene	0.4	0.4	0.3	0.1	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
Pyrene	0.025	0.025	-	0.1*	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○
Retene	-	-	-	0.021	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○	n=6 ○	n=3 ○	n=3 ○	n=2 ○	n=3 ◑	n=2 ◑	n=2 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes

*All values were below the common detection limit, but common detection limit value is higher than published guideline. Samples with concentrations greater than the guideline are highlighted in r

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◕ = 51-75% of data above detection
● = 76-100% of data above detection

Red highlighting indicates guideline exceedence

Table 9 PAHs in surface water at AESRD stations with at least one year of current data available.

Analyte	Guideline (µg/L)			Common Detection Limit (µg/L)	Station																								
					Upper Athabasca	McLeod										Upper Central Athabasca	Lesser Slave		Lower Central Athabasca	Lower Athabasca									
	AESRD (2013)	CCME	BC		AB07AD0100	AB07AF0010	AB07AF0041	AB07AF0045	AB07AF0065	AB07AF0088	AB07AF0100	AB07AF0210	AB07AF0262	AB07AF0340	AB07AG0390	AB07BE0010	AB07BK0005	AB07BK0125	AB07CC0030	AB07DA0440	AB07DA0475	AB07DA0595	AB07DA0600	AB07DA0610	AB07DA0980	AB07DA1090	AB07DA2755	AB07DD0010	AB07DD0105
1-methylnaphthalene	-	-	-	0.01	-	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=9 ○	n=1 ○	n=1 ●	n=31 ◔	-	-	-	-	n=35 ○	n=29 ◔	-	-	n=19 ○	n=10 ◑
2-methylnaphthalene	-	-	-	0.01	-	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ●	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=9 ○	n=1 ○	n=1 ●	n=31 ○	-	-	-	-	n=35 ◔	n=29 ◔	-	-	n=19 ○	n=10 ◑
2-chloronapthalene	-	-	-	0.1	n=3 ○	-	-	-	-	-	-	-	-	-	-	n=3 ○	n=1 ○	n=2 ○	n=3 ○	-	-	-	-	-	-	-	-	-	n=3 ○
3-Methylchloranthrene	-	-	-	0.01	-	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	-	n=1 ○	n=1 ○	n=18 ○	n=4 ○	n=5 ○	n=4 ○	n=4 ○	n=37 ○	n=17 ○	n=1 ○	n=3 ○	n=10 ○	n=8 ○
7,12-Dimethylbenz[a]anthracene	-	-	-	0.01	-	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	-	n=1 ○	n=1 ○	n=18 ○	n=4 ○	n=5 ○	n=4 ○	n=4 ○	n=37 ○	n=17 ○	n=1 ○	n=3 ○	n=10 ○	n=8 ○
Acenaphthene	5.8	5.8	6.0	0.1	n=3 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=12 ○	n=2 ○	n=3 ○	n=42 ○	n=4 ○	n=5 ○	n=4 ○	n=4 ○	n=58 ○	n=36 ○	n=1 ○	n=3 ○	n=24 ○	n=17 ○
Acenaphthylene	-	-	-	0.1	n=3 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=12 ○	n=2 ○	n=3 ○	n=42 ○	n=4 ○	n=5 ○	n=4 ○	n=4 ○	n=58 ○	n=36 ○	n=1 ○	n=3 ○	n=24 ○	n=17 ○
Acridine	4.4	4.4	3	0.01	-	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	-	n=1 ○	n=1 ○	n=18 ○	n=4 ○	n=5 ○	n=4 ○	n=4 ○	n=37 ○	n=17 ○	n=1 ○	n=3 ○	n=10 ○	n=8 ○
Anthracene	0.012	0.012	4.0	0.1*	n=3 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=12 ○	n=2 ○	n=3 ○	n=42 ○	n=4 ○	n=5 ○	n=4 ○	n=4 ○	n=58 ○	n=36 ○	n=1 ○	n=3 ○	n=24 ○	n=17 ○
Benz[a]anthracene	0.018	0.018	0.1	0.1*	n=3 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=12 ○	n=2 ○	n=3 ○	n=42 ○	n=4 ○	n=5 ○	n=4 ○	n=4 ○	n=58 ○	n=36 ○	n=1 ○	n=3 ○	n=24 ○	n=17 ○
Benzo[a]pyrene	0.015	0.015	0.01	0.1*	n=3 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=12 ○	n=2 ○	n=3 ○	n=42 ○	n=4 ○	n=5 ○	n=4 ○	n=4 ○	n=58 ○	n=36 ○	n=1 ○	n=3 ○	n=24 ○	n=17 ○
Benzo[b,j,k]fluoranthene	-	-	-	0.01	-	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=9 ○	n=1 ○	n=1 ●	n=39 ◔	n=4 ○	n=5 ○	n=4 ○	n=4 ○	n=58 ◔	n=36 ○	n=1 ○	n=3 ○	n=24 ○	n=14 ○
Benzo[b]fluoranthene	-	-	-	0.1	n=3 ○	-	-	-	-	-	-	-	-	-	n=1 ○	n=3 ○	n=1 ○	n=2 ○	n=3 ○	-	-	-	-	-	-	-	-	-	n=3 ○
Benzo[c]phenanthrene	-	-	-	0.01	-	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	-	n=1 ○	n=1 ○	n=18 ○	n=4 ○	n=5 ○	n=4 ○	n=4 ○	n=37 ○	n=17 ○	n=1 ○	n=3 ○	n=10 ○	n=8 ○
Benzo[e]pyrene	-	-	-	0.01	-	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	-	n=1 ○	n=1 ○	n=18 ○	n=4 ○	n=5 ○	n=4 ○	n=4 ○	n=37 ○	n=17 ○	n=1 ○	n=3 ○	n=10 ○	n=8 ○
Benzo[g,h,i]perylene	-	-	-	0.2	n=3 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=12 ○	n=2 ○	n=3 ○	n=42 ○	n=4 ○	n=5 ○	n=4 ○	n=4 ○	n=58 ○	n=36 ○	n=1 ○	n=3 ○	n=24 ○	n=17 ○
Benzo[k]fluoranthene	-	-	-	0.1	n=3 ○	-	-	-	-	-	-	-	-	-	n=1 ○	n=3 ○	n=1 ○	n=2 ○	n=3 ○	-	-	-	-	-	-	-	-	-	n=3 ○
C1-Chrysene	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	n=9 ○	-	-	n=21 ○	-	-	-	-	n=21 ○	n=19 ○	-	-	n=14 ◔	n=6 ○
C1-Dibenzothiophenes	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	n=9 ○	-	-	n=21 ○	-	-	-	-	n=21 ○	n=19 ○	-	-	n=14 ○	n=6 ○
C1-Fluoranthenes/Pyrenes	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	n=9 ○	-	-	n=21 ○	-	-	-	-	n=21 ○	n=19 ○	-	-	n=14 ○	n=6 ○
C1-Fluorenes	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	n=9 ○	-	-	n=21 ○	-	-	-	-	n=21 ○	n=19 ○	-	-	n=14 ○	n=6 ○
C1-Phenanthrenes/Anthracenes	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	n=9 ○	-	-	n=21 ○	-	-	-	-	n=21 ○	n=19 ○	-	-	n=14 ○	n=6 ○
C2-Chrysene	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	n=9 ○	-	-	n=21 ○	-	-	-	-	n=21 ○	n=19 ○	-	-	n=14 ○	n=6 ○
C2-Dibenzothiophenes	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	n=9 ○	-	-	n=21 ○	-	-	-	-	n=21 ○	n=19 ○	-	-	n=14 ○	n=6 ○
C2-Fluoranthenes/Pyrenes	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	n=9 ○	-	-	n=21 ○	-	-	-	-	n=21 ○	n=19 ○	-	-	n=14 ○	n=6 ○
C2-Fluorenes	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	n=9 ○	-	-	n=21 ○	-	-	-	-	n=21 ○	n=19 ○	-	-	n=14 ○	n=6 ○
C2-Naphthalenes	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	n=9 ○	-	-	n=21 ○	-	-	-	-	n=21 ○	n=19 ○	-	-	n=14 ○	n=6 ○
C2-Phenanthrenes/Anthracenes	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	n=9 ○	-	-	n=21 ○	-	-	-	-	n=21 ○	n=19 ○	-	-	n=14 ○	n=6 ○
C3-Chrysene	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	n=9 ○	-	-	n=21 ○	-	-	-	-	n=21 ○	n=19 ○	-	-	n=14 ○	n=6 ○

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes.

*All values were below the common detection limit, but common detection limit value is higher than published guideline. Samples with concentrations greater than the guideline are highlighted in red.

Legend

○ = All data below detection limit

◔ = 1-25% of data above detection

◑ = 26-50% of data above detection

◕ = 51-75% of data above detection

● = 76-100% of data above detection

Red highlighting indicates guideline exceedence.

Table 9 (Cont'd.)

Analyte	Guideline (µg/L)			Common Detection Limit (µg/L)	Station																									
					Upper Athabasca	McLeod										Upper Central Athabasca	Lesser Slave		Lower Central Athabasca	Lower Athabasca									
	AESRD (2013)	CCME	BC		AB07AD0100	AB07AF0010	AB07AF0041	AB07AF0045	AB07AF0065	AB07AF0088	AB07AF0100	AB07AF0210	AB07AF0262	AB07AF0340	AB07AG0390	AB07BE0010	AB07BK0005	AB07BK0125	AB07CC0030	AB07DA0440	AB07DA0475	AB07DA0595	AB07DA0600	AB07DA0610	AB07DA0980	AB07DA1090	AB07DA2755	AB07DD0010	AB07DD0105
C3-Dibenzothiophenes	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	n=9 ○	-	-	n=21 ○	-	-	-	-	n=21 ○	n=19 ○	-	-	n=14 ○	n=6 ○
C3-Fluoranthenes/Pyrenes	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	n=9 ○	-	-	n=21 ○	-	-	-	-	n=21 ○	n=19 ○	-	-	n=14 ○	n=6 ○
C3-Fluorenes	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	n=9 ○	-	-	n=21 ○	-	-	-	-	n=21 ○	n=19 ○	-	-	n=14 ○	n=6 ○
C3-Naphthalenes	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	n=9 ○	-	-	n=21 ○	-	-	-	-	n=21 ○	n=19 ○	-	-	n=14 ○	n=6 ○
C3-Phenanthrenes/Anthracenes	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	n=9 ○	-	-	n=21 ○	-	-	-	-	n=21 ○	n=19 ○	-	-	n=14 ○	n=6 ○
C4-Chrysene	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	n=9 ○	-	-	n=21 ○	-	-	-	-	n=21 ○	n=19 ○	-	-	n=14 ○	n=6 ○
C4-Dibenzothiophenes	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	n=9 ○	-	-	n=21 ○	-	-	-	-	n=21 ○	n=19 ○	-	-	n=14 ○	n=6 ○
C4-Fluoranthene/Pyrene	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	n=9 ○	-	-	n=21 ○	-	-	-	-	n=21 ○	n=19 ○	-	-	n=14 ○	n=6 ○
C4-Fluorene	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	n=9 ○	-	-	n=21 ○	-	-	-	-	n=21 ○	n=19 ○	-	-	n=14 ○	n=6 ○
C4-Naphthalenes	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	n=9 ○	-	-	n=21 ○	-	-	-	-	n=21 ○	n=19 ○	-	-	n=14 ○	n=6 ○
C4-Phenanthrenes/Anthracenes	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	n=9 ○	-	-	n=21 ◔	-	-	-	-	n=21 ○	n=19 ○	-	-	n=14 ○	n=6 ○
Chrysene	-	-	-	0.1	n=3 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=12 ○	n=2 ○	n=3 ○	n=42 ○	n=4 ○	n=5 ○	n=4 ○	n=4 ○	n=58 ○	n=36 ○	n=1 ○	n=3 ○	n=24 ○	n=17 ○
Dibenz[a,h]anthracene	-	-	-	0.5	n=3 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=12 ○	n=2 ○	n=3 ○	n=42 ○	n=4 ○	n=5 ○	n=4 ○	n=4 ○	n=58 ○	n=36 ○	n=1 ○	n=3 ○	n=24 ○	n=17 ○
Dibenzo[a,h]pyrene	-	-	-	0.01	-	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	-	n=1 ○	n=1 ○	n=18 ○	n=4 ○	n=5 ○	n=4 ○	n=4 ○	n=37 ○	n=17 ○	n=1 ○	n=3 ○	n=10 ○	n=8 ○
Dibenzo[a,i]pyrene	-	-	-	0.01	-	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	-	n=1 ○	n=1 ○	n=18 ○	n=4 ○	n=5 ○	n=4 ○	n=4 ○	n=37 ○	n=17 ○	n=1 ○	n=3 ○	n=10 ○	n=8 ○
Dibenzo[a,l]pyrene	-	-	-	0.01	-	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	-	n=1 ○	n=1 ○	n=18 ○	n=4 ○	n=5 ○	n=4 ○	n=4 ○	n=37 ○	n=17 ○	n=1 ○	n=3 ○	n=10 ○	n=8 ○
Fluoranthene	0.04	0.04	4.0	0.1*	n=3 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=12 ○	n=2 ○	n=3 ○	n=42 ○	n=4 ○	n=5 ○	n=4 ○	n=4 ○	n=58 ○	n=36 ○	n=1 ○	n=3 ○	n=24 ○	n=17 ○
Fluorene	3.0	3.0	12	0.1	n=3 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=12 ○	n=2 ○	n=3 ○	n=42 ○	n=4 ○	n=5 ○	n=4 ○	n=4 ○	n=58 ○	n=36 ○	n=1 ○	n=3 ○	n=24 ○	n=17 ○
Indeno[1,2,3-c,d]-pyrene	-	-	-	0.1	n=3 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=12 ○	n=2 ○	n=3 ○	n=42 ○	n=4 ○	n=5 ○	n=4 ○	n=4 ○	n=58 ○	n=36 ○	n=1 ○	n=3 ○	n=24 ○	n=17 ○
Naphthalene	1.0	1.1	1.0	0.1	n=6 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=15 ○	n=3 ○	n=5 ○	n=45 ○	n=4 ○	n=5 ○	n=4 ○	n=4 ○	n=58 ◔	n=36 ◔	n=1 ○	n=3 ○	n=24 ◔	n=20 ◑
Perylene	-	-	-	0.013	-	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=12 ○	n=1 ○	n=1 ○	n=17 ○	n=4 ○	n=5 ○	n=4 ○	n=4 ○	n=37 ○	n=17 ◔	n=1 ○	n=3 ○	n=10 ○	n=7 ○
Phenanthrene	0.4	0.4	0.3	0.1	n=3 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=12 ○	n=2 ○	n=3 ○	n=42 ○	n=4 ○	n=5 ○	n=4 ○	n=4 ○	n=58 ○	n=36 ○	n=1 ○	n=3 ○	n=24 ○	n=17 ○
Pyrene	0.025	0.025	-	0.1*	n=3 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=12 ○	n=2 ○	n=3 ○	n=42 ○	n=4 ○	n=5 ○	n=4 ○	n=4 ○	n=58 ○	n=36 ○	n=1 ○	n=3 ○	n=24 ○	n=17 ○
Retene	-	-	-	0.021	-	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	-	n=1 ○	n=1 ○	n=18 ○	n=4 ○	n=5 ○	n=4 ○	n=4 ○	n=37 ○	n=17 ○	n=1 ○	n=3 ○	n=10 ○	n=8 ○

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes.

*All values were below the common detection limit, but common detection limit value is higher than published guideline. Samples with concentrations greater than the guideline are highlighted in red.

Legend

○ = All data below detection limit
◔ = 1-25% of data above detection
◑ = 26-50% of data above detection
◕ = 51-75% of data above detection
● = 76-100% of data above detection

Red highlighting indicates guideline exceedence.

Table 10 PAHs in surface water at EC (JOSM) stations with at least one year of current data available.

Analyte	Guidelines (μg/L)			Common Detection Limit (μg/L)	Station																		
	AESRD (2013)	CCME	BC		AL07DD0001	AL07DD0004	AL07DD0005	ELLS RIFF 1	ELLS RIFF 2	ELLS RIFF 3	FIR RIFF 1	JOS RIFF 1	JP RIFF DN	JP RIFF UP	M1 GRAVEL	M1 SAND	M3 GRAVEL	M3 SAND	M4 GRAVEL	M4 SAND	M6 GRAVEL	M6 SAND	M8 GRAVEL
1-methylnaphthalene	-	-	-	0.01	n=1 ○	n=9 ○	n=9 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=1 ○
1,2,3,4-tetrahydronaphthalene	-	-	-	0.00571	n=1 ○	n=9 ○	n=9 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=1 ○
2-methylnaphthalene	-	-	-	0.01	n=1 ○	n=9 ○	n=9 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=2 ○	n=2 ◑	n=2 ○	n=3 ◑	n=2 ○	n=1 ○
2-chloronaphthalene	-	-	-	0.1	n=1 ○	n=9 ○	n=9 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=1 ○
Acenaphthene	5.8	5.8	6.0	0.1	n=1 ○	n=9 ○	n=9 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=1 ○
Acenaphthylene	-	-	-	0.1	n=1 ○	n=9 ○	n=9 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=1 ○
Anthracene	0.012	0.012	4.0	0.1*	n=1 ○	n=9 ○	n=9 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=1 ○
Benz[a]anthracene	0.018	0.018	0.1	0.1*	n=1 ○	n=9 ○	n=9 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=1 ○
Benzo[a]pyrene	0.015	0.015	0.01	0.1*	n=1 ○	n=9 ○	n=9 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=1 ○
Benzo[b]fluoranthene	-	-	-	0.1	n=1 ○	n=9 ○	n=9 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=1 ○
Benzo[e]pyrene	-	-	-	0.01	n=1 ○	n=9 ○	n=9 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=1 ○
Benzo[g,h,i]perylene	-	-	-	0.2	n=1 ○	n=9 ○	n=9 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=1 ○
Benzo[k]fluoranthene	-	-	-	0.1	n=1 ○	n=9 ○	n=9 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=1 ○
Chrysene	-	-	-	0.1	n=1 ○	n=9 ○	n=9 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=1 ○
Dibenz[a,h]anthracene	-	-	-	0.5	n=1 ○	n=9 ○	n=9 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=1 ○
Dibenzothiophene	-	-	-	0.00816	n=1 ○	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoranthene	0.04	0.04	4.0	0.1*	n=1 ○	n=9 ○	n=9 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=1 ○
Fluorene	3.0	3.0	12	0.1	n=1 ○	n=9 ○	n=9 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=1 ○
Indene	-	-	-	0.0051	n=1 ○	n=9 ○	n=9 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=1 ○
Indeno[1,2,3-c,d]-pyrene	-	-	-	0.1	n=1 ○	n=9 ○	n=9 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=1 ○
Naphthalene	1.0	1.1	1.0	0.1	n=1 ○	n=9 ○	n=9 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=1 ○	n=2 ○	n=1 ○
Perylene	-	-	-	0.013	n=1 ○	n=9 ○	n=9 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=1 ○
Phenanthrene	0.4	0.4	0.3	0.1	n=1 ○	n=9 ○	n=9 ○	n=1 ○	n=1 ○	-	n=1 ○	n=1 ○	n=1 ○	-	-	-	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	-
Pyrene	0.025	0.025	-	0.1*	n=1 ○	n=9 ○	n=9 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=2 ○	n=2 ○	n=2 ○	n=3 ○	n=2 ○	n=1 ○

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes.

*All values were below the common detection limit, but common detection limit value is higher than published guideline. Samples with concentrations greater than the guideline are highlighted in red.

Legend

○ = All data below detection limit

◔ = 1-25% of data above detection

◑ = 26-50% of data above detection

◕ = 51-75% of data above detection

● = 76-100% of data above detection

Red highlighting indicates guideline exceedence.

Table 10 (Cont'd.)

Analyte	Guidelines (µg/L)			Common Detection Limit (µg/L)	Station																		
	AESRD (2013)	CCME	BC		M9 GRAVEL	M9 SAND	MCK RIFF 12	MCK RIFF 15	MCK RIFF 2	MCK RIFF 5	MCK RIFF 7	MCK RIFF 9	STB RIFF 1	STB RIFF 10	STB RIFF 11	STB RIFF 13	STB RIFF 16	STB RIFF 17	STB RIFF 19	STB RIFF 4	STB RIFF 5A	STB RIFF 5B	STB RIFF 7
1-methylnaphthalene	-	-	-	0.01	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=1 ○
1,2,3,4-tetrahydronaphthalene	-	-	-	0.00571	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=1 ○
2-methylnaphthalene	-	-	-	0.01	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=1 ○
2-chloronaphthalene	-	-	-	0.1	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=1 ○
Acenaphthene	5.8	5.8	6.0	0.1	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=1 ○
Acenaphthylene	-	-	-	0.1	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=1 ○
Anthracene	0.012	0.012	4.0	0.1*	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=1 ○
Benz[a]anthracene	0.018	0.018	0.1	0.1*	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=1 ○
Benzo[a]pyrene	0.015	0.015	0.01	0.1*	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=1 ○
Benzo[b]fluoranthene	-	-	-	0.1	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=1 ○
Benzo[e]pyrene	-	-	-	0.01	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=1 ○
Benzo[g,h,i]perylene	-	-	-	0.2	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=1 ○
Benzo[k]fluoranthene	-	-	-	0.1	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=1 ○
Chrysene	-	-	-	0.1	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=1 ○
Dibenz[a,h]anthracene	-	-	-	0.5	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=1 ○
Dibenzothiophene	-	-	-	0.00816	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoranthene	0.04	0.04	4.0	0.1*	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=1 ○
Fluorene	3.0	3.0	12	0.1	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=1 ○
Indene	-	-	-	0.0051	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=1 ○
Indeno[1,2,3-c,d]-pyrene	-	-	-	0.1	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=1 ○
Naphthalene	1.0	1.1	1.0	0.1	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=1 ○
Perylene	-	-	-	0.013	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=1 ○
Phenanthrene	0.4	0.4	0.3	0.1	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○
Pyrene	0.025	0.025	-	0.1*	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=1 ○	n=4 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=1 ○	n=1 ○

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes.

*All values were below the common detection limit, but common detection limit value is higher than published guideline. Samples with concentrations greater than the guideline are highlighted in red.

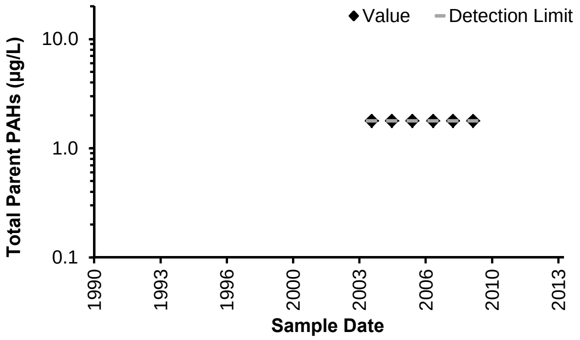
Legend

○ = All data below detection limit
◔ = 1-25% of data above detection
◑ = 26-50% of data above detection
◕ = 51-75% of data above detection
● = 76-100% of data above detection

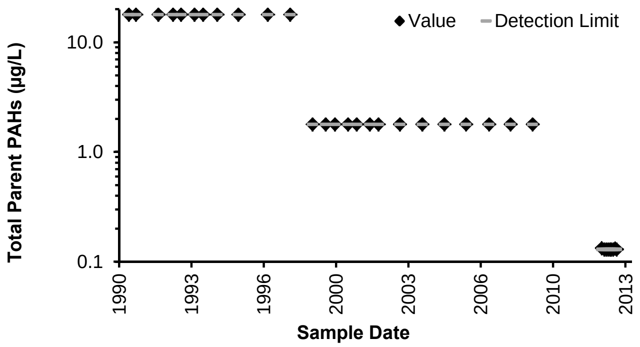
Red highlighting indicates guideline exceedence.

Figure 15 Total Parent PAHs (Log Scale) in surface water at AESRD stations with historical datasets.

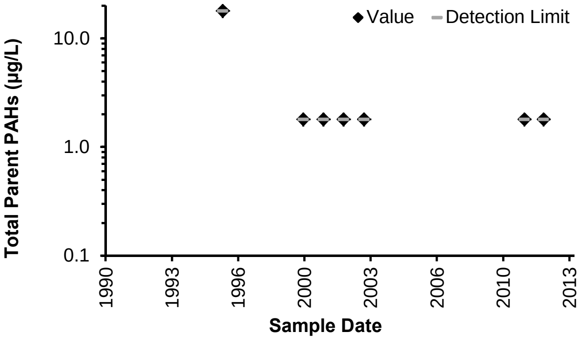
AB07AD0100 (Athabasca River at Old Entrance town site)



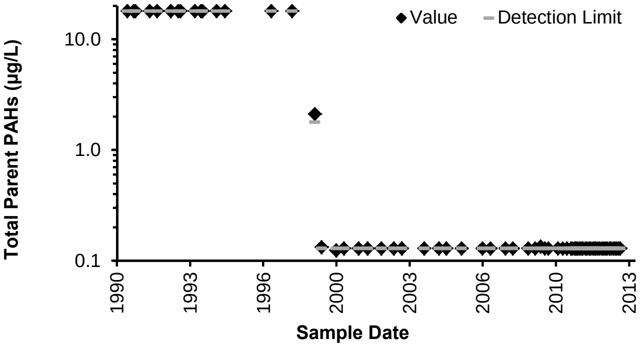
AB07BE0010 (Athabasca River at the town of Athabasca)



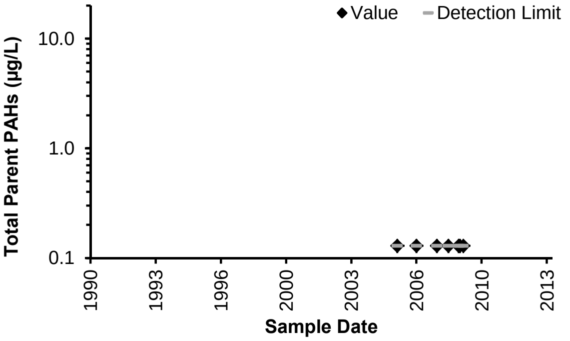
AB07BK0125 (Lesser Slave River)



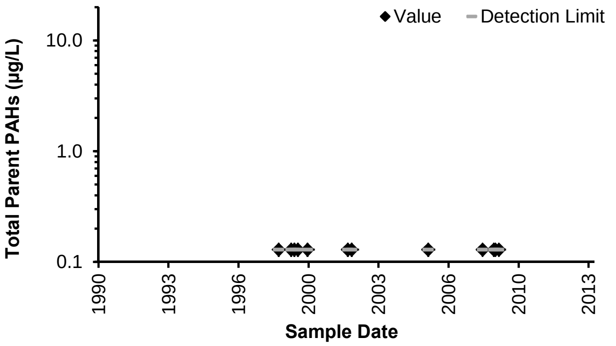
AB07CC0030 (Athabasca River upstream of Fort McMurray)



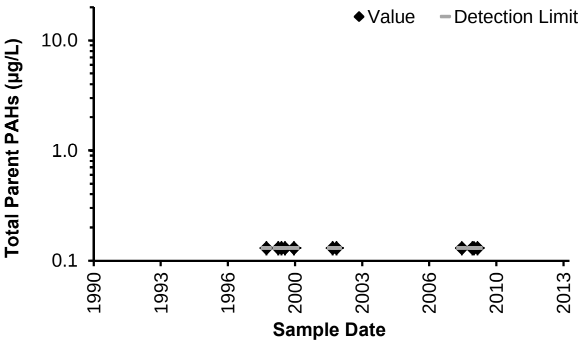
AB07DA0475 (Muskeg River upstream of Stanley Creek)



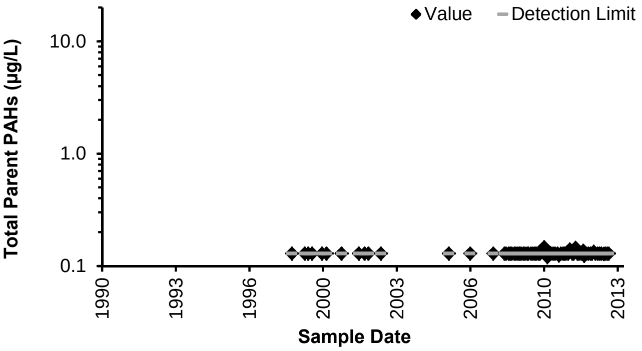
AB07DA0595 (Muskeg River upstream of Jackpine Creek)



AB07DA0600 (Jackpine Creek)



AB07DA0610 (Muskeg River downstream of Kearl Lake road)

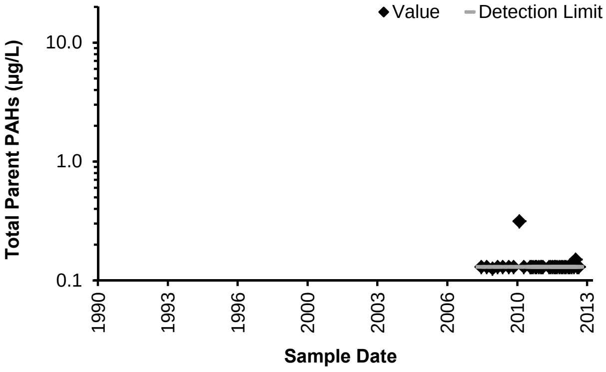


Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

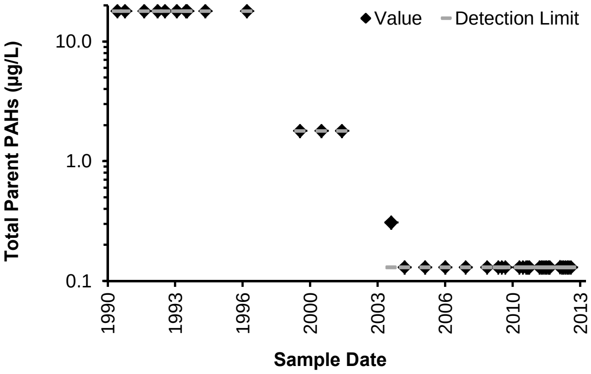
Note: No guideline available for Total Parent PAHs in surface water.

Figure 15 (Cont'd.)

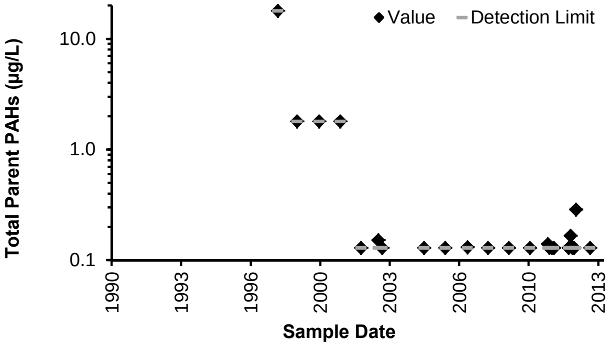
AB07DA0980 (Athabasca River above Firebag River)



AB07DD0010 (Athabasca River at Old Fort)



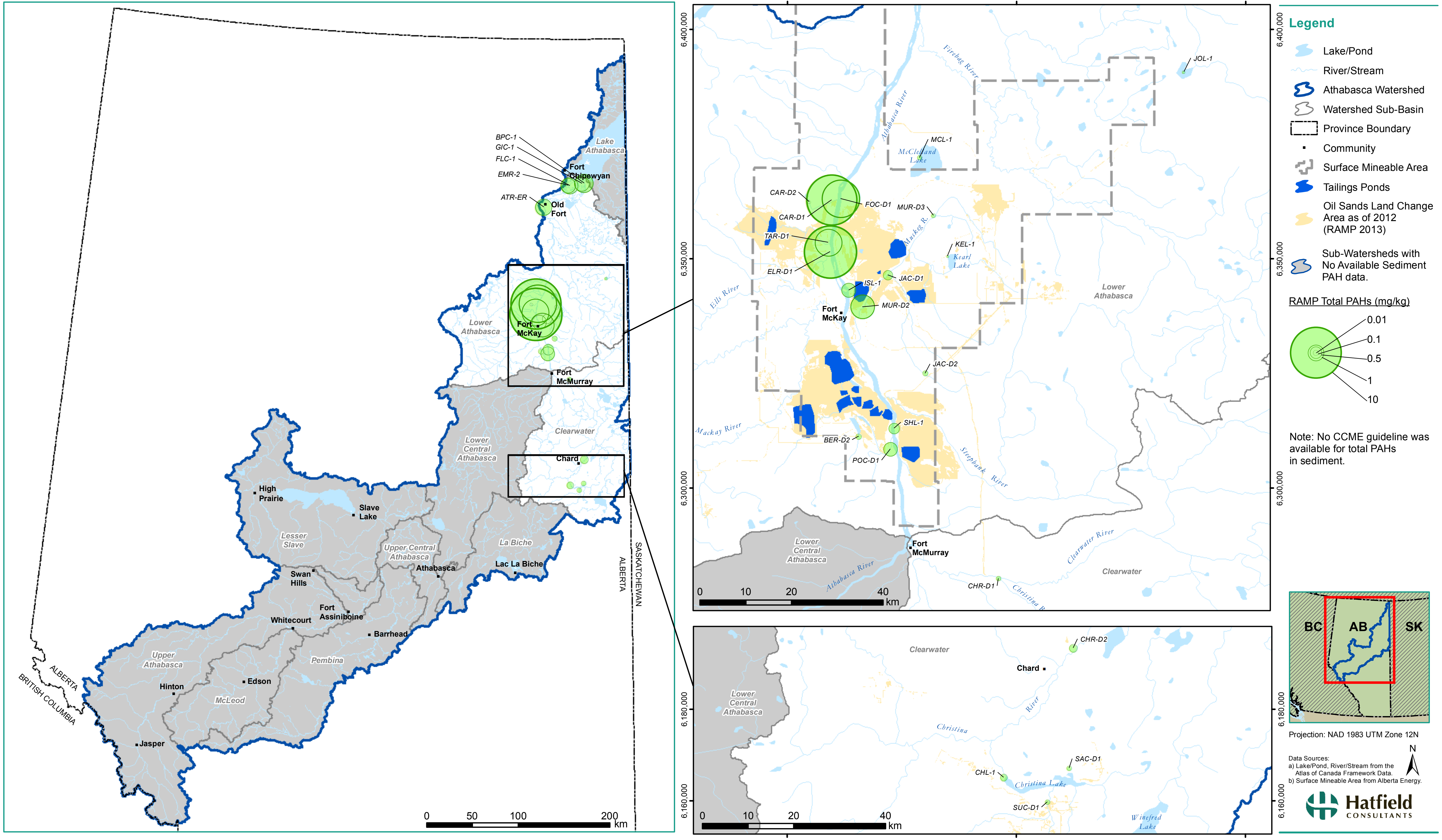
AB07DD0105 (Athabasca River downstream of Devils Elbow)



Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

Note: No guideline available for Total Parent PAHs in surface water.

Figure 16 Total PAHs in sediments normalized to 1% TOC (mg/kg), fall 2012.



Note: No CCME guideline was available for total PAHs in sediment.

Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Lake/Pond, River/Stream from the Atlas of Canada Framework Data.
b) Surface Mineable Area from Alberta Energy.

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Table 11 PAHs in sediments at RAMP and AESRD stations with at least one year of current data available.

Analyte	Guideline		Common Detection Limit (mg/kg)	Station																
	CCME - ISQG	CCME - PEL		ATR-ER	BER-D2	BPC-1	CAR-D1	CAR-D2	CHL-1	CHR-D1	CHR-D2	CLR-D1	CLR-D2	ELR-D1	EMR-1	EMR-2	FIR-D1	FLC-1	FOC-D1	GIC-1
3-methylcholanthrene	-	-	0.001	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7, 12-Dimethylbenz[a]anthracene	-	-	0.001	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2-Chloronapthalene	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acenaphthene	0.00671 mg/kg	0.0889 mg/kg	2*	n=6 ○	n=5 ○	n=6 ○	n=2 ○	n=2 ○	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ○	n=1 ○	n=2 ○	n=2 ○	n=6 ○	n=5 ○	n=6 ○
Acenaphthylene	0.00587 mg/kg	0.128 mg/kg	2*	n=6 ○	n=5 ○	n=6 ○	n=2 ○	n=2 ○	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ○	n=1 ○	n=2 ○	n=2 ○	n=6 ○	n=5 ○	n=6 ○
Acridine	-	-	0.001	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anthracene	0.0469 mg/kg	0.245 mg/kg	2	n=6 ○	n=5 ○	n=6 ○	n=2 ○	n=2 ○	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ○	n=1 ○	n=2 ○	n=2 ○	n=6 ○	n=5 ○	n=6 ○
Benz[a]anthracene	0.0317 mg/kg	0.385 mg/kg	2*	n=6 ○	n=5 ○	n=6 ○	n=2 ○	n=2 ○	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ◔	n=1 ○	n=2 ○	n=2 ○	n=6 ○	n=5 ○	n=6 ○
Benzo[a]pyrene	0.0319 mg/kg	0.782 mg/kg	2*	n=6 ○	n=5 ○	n=6 ○	n=2 ○	n=2 ○	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ○	n=1 ○	n=2 ○	n=2 ○	n=6 ○	n=5 ○	n=6 ○
Benzo[b]flouranthene	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Benzo[b,j,k]fluoranthene	-	-	0.0187	n=6 ◔	n=5 ○	n=6 ◔	n=2 ●	n=2 ○	n=1 ○	n=3 ◑	n=2 ○	n=2 ○	n=2 ○	n=4 ◕	n=1 ○	n=2 ●	n=2 ◑	n=6 ◔	n=5 ◔	n=6 ◔
Benzo[c]phenanthrene	-	-	0.001	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Benzo[e]pyrene	-	-	0.001	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Benzo[g,h,i]perylene	-	-	4	n=6 ○	n=5 ○	n=6 ○	n=2 ○	n=2 ○	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ○	n=1 ○	n=2 ○	n=2 ○	n=6 ○	n=5 ○	n=6 ○
Benzo[k]fluoranthene	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Biphenyl	-	-	0.00255	n=6 ◕	n=5 ○	n=6 ●	n=2 ○	n=2 ○	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ◔	n=1 ○	n=2 ●	n=2 ○	n=6 ◕	n=5 ◔	n=6 ●
C1-Acenaphthenes	-	-	0.004	n=6 ○	n=5 ○	n=6 ○	n=2 ○	n=2 ○	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ○	n=1 ○	n=2 ○	n=2 ○	n=6 ○	n=5 ○	n=6 ○
C1-Benzo[a]anthracenes/Chrysenes	-	-	0.016	n=6 ◕	n=5 ○	n=6 ●	n=2 ●	n=2 ○	n=1 ○	n=3 ●	n=2 ○	n=2 ◑	n=2 ○	n=4 ●	n=1 ○	n=2 ●	n=2 ◑	n=6 ●	n=5 ●	n=6 ◕
C1-Benzofluoranthenes/Benzopyrenes	-	-	0.023	n=6 ◑	n=5 ○	n=6 ●	n=2 ●	n=2 ○	n=1 ○	n=3 ●	n=2 ○	n=2 ◑	n=2 ○	n=4 ●	n=1 ○	n=2 ●	n=2 ●	n=6 ●	n=5 ●	n=6 ◕
C1-Biphenyls	-	-	0.003	n=6 ◕	n=5 ◔	n=6 ●	n=2 ○	n=2 ○	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ◑	n=1 ○	n=2 ●	n=2 ◑	n=6 ●	n=5 ◔	n=6 ●
C1-Dibenzothiophenes	-	-	0.0105	n=6 ◔	n=5 ○	n=6 ◑	n=2 ●	n=2 ○	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ●	n=1 ○	n=2 ●	n=2 ○	n=6 ◑	n=5 ◕	n=6 ◑
C1-Fluoranthenes/Pyrenes	-	-	0.0217	n=6 ◕	n=5 ○	n=6 ●	n=2 ●	n=2 ○	n=1 ○	n=3 ●	n=2 ○	n=2 ◑	n=2 ○	n=4 ●	n=1 ○	n=2 ●	n=2 ◑	n=6 ●	n=5 ●	n=6 ●
C1-Fluorenes	-	-	0.003	n=6 ◕	n=5 ○	n=6 ●	n=2 ●	n=2 ●	n=1 ○	n=3 ●	n=2 ○	n=2 ◑	n=2 ○	n=4 ●	n=1 ○	n=2 ●	n=2 ●	n=6 ●	n=5 ●	n=6 ●
C1-Naphthalenes	-	-	0.005	n=6 ◕	n=5 ○	n=6 ●	n=2 ◑	n=2 ◑	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ●	n=1 ○	n=2 ●	n=2 ●	n=6 ●	n=5 ◔	n=6 ●
C1-Phenanthrenes/Anthracenes	-	-	0.036	n=6 ◔	n=5 ○	n=6 ◑	n=2 ●	n=2 ○	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ◕	n=1 ○	n=2 ●	n=2 ○	n=6 ◑	n=5 ◕	n=6 ◑
C2-Benzo[a]anthracenes/Chrysenes	-	-	0.012	n=6 ◕	n=5 ○	n=6 ●	n=2 ●	n=2 ○	n=1 ○	n=3 ●	n=2 ○	n=2 ◑	n=2 ○	n=4 ●	n=1 ○	n=2 ●	n=2 ◑	n=6 ●	n=5 ●	n=6 ●
C2-Benzofluoranthenes/Benzopyrenes	-	-	0.0211	n=6 ◔	n=5 ○	n=6 ◑	n=2 ●	n=2 ○	n=1 ○	n=3 ●	n=2 ○	n=2 ◑	n=2 ○	n=4 ●	n=1 ○	n=2 ●	n=2 ◑	n=6 ◑	n=5 ●	n=6 ◑

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes.

*All values were below the common detection limit, but common detection limit value is higher than published guideline. Samples with concentrations greater than the guideline are highlighted in red.

Legend

○ = All data below detection limit
◔ = 1-25% of data above detection
◑ = 26-50% of data above detection
◕ = 51-75% of data above detection
● = 76-100% of data above detection

Red highlighting indicates guideline exceedence.

Table 11 (Cont'd.)

Analyte	Guideline		Common Detection Limit (mg/kg)	Station																
	CCME - ISQG	CCME - PEL		ATR-ER	BER-D2	BPC-1	CAR-D1	CAR-D2	CHL-1	CHR-D1	CHR-D2	CLR-D1	CLR-D2	ELR-D1	EMR-1	EMR-2	FIR-D1	FLC-1	FOC-D1	GIC-1
C2-Biphenyls	-	-	0.0008	n=6 ●	n=5 ●	n=6 ●	n=2 ●	n=2 ●	n=1 ●	n=3 ●	n=2 ●	n=2 ●	n=2 ◑	n=4 ●	n=1 ●	n=2 ●	n=2 ●	n=6 ●	n=5 ●	n=6 ●
C2-Dibenzothiophenes	-	-	0.006	n=6 ●	n=5 ○	n=6 ●	n=2 ●	n=2 ◑	n=1 ○	n=3 ●	n=2 ○	n=2 ◑	n=2 ○	n=4 ●	n=1 ○	n=2 ●	n=2 ●	n=6 ●	n=5 ●	n=6 ●
C2-Fluoranthenes/Pyrenes	-	-	0.0266	n=6 ●	n=5 ◔	n=6 ●	n=2 ●	n=2 ◑	n=1 ○	n=3 ●	n=2 ○	n=2 ●	n=2 ○	n=4 ●	n=1 ○	n=2 ●	n=2 ◑	n=6 ●	n=5 ●	n=6 ●
C2-Fluorenes	-	-	0.003	n=6 ●	n=5 ◔	n=6 ●	n=2 ●	n=2 ●	n=1 ○	n=3 ●	n=2 ○	n=2 ◑	n=2 ○	n=4 ●	n=1 ○	n=2 ●	n=2 ●	n=6 ●	n=5 ●	n=6 ●
C2-Naphthalenes	-	-	0.0024	n=6 ●	n=5 ◑	n=6 ●	n=2 ●	n=2 ●	n=1 ●	n=3 ●	n=2 ○	n=2 ◑	n=2 ○	n=4 ●	n=1 ○	n=2 ●	n=2 ●	n=6 ●	n=5 ●	n=6 ●
C2-Phenanthrenes/Anthracenes	-	-	0.01	n=6 ◕	n=5 ○	n=6 ●	n=2 ●	n=2 ○	n=1 ○	n=3 ●	n=2 ○	n=2 ◑	n=2 ○	n=4 ●	n=1 ○	n=2 ●	n=2 ◑	n=6 ●	n=5 ●	n=6 ●
C3-Dibenzothiophenes	-	-	0.009	n=6 ●	n=5 ○	n=6 ●	n=2 ●	n=2 ○	n=1 ○	n=3 ●	n=2 ○	n=2 ◑	n=2 ○	n=4 ●	n=1 ○	n=2 ●	n=2 ●	n=6 ●	n=5 ●	n=6 ●
C3-Fluoranthenes/Pyrenes	-	-	0.0583	n=6 ◑	n=5 ○	n=6 ◕	n=2 ●	n=2 ○	n=1 ○	n=3 ●	n=2 ○	n=2 ◑	n=2 ○	n=4 ●	n=1 ○	n=2 ●	n=2 ●	n=6 ◑	n=5 ●	n=6 ◑
C3-Fluorenes	-	-	0.0151	n=6 ◑	n=5 ○	n=6 ●	n=2 ●	n=2 ○	n=1 ○	n=3 ●	n=2 ○	n=2 ◑	n=2 ○	n=4 ●	n=1 ○	n=2 ●	n=2 ●	n=6 ●	n=5 ●	n=6 ●
C3-Naphthalenes	-	-	0.004	n=6 ◑	n=5 ○	n=6 ●	n=2 ●	n=2 ●	n=1 ○	n=3 ●	n=2 ○	n=2 ◑	n=2 ○	n=4 ●	n=1 ○	n=2 ●	n=2 ●	n=6 ●	n=5 ●	n=6 ●
C3-Phenanthrenes/Anthracenes	-	-	0.0188	n=6 ◕	n=5 ○	n=6 ●	n=2 ●	n=2 ○	n=1 ○	n=3 ●	n=2 ○	n=2 ◑	n=2 ○	n=4 ●	n=1 ○	n=2 ●	n=2 ◑	n=6 ●	n=5 ●	n=6 ●
C4-Dibenzothiophenes	-	-	0.0101	n=6 ●	n=5 ○	n=6 ●	n=2 ●	n=2 ○	n=1 ○	n=3 ●	n=2 ○	n=2 ◑	n=2 ○	n=4 ●	n=1 ○	n=2 ●	n=2 ●	n=6 ●	n=5 ●	n=6 ●
C4-Naphthalenes	-	-	0.0158	n=6 ◕	n=5 ○	n=6 ●	n=2 ●	n=2 ○	n=1 ○	n=3 ◕	n=2 ○	n=2 ○	n=2 ○	n=4 ●	n=1 ○	n=2 ●	n=2 ◑	n=6 ◕	n=5 ●	n=6 ●
C4-Phenanthrenes/Anthracenes	-	-	0.0751	n=6 ◕	n=5 ◔	n=6 ◔	n=2 ●	n=2 ◕	n=1 ○	n=3 ●	n=2 ◑	n=2 ◑	n=2 ○	n=4 ●	n=1 ◑	n=2 ●	n=2 ◕	n=6 ●	n=5 ●	n=6 ●
Chrysene	0.0571 mg/kg	0.862 mg/kg	2*	n=6 ○	n=5 ○	n=6 ○	n=2 🔴	n=2 ○	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 🔴	n=1 ○	n=2 ○	n=2 ◑	n=6 ○	n=5 🔴	n=6 ○
Dibenz[a,h]anthracene	0.00622 mg/kg	0.135 mg/kg	5*	n=6 ○	n=5 ○	n=6 ○	n=2 🔴	n=2 ○	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ◔	n=1 ○	n=2 ○	n=2 ◑	n=6 ○	n=5 🔴	n=6 ○
Dibenz[a,h]pyrene	-	-	0.001	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dibenz[a,i]pyrene	-	-	0.001	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dibenz[a,l]pyrene	-	-	0.001	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dibenzothiophene	-	-	0.0241	n=6 ○	n=5 ○	n=6 ○	n=2 ○	n=2 ○	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ○	n=1 ○	n=2 ○	n=2 ○	n=6 ○	n=5 ○	n=6 ○
Fluoranthene	0.111 mg/kg	2.355 mg/kg	2*	n=6 ○	n=5 ○	n=6 ○	n=2 ○	n=2 ○	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ○	n=1 ○	n=2 ○	n=2 ○	n=6 ○	n=5 ○	n=6 ○
Fluorene	0.0212 mg/kg	0.144 mg/kg	2*	n=6 ○	n=5 ○	n=6 ○	n=2 ○	n=2 ○	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ○	n=1 ○	n=2 ○	n=2 ○	n=6 ○	n=5 ○	n=6 ○
Indeno[1,2,3-c,d]-pyrene	-	-	2	n=6 ○	n=5 ○	n=6 ○	n=2 ○	n=2 ○	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ○	n=1 ○	n=2 ○	n=2 ○	n=6 ○	n=5 ○	n=6 ○
Naphthalene	0.0346 mg/kg	0.391 mg/kg	2*	n=6 ○	n=5 ○	n=6 ○	n=2 ○	n=2 ○	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ○	n=1 ○	n=2 ○	n=2 ○	n=6 ○	n=5 ○	n=6 ○
Perylene	-	-	0.001	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phenanthrene	0.0419 mg/kg	0.515 mg/kg	2*	n=6 ○	n=5 ○	n=6 ○	n=2 ○	n=2 ○	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ◔	n=1 ○	n=2 ○	n=2 ○	n=6 ○	n=5 ○	n=6 ○
Pyrene	0.053 mg/kg	0.875 mg/kg	2*	n=6 ○	n=5 ○	n=6 ○	n=2 ◑	n=2 ○	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ◔	n=1 ○	n=2 ○	n=2 ○	n=6 ○	n=5 ○	n=6 ○
Retene	-	-	0.075	n=6 ◔	n=5 ◔	n=6 ◔	n=2 ◑	n=2 ◑	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ●	n=1 ○	n=2 ◑	n=2 ◑	n=6 ◔	n=5 ●	n=6 ○

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes

*All values were below the common detection limit, but common detection limit value is higher than published guideline. Samples with concentrations greater than the guideline are highlighted in red.

Legend

○ = All data below detection limit

◔ = 1-25% of data above detection

◑ = 26-50% of data above detection

◕ = 51-75% of data above detection

● = 76-100% of data above detection

Red highlighting indicates guideline exceedence.

Table 11 (Cont'd.)

Analyte	Guideline		Common Detection	Station																
	CCME - ISQG	CCME - PEL	Limit (mg/kg)	ISL-1	JAC-D1	JAC-D2	JOL-1	KEL-1	MCL-1	MUR-D2	MUR-D3	POC-D1	SAC-D1	SHL-1	SUC-D1	TAR-D1	AB07AD0100	AB07BE0010	AB07CC0030	AB07DD0010
3-methylcholanthrene	-	-	0.001	-	-	-	-	-	-	-	-	-	-	-	-	-	n=1 ○	n=1 ○	n=3 ○	n=1 ○
7, 12-Dimethylbenz[a]anthracene	-	-	0.001	-	-	-	-	-	-	-	-	-	-	-	-	-	n=1 ○	n=1 ○	n=3 ○	n=1 ○
2-Chloronapthalene	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Acenaphthene	0.00671 mg/kg	0.0889 mg/kg	2*	n=6 ○	n=6 ○	n=5 ○	n=2 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=5 ○	n=1 ○	n=6 ○	n=1 ○	n=4 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○
Acenaphthylene	0.00587 mg/kg	0.128 mg/kg	2*	n=6 ○	n=6 ○	n=5 ○	n=2 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=5 ○	n=1 ○	n=6 ○	n=1 ○	n=4 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○
Acridine	-	-	0.001	-	-	-	-	-	-	-	-	-	-	-	-	-	n=1 ○	n=1 ○	n=3 ◕	n=1 ●
Anthracene	0.0469 mg/kg	0.245 mg/kg	2*	n=6 ○	n=6 ○	n=5 ○	n=2 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=5 ○	n=1 ○	n=6 ○	n=1 ○	n=4 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○
Benz[a]anthracene	0.0317 mg/kg	0.385 mg/kg	2*	n=6 ○	n=6 ○	n=5 ○	n=2 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=5 ○	n=1 ○	n=6 ◕	n=1 ○	n=4 ◔	n=2 ○	n=2 ○	n=6 ○	n=2 ○
Benzo[a]pyrene	0.0319 mg/kg	0.782 mg/kg	2*	n=6 ○	n=6 ○	n=5 ○	n=2 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=5 ○	n=1 ○	n=6 ◕	n=1 ○	n=4 ◔	n=2 ○	n=2 ○	n=6 ○	n=2 ○
Benzo[b]flouranthene	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Benzo[b,j,k]fluoranthene	-	-	0.0187	n=6 ◑	n=6 ○	n=5 ○	n=2 ○	n=6 ○	n=6 ○	n=6 ◔	n=6 ○	n=5 ◕	n=1 ○	n=6 ●	n=1 ○	n=4 ◕	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Benzo[c]phenanthrene	-	-	0.001	-	-	-	-	-	-	-	-	-	-	-	-	-	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Benzo[e]pyrene	-	-	0.001	-	-	-	-	-	-	-	-	-	-	-	-	-	n=1 ○	n=1 ○	n=3 ◕	n=1 ○
Benzo[g,h,i]perylene	-	-	4	n=6 ○	n=6 ○	n=5 ○	n=2 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=5 ○	n=1 ○	n=6 ○	n=1 ○	n=4 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○
Benzo[k]fluoranthene	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Biphenyl	-	-	0.003	n=6 ●	n=6 ○	n=5 ○	n=2 ●	n=6 ●	n=6 ◕	n=6 ○	n=6 ◔	n=5 ●	n=1 ○	n=6 ●	n=1 ○	n=4 ◑	-	-	-	-
C1-Acenaphthenes	-	-	0.004	n=6 ○	n=6 ○	n=5 ○	n=2 ○	n=6 ◑	n=6 ◔	n=6 ○	n=6 ○	n=5 ◔	n=1 ○	n=6 ◔	n=1 ○	n=4 ○	-	-	-	-
C1-Benzo[a]anthracenes/Chrysenes	-	-	0.016	n=6 ●	n=6 ●	n=5 ○	n=2 ◑	n=6 ◔	n=6 ◔	n=6 ●	n=6 ●	n=5 ●	n=1 ○	n=6 ●	n=1 ○	n=4 ●	-	-	-	-
C1-Benzofluoranthenes/Benzopyrenes	-	-	0.023	n=6 ●	n=6 ●	n=5 ○	n=2 ○	n=6 ○	n=6 ○	n=6 ●	n=6 ○	n=5 ●	n=1 ○	n=6 ●	n=1 ○	n=4 ●	-	-	-	-
C1-Biphenyls	-	-	0.003	n=6 ◕	n=6 ○	n=5 ◔	n=2 ○	n=6 ●	n=6 ◑	n=6 ○	n=6 ◔	n=5 ◕	n=1 ○	n=6 ●	n=1 ○	n=4 ◑	-	-	-	-
C1-Dibenzothiophenes	-	-	0.0105	n=6 ◑	n=6 ◕	n=5 ○	n=2 ○	n=6 ○	n=6 ○	n=6 ●	n=6 ○	n=5 ●	n=1 ○	n=6 ●	n=1 ○	n=4 ●	-	-	-	-
C1-Fluoranthenes/Pyrenes	-	-	0.0217	n=6 ●	n=6 ●	n=5 ○	n=2 ○	n=6 ●	n=6 ○	n=6 ●	n=6 ●	n=5 ●	n=1 ○	n=6 ●	n=1 ○	n=4 ●	-	-	-	-
C1-Fluorenes	-	-	0.003	n=6 ●	n=6 ●	n=5 ○	n=2 ●	n=6 ●	n=6 ●	n=6 ●	n=6 ●	n=5 ●	n=1 ●	n=6 ◕	n=1 ●	n=4 ●	-	-	-	-
C1-Naphthalenes	-	-	0.005	n=6 ●	n=6 ○	n=5 ○	n=2 ◑	n=6 ●	n=5 ◑	n=6 ○	n=6 ◕	n=5 ●	n=1 ○	n=6 ●	n=1 ○	n=4 ◕	-	-	-	-
C1-Phenanthrenes/Anthracenes	-	-	0.036	n=6 ◕	n=6 ◔	n=5 ○	n=2 ○	n=6 ○	n=6 ○	n=6 ◑	n=6 ○	n=5 ●	n=1 ○	n=6 ●	n=1 ○	n=4 ●	-	-	-	-
C2-Benzo[a]anthracenes/Chrysenes	-	-	0.012	n=6 ●	n=6 ●	n=5 ○	n=2 ◑	n=6 ◕	n=6 ◑	n=6 ●	n=6 ◕	n=5 ●	n=1 ○	n=6 ●	n=1 ○	n=4 ●	-	-	-	-
C2-Benzofluoranthenes/Benzopyrenes	-	-	0.0211	n=6 ◑	n=6 ●	n=5 ○	n=2 ◑	n=6 ◔	n=6 ○	n=6 ●	n=6 ◔	n=5 ●	n=1 ○	n=6 ●	n=1 ○	n=4 ●	-	-	-	-

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes.

*All values were below the common detection limit, but common detection limit value is higher than published guideline. Samples with concentrations greater than the guideline are highlighted in red.

Legend

○ = All data below detection limit
◔ = 1-25% of data above detection
◑ = 26-50% of data above detection
◕ = 51-75% of data above detection
● = 76-100% of data above detection

Red highlighting indicates guideline exceedence.

Table 11 (Cont'd.)

Analyte	Guideline CCME - ISQG	CCME - PEL	Common Detection Limit (mg/kg)	Station ISL-1	JAC-D1	JAC-D2	JOL-1	KEL-1	MCL-1	MUR-D2	MUR-D3	POC-D1	SAC-D1	SHL-1	SUC-D1	TAR-D1	AB07AD0100	AB07BE0010	AB07CC0030	AB07DD0010
C2-Biphenyls	-	-	0.0008	n=6 ●	n=6 ●	n=5 ●	n=2 ●	n=6 ●	n=6 ●	n=6 ●	n=6 ●	n=5 ●	n=1 ●	n=6 ●	n=1 ●	n=4 ●	-	-	-	-
C2-Dibenzothiophenes	-	-	0.006	n=6 ●	n=6 ●	n=5 ○	n=2 ●	n=6 ●	n=6 ●	n=6 ●	n=6 ●	n=5 ●	n=1 ●	n=6 ●	n=1 ○	n=4 ●	-	-	-	-
C2-Fluoranthenes/Pyrenes	-	-	0.0266	n=6 ●	n=6 ●	n=5 ○	n=2 ○	n=6	n=6 ○	n=6 ●	n=6 ●	n=5 ●	n=1 ○	n=6 ●	n=1 ○	n=4 ●	-	-	-	-
C2-Fluorenes	-	-	0.003	n=6 ●	n=6 ●	n=5 ○	n=2 ●	n=6 ●	n=6 ●	n=6 ●	n=6 ●	n=5 ●	n=1 ●	n=6 ●	n=1 ○	n=4 ●	-	-	-	-
C2-Naphthalenes	-	-	0.0024	n=6 ●	n=6 ●	n=5 ◕	n=2 ●	n=6 ●	n=6 ●	n=6 ●	n=6 ●	n=5 ●	n=1 ●	n=6 ●	n=1 ○	n=4 ●	-	-	-	-
C2-Phenanthrenes/Anthracenes	-	-	0.01	n=6 ●	n=6 ●	n=5 ○	n=2 ●	n=6 ●	n=6 ◕	n=6 ●	n=6 ●	n=5 ●	n=1 ○	n=6 ●	n=1 ○	n=4 ●	-	-	-	-
C3-Dibenzothiophenes	-	-	0.009	n=6 ●	n=6 ●	n=5 ○	n=2 ●	n=6 ●	n=6 ◕	n=6 ●	n=6 ●	n=5 ●	n=1 ○	n=6 ●	n=1 ○	n=4 ●	-	-	-	-
C3-Fluoranthenes/Pyrenes	-	-	0.0583	n=6 ◑	n=6 ●	n=5 ○	n=2 ○	n=6 ○	n=6 ○	n=6 ●	n=6 ○	n=5 ●	n=1 ○	n=6 ●	n=1 ○	n=4 ●	-	-	-	-
C3-Fluorenes	-	-	0.0151	n=6 ●	n=6 ●	n=5 ○	n=2 ●	n=6 ●	n=6 ◕	n=6 ●	n=6 ●	n=5 ●	n=1 ○	n=6 ●	n=1 ○	n=4 ●	-	-	-	-
C3-Naphthalenes	-	-	0.004	n=6 ●	n=6 ●	n=5 ○	n=2 ●	n=6 ●	n=6 ●	n=6 ●	n=6 ●	n=5 ●	n=1 ●	n=6 ●	n=1 ○	n=4 ●	-	-	-	-
C3-Phenanthrenes/Anthracenes	-	-	0.0188	n=6 ●	n=6 ●	n=5 ○	n=2 ●	n=6 ●	n=6 ◕	n=6 ●	n=6 ●	n=5 ●	n=1 ○	n=6 ●	n=1 ○	n=4 ●	-	-	-	-
C4-Dibenzothiophenes	-	-	0.0101	n=6 ●	n=6 ●	n=5 ○	n=2 ●	n=6 ●	n=6 ◑	n=6 ●	n=6 ●	n=5 ●	n=1 ○	n=6 ●	n=1 ○	n=4 ●	-	-	-	-
C4-Naphthalenes	-	-	0.0158	n=6 ●	n=6 ◕	n=5 ○	n=2 ○	n=6 ●	n=6 ◑	n=6 ●	n=6 ◑	n=5 ●	n=1 ○	n=6 ●	n=1 ○	n=4 ●	-	-	-	-
C4-Phenanthrenes/Anthracenes	-	-	0.0751	n=6 ●	n=6 ●	n=5 ○	n=2 ●	n=6 ◕	n=6 ◕	n=6 ●	n=6 ●	n=5 ●	n=1 ●	n=6 ●	n=1 ○	n=4 ●	-	-	-	-
Chrysene	0.0571 mg/kg	0.862 mg/kg	2*	n=6 ○	n=6 ○	n=5 ○	n=2 ○	n=6 ○	n=6 ○	n=6 ◑	n=6 ○	n=5 ◔	n=1 ○	n=6 🔴	n=1 ○	n=4 ◑	n=2 ○	n=2 ○	n=6 ○	n=2 ○
Dibenz[a,h]anthracene	0.00622 mg/kg	0.135 mg/kg	5*	n=6 ○	n=6 ○	n=5 ○	n=2 ○	n=6 ○	n=6 ○	n=6 ◔	n=6 ○	n=5 ◔	n=1 ○	n=6 🔴	n=1 ○	n=4 ◕	n=2 ○	n=2 ○	n=6 ○	n=2 ○
Dibenz[a,h]pyrene	-	-	0.001	-	-	-	-	-	-	-	-	-	-	-	-	-	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Dibenz[a,i]pyrene	-	-	0.001	-	-	-	-	-	-	-	-	-	-	-	-	-	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Dibenz[a,l]pyrene	-	-	0.001	-	-	-	-	-	-	-	-	-	-	-	-	-	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Dibenzothiophene	-	-	0.0241	n=6 ○	n=6 ○	n=5 ○	n=2 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=5 ○	n=1 ○	n=6 ◕	n=1 ○	n=4 ○	-	-	-	-
Fluoranthene	0.111 mg/kg	2.355 mg/kg	2*	n=6 ○	n=6 ○	n=5 ○	n=2 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=5 ○	n=1 ○	n=6 ○	n=1 ○	n=4 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○
Fluorene	0.0212 mg/kg	0.144 mg/kg	2*	n=6 ○	n=6 ○	n=5 ○	n=2 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=5 ○	n=1 ○	n=6 ○	n=1 ○	n=4 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○
Indeno[1,2,3-c,d]-pyrene	-	-	2	n=6 ○	n=6 ○	n=5 ○	n=2 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=5 ○	n=1 ○	n=6 ○	n=1 ○	n=4 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○
Naphthalene	0.0346 mg/kg	0.391 mg/kg	2*	n=6 ○	n=6 ○	n=5 ○	n=2 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=5 ○	n=1 ○	n=6 ○	n=1 ○	n=4 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○
Perylene	-	-	0.001	-	-	-	-	-	-	-	-	-	-	-	-	-	n=1 ●	n=1 ●	n=3 ●	n=1 ●
Phenanthrene	0.0419 mg/kg	0.515 mg/kg	2*	n=6 ○	n=6 ○	n=5 ○	n=2 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=5 ◔	n=1 ○	n=6 🔴	n=1 ○	n=4 ◔	n=2 ○	n=2 ○	n=6 ○	n=2 ○
Pyrene	0.053 mg/kg	0.875 mg/kg	2*	n=6 ○	n=6 ○	n=5 ○	n=2 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=5 ○	n=1 ○	n=6 ◑	n=1 ○	n=4 ○	n=2 ○	n=2 ○	n=6 ○	n=2 ○
Retene	-	-	0.075	n=6 ○	n=6 ◔	n=5 ○	n=2 ●	n=6 ○	n=6 ◔	n=6 ◑	n=6 ◕	n=5 ●	n=1 ●	n=6 ◕	n=1 ○	n=4 ◑	n=1 ○	n=1 ○	n=3 ○	n=1 ○

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes

*All values were below the common detection limit, but common detection limit value is higher than published guideline. Samples with concentrations greater than the guideline are highlighted in red.

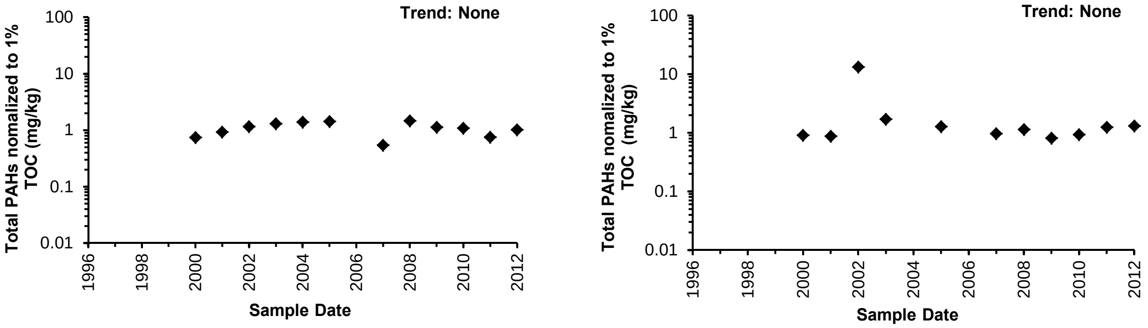
Legend

○ = All data below detection limit
◔ = 1-25% of data above detection
◑ = 26-50% of data above detection
◕ = 51-75% of data above detection
● = 76-100% of data above detection

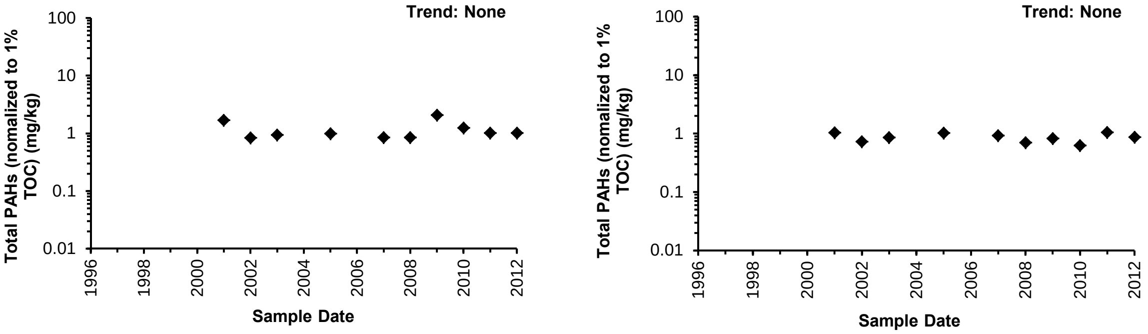
Red highlighting indicates guideline exceedence.

Figure 17 Total PAHs in sediments normalized to 1% Total Organic Carbon at RAMP stations with historical data.

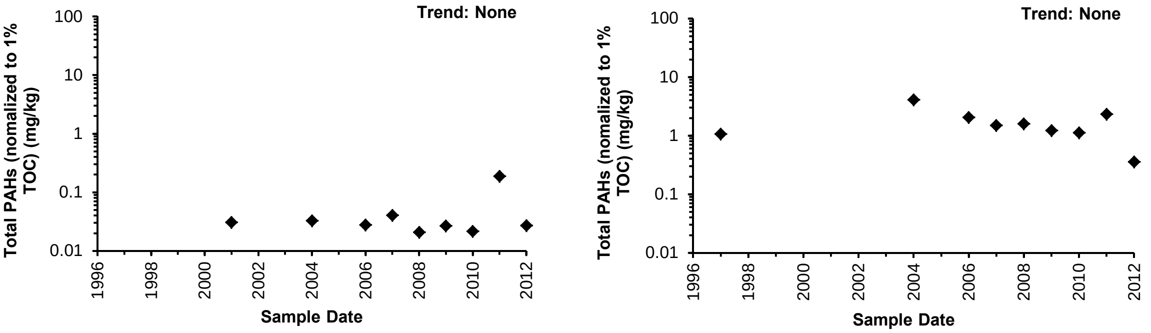
ATR-ER (Athabasca River) **BPC-1** (Big Point Channel)



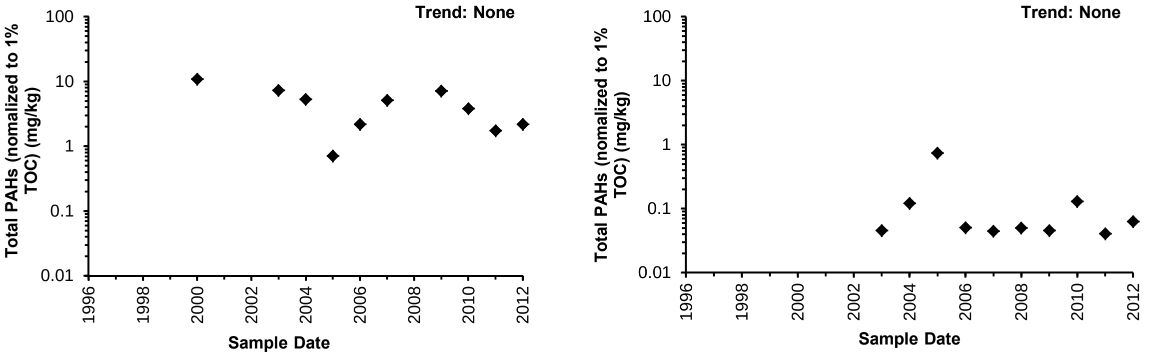
FLC-1 (Fletcher Channel) **GIC-1** (Goose Island Channel)



KEL-1 (Kearl Lake) **JAC-D1** (Jackpine Creek)



MUR-D2 (Muskeg River) **MUR-D3** (Muskeg River)

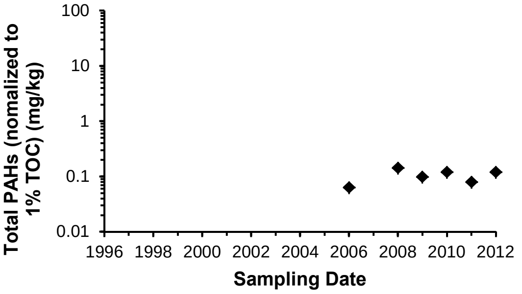


Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

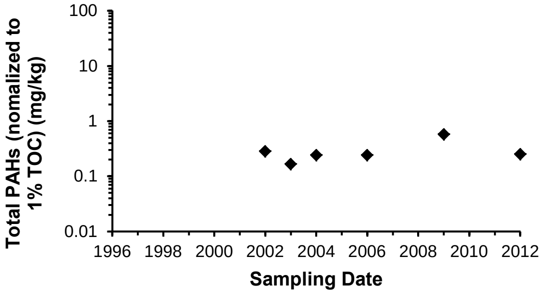
Note: No guideline or detection limit available for Total PAHs in sediments normalized to 1% Total Organic Carbon.

Figure 17 (Cont'd.)

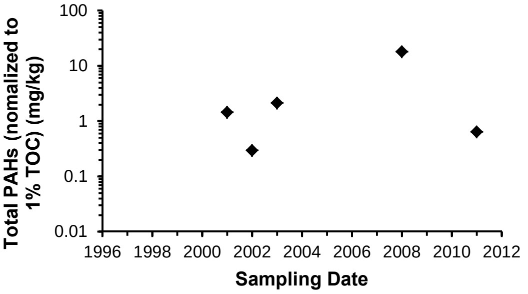
JAC-D1 (Jackpine Creek)



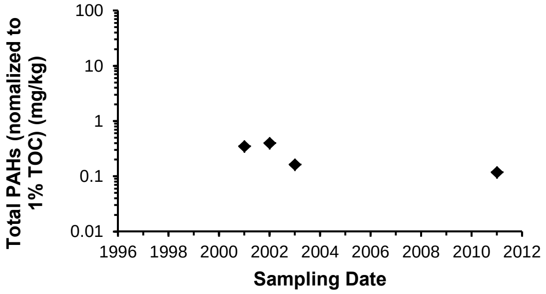
CHR-D2 (Christina River)



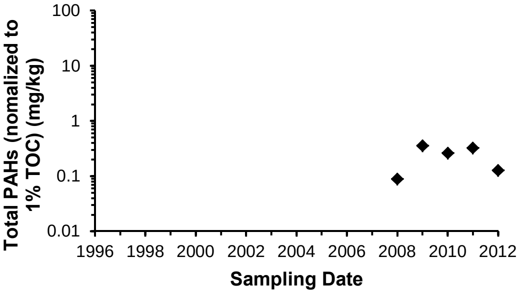
CLR-D1 (Clearwater River)



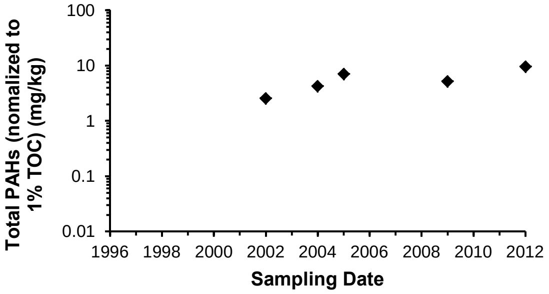
CLR-D2 (Clearwater River)



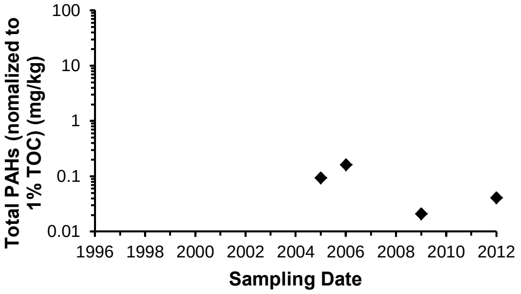
BER-D2 (Beaver River)



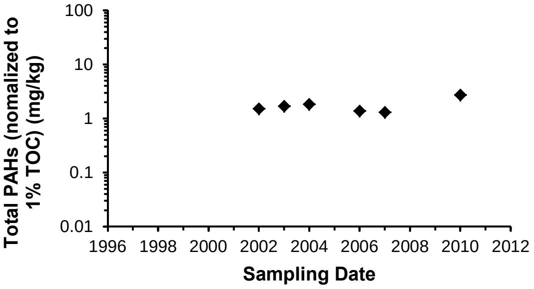
CAR-D1 (Calumet River)



CAR-D2 (Calumet River)



FIR-D1 (Firebag River)



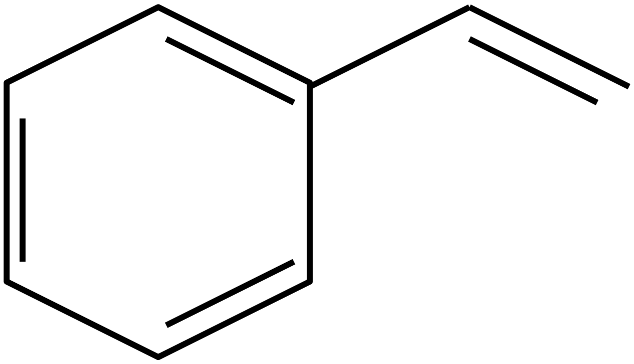
Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

Note: No guideline or detection limit available for Total PAHs in sediments normalized to 1% Total Organic Carbon.

3.3 OTHER AROMATIC HYDROCARBONS

Other aromatic hydrocarbons considered consisted of organic compounds with one or more benzene rings as part of their structure (Williams et al. 2006), and did not include PAHs or total hydrocarbons (Figure 18). Similar to PAHs and total hydrocarbons, these organic compounds can be found in freshwater ecosystems from natural (i.e., from erosion of bituminous geological formations) or anthropogenic (i.e., evaporation of process water, bitumen upgrading processes, or vehicle emissions) sources.

Figure 18 Structural formula of aromatic hydrocarbon styrene.



3.3.1 Data Availability

3.3.1.1 Water Quality

Aromatic hydrocarbons data for surface waters were obtained from AESRD (Figure 19). AESRD provided current aromatics data for six stations within the Athabasca watershed. No data were available for aromatic hydrocarbons in surface water for the McLeod, Pembina, La Biche, Clearwater, or Lake Athabasca sub-watersheds.

3.3.1.2 Sediment Quality

Aromatic hydrocarbons data for sediments were obtained from four AESRD LTRN stations (Figure 19). No data were available for aromatic hydrocarbons in sediment for the McLeod, Pembina, Lesser Slave, La Biche, Clearwater, or Lake Athabasca sub-watersheds.

3.3.2 Other Aromatic Hydrocarbons in Water

3.3.2.1 2012 Spatial Comparisons

Given all 2012 data for aromatic hydrocarbons in surface waters were below detection (i.e., <0.1 to 0.2 µg/L) for all stations, spatial comparisons were not conducted.

3.3.2.2 Compilation of Current Aromatic Hydrocarbons in Water and Comparison with Guidelines

Aromatic hydrocarbons in surface waters were below detection (i.e., <0.1 to <0.2 µg/L) at all AESRD stations, with the exception of 1,2,4-trimethylbenzene, which was detected in one sample downstream of Devil's Elbow at Winter Road (AESRD station: AB07DD0105) in 2007 (Table 12). No guidelines were exceeded for any aromatic hydrocarbons at any station, although few published guidelines were available.

3.3.2.3 Historical Trend Analysis

Trend analysis was not conducted on any AESRD surface water stations, given all aromatic hydrocarbons had more than 50% non-detectable values, making it difficult to determine any trends over time.

3.3.3 Other Aromatic Hydrocarbons in Sediment

3.3.3.1 2012 Spatial Comparisons

Given only 2008 data were available for aromatic hydrocarbons in sediments, spatial comparisons were not conducted.

3.3.3.2 Compilation of Current Aromatic Hydrocarbons in Sediment and Comparison with Guidelines

Aromatic compounds in sediments were below detection (i.e., <2 to <4 mg/kg) at all AESRD stations (Table 13).

3.3.3.3 Historical Trend Analysis

Only 2008 data were available for aromatic hydrocarbons in sediments; therefore, historical trend analysis was not conducted on any AESRD sediment stations.

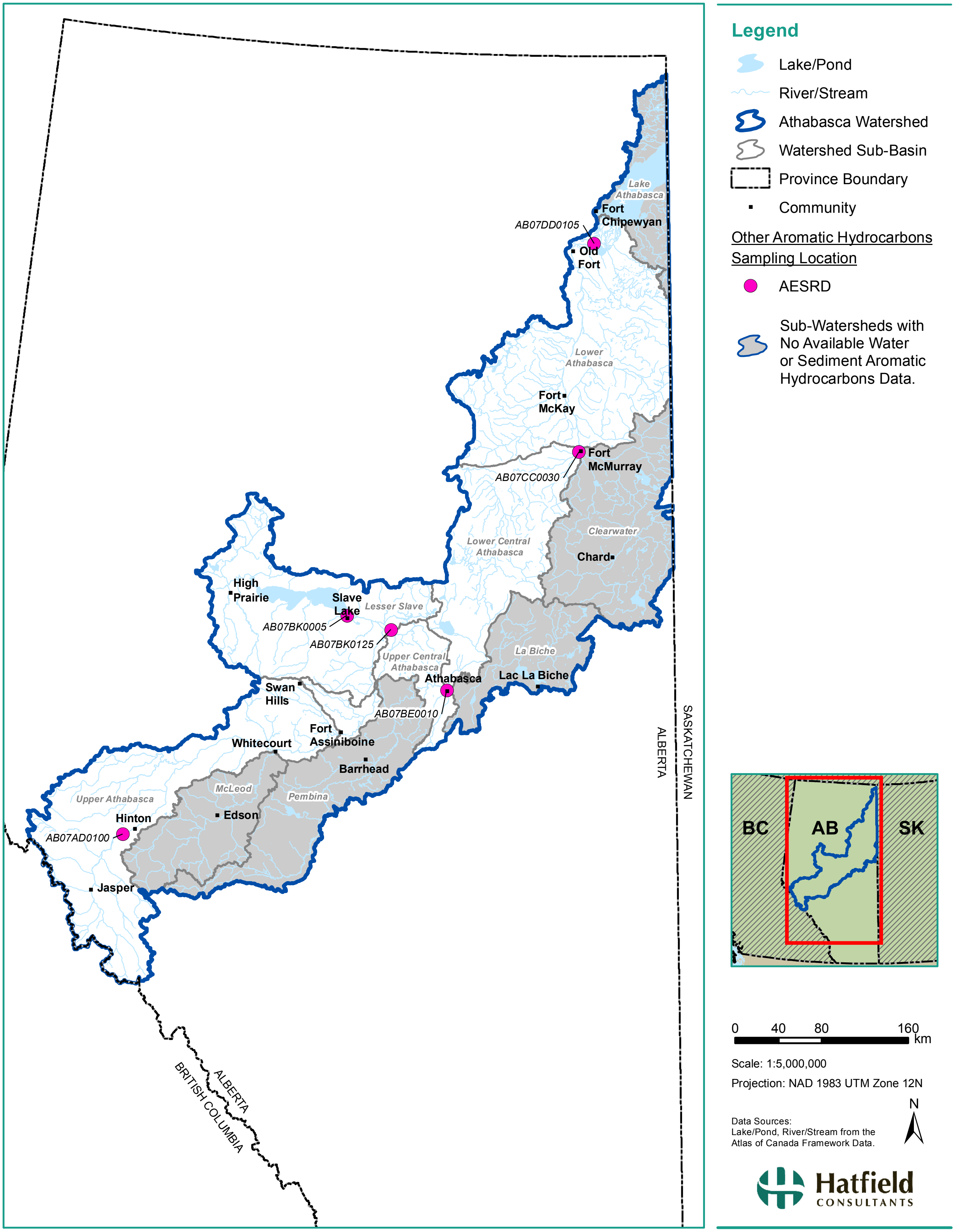
3.3.4 Overall Assessment: Other Aromatic Hydrocarbons

- Most surface water and sediment aromatic hydrocarbons data were obtained from four LTRN stations located in the Upper Athabasca, Upper Central Athabasca, Lower Central Athabasca, and Lower Athabasca sub-watersheds, indicating a general gap in sampling of aromatic hydrocarbons throughout the rest of the Athabasca watershed.

- Sediment data were particularly sparse for aromatic hydrocarbons in the Athabasca watershed given that only 2008 data were available for the current period.

- All aromatic hydrocarbons in surface waters were below detection at all stations, with the exception of 1,2,4-trimethylbenzene, which was detected in one sample downstream of Devil's Elbow at Winter Road (AESRD station: AB07DD0105) in 2007. All aromatic hydrocarbons in sediments were below detection at all stations.

Figure 19 Sampling locations for other aromatic hydrocarbons in water and sediment.



Scale: 1:5,000,000

Projection: NAD 1983 UTM Zone 12N

Data Sources:
Lake/Pond, River/Stream from the Atlas of Canada Framework Data.

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Table 12 Other aromatic hydrocarbons in surface water at AESRD stations with at least one year of current data available.

Analyte	Guideline (µg/L)			Common Detection Limit (µg/L)	Station					
					Upper Athabasca	Upper Central Athabasca	Lesser Slave		Lower Central Athabasca	Lower Athabasca
	AESRD (2013)	CCME	BC		AB07AD0100	AB07BE0010	AB07BK0005	AB07BK0125	AB07CC0030	AB07DD0105
1,2,4-trimethylbenzene	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	n=2 ○	n=3 ○	n=3 ◑
1.2-diphenylhydrazine	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	n=2 ○	n=3 ○	n=3 ○
1,3,5-trimethylbenzene	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	n=2 ○	n=3 ○	n=3 ○
2,4-dinitrotoluene	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	n=2 ○	n=3 ○	n=3 ○
2,6-dinitrotoluene	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	n=2 ○	n=3 ○	n=3 ○
4-bromophenyl phenyl ether	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	n=2 ○	n=3 ○	n=3 ○
Benzidine	-	-	-	0.2	n=3 ○	n=3 ○	n=1 ○	n=2 ○	n=3 ○	n=3 ○
Bromobenzene	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	n=2 ○	n=3 ○	n=3 ○
Isopropylbenzene	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	n=2 ○	n=3 ○	n=3 ○
N-butylbenzene	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	n=2 ○	n=3 ○	n=3 ○
Nitrobenzene	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	n=2 ○	n=3 ○	n=3 ○
N-propylbenzene	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	n=2 ○	n=3 ○	n=3 ○
P-isopropyltoluene	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	n=2 ○	n=3 ○	n=3 ○
Sec-butylbenzene	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	n=2 ○	n=3 ○	n=3 ○
Styrene	72	72	-	0.1	n=3 ○	n=3 ○	n=1 ○	n=2 ○	n=3 ○	n=3 ○
Tert-butylbenzene	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	n=2 ○	n=3 ○	n=3 ○
N-nitrosodiphenylamine	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	n=2 ○	n=3 ○	n=3 ○

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes.

Legend

○= All data below detection limit
◔= 1-25% of data above detection
◑= 26-50% of data above detection
◕= 51-75% of data above detection
●= 76-100% of data above detection

Red highlighting indicates guideline exceedence.

Table 13 Other aromatic hydrocarbons in sediments at AESRD stations with at least one year of current data available.

Analyte	Guideline		Common Detection Limit (mg/kg)	Station			
				Upper Athabasca	Upper Central Athabasca	Lower Central Athabasca	Lower Athabasca
	CCME - ISQG	CCME - PEL		AB07AD0100	AB07BE0010	AB07CC0030	AB07DD0010
1,2-diphenylhydrazine	-	-	2	n=1 ○	n=1 ○	n=3 ○	n=1 ○
2,4-dinitrotoluene	-	-	2	n=1 ○	n=1 ○	n=3 ○	n=1 ○
2,6-dinitrotoluene	-	-	2	n=1 ○	n=1 ○	n=3 ○	n=1 ○
4-bromophenyl phenyl ether	-	-	2	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Benzidine	-	-	4	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Nitrobenzene	-	-	2	n=1 ○	n=1 ○	n=3 ○	n=1 ○
N-nitrosodiphenylamine	-	-	2	n=1 ○	n=1 ○	n=3 ○	n=1 ○

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes.

Legend

○ = All data below detection limit
◔ = 1-25% of data above detection
◑ = 26-50% of data above detection
◕ = 51-75% of data above detection
● = 76-100% of data above detection

Red highlighting indicates guideline exceedence.

3.4 PESTICIDES

Pesticides are chemical compounds used to control or destroy pests and protect humans and their crops from other organisms. Depending on their chemical structure, pesticides will behave differently according to the following: their water solubility and affinity for soil, sediment, and organic particles; their persistence and susceptibility to transport, dissipation, or degradation by volatilization, photodegradation (i.e., broken down by exposure to light), and microbial action; their tendency to bioaccumulate (i.e., build up in and on an organism) or biomagnify (i.e., increase in concentration from one trophic level to the next); and their effects on living organisms. Pesticides in aquatic ecosystems can originate from runoff from agricultural fields or leaching of water through agricultural fields to groundwater systems, through deposition of volatilized compounds or pesticide-adsorbed dust particles, and through spills (Phelan 2012, ARD 2010, Stephenson & Solomon 2007).

In Alberta, large-scale pesticide use is common in agricultural areas, and pesticides have been detected in surface water samples from Alberta's streams and irrigation canals across the province (Phelan 2012). Furthermore, in modern forestry practices, pesticides (herbicides in particular) have been used to increase reforestation success and long-term timber yields through increases in tree survival and growth (Wagner et al. 2004). Pesticides are of interest in aquatic ecosystems due to their potential negative effects on aquatic organisms. For example, several pesticides have been identified as having endocrine-disrupting properties (Anderson 2005) and nine of the 12 "Dirty Dozen" persistent organic pollutants (POPs) targeted for elimination or reduction by the Stockholm Convention are organochlorine pesticides, including: aldrin, dieldrin, DDT, endrin, chlordane, hexachlorobenzene, mirex, toxaphene, and heptachlor (UNIDO 2013). A recent study also found that agricultural pesticides reduced both species and family richness of aquatic invertebrates (Beketov et al. 2013). However, the toxicity of pesticides to aquatic organisms is dependent on the species, exposure time, dose rate, and persistence of the pesticide in the environment (Helfrich et al 2009).

Pesticides are often grouped by the species that they are intended to control (i.e., herbicides (plants), insecticides (insects), and fungicides (fungi) (Anderson 2005), therefore all pesticides data will be grouped accordingly.

3.4.1 Data Availability

3.4.1.1 Water Quality

Current data for fungicides in surface water were available from 13 AESRD stations (Figure 20). Herbicide data were available for 15 AESRD stations and one EC (JOSM) station (Figure 20). Insecticide data were available for 16 AESRD stations (Figure 20). No data were available for pesticides in surface water for the McLeod, La Biche, Clearwater, or Lake Athabasca sub-watersheds.

3.4.1.2 Sediment Quality

Only one year of current data (i.e., 2008) were available for pesticides (i.e., fungicides, herbicides, and insecticides) in sediments from four AESRD LTRN stations (Figure 20). No data were available for pesticides in sediment for the McLeod, Pembina, Lesser Slave, La Biche, Clearwater, or Lake Athabasca sub-watersheds.

3.4.2 Fungicides in Water

3.4.2.1 2012 Spatial Comparisons

Given all 2012 data for fungicides in surface waters were below detection (i.e., <0.005 to <0.1µg/L) for all stations, spatial comparisons were not conducted.

3.4.2.2 Compilation of Current Fungicides in Water and Comparison with Guidelines

All fungicides in surface water were below detection (i.e., <0.005 to <0.1 µg/L) for all AESRD stations (Table 14). No guidelines were exceeded for any fungicides at any station, although only one guideline was available for fungicides in surface waters.

3.4.2.3 Historical Trend Analysis

Given that numerous pesticides were measured in surface waters, trend analysis was limited to those pesticides that were listed as the top agricultural active ingredients sold in Alberta (with available historical data): 2,4-D, MCPA, Triallate, Ethalfuralin, Bromoxynil, Trifluralin, Imazamethabenz-methyl A/B, Chlorpyrifos, and Dicamba (Byrtus 2011, Environment Canada 2011). No fungicides were listed as the top agricultural active ingredients sold in Alberta; therefore, trend analysis was not conducted on any fungicides in surface waters.

3.4.3 Fungicides in Sediment

3.4.3.1 2012 Spatial Comparisons

Given only 2008 data were available for fungicides in sediments, spatial comparisons were not conducted.

3.4.3.2 Compilation of Current Fungicides in Sediment and Comparison with Guidelines

All fungicides measured in sediments were below detection (i.e., <0.005 to <0.05 mg/kg) for all four AESRD LTRN stations (Table 15). No CCME guidelines were available for the fungicide species measured.

3.4.3.3 Historical Trend Analysis

Given fungicides were only measured in 2008, and no fungicides were listed as the top agricultural active ingredients sold in Alberta, historical trend analysis was not conducted on any AESRD sediment stations.

3.4.4 Herbicides in Water

3.4.4.1 2012 Spatial Comparisons

Given all 2012 data for herbicides in surface waters were below detection (i.e., <0.005 to <0.2 µg/L) for all stations, spatial comparisons were not conducted.

3.4.4.2 Compilation of Current Herbicides in Water and Comparison with Guidelines

The majority of herbicides in surface water were below detection (i.e., <0.005 to <1 µg/L) for all AESRD stations (Table 16). However, concentrations of nine herbicides: 2,4-D (dichlorophenoxyacetic acid), Clopyralid (Lontrel), Dicamba (Banvel), Glyphosate (Roundup), Imazamethabenz-methyl, MCPA, MCPP (Mecoprop), Picloram (Tordon), and Triclopyr were detected in at least one sample at AESRD station Wabash Creek near Pibroch (AB07BC0540), which is located in an area of heavy agricultural land use within the Pembina sub-watershed (AWC-WPAC 2013). No guidelines were exceeded for any herbicides at any station.

3.4.4.3 Historical Trend Analysis

A total of eight herbicides were listed as the top agricultural active ingredients sold in Alberta (with available historical data): 2,4-D, MCPA, Triallate, Ethalfuralin, Bromoxynil, Trifluralin, Imazamethabenz-methyl A/B, and Dicamba. Historical data for all eight herbicides were plotted for each station and statistical trend analysis was conducted on stations with fewer than 50% non-detectable values.

2,4-D (dichlorophenoxyacetic acid)

2,4-D (dichlorophenoxyacetic acid) was below detection for most years at most stations with the exception of Wabash Creek near Pibroch (AESRD station AB07BC0540), which had multiple detectable samples but showed a significant decreasing trend over time (Figure 21).

MCPA

Similar to 2,4-D, MCPA was below detection for most years at most stations with the exception of Wabash Creek near Pibroch (AESRD station AB07BC0540) which had multiple detectable samples but showed a significant decreasing trend over time (Figure 22).

Triallate

Triallate was below detection for most years at most stations with the exception of Wabash Creek near Pibroch (AESRD station AB07BC0540) which had a few detectable samples but still had greater than 50% non-detectable samples; therefore no statistical trend analysis was conducted (Figure 23).

Ethalfuralin

Ethalfuralin was below detection for all years at all stations (Figure 24); therefore no statistical trend analysis was conducted.

Bromoxynil

Bromoxynil was below detection for all years at all stations (Figure 25); therefore therefore no statistical trend analysis was conducted.

Trifluralin

Trifluralin was below detection for all years at all stations (Figure 26); therefore no statistical trend analysis was conducted.

Imazamethabenz-methyl

Imazamethabenz-methyl was below detection for most years at most stations with the exception of Wabash Creek near Pibroch (AESRD station AB07BC0540) which had a few detectable samples but still had greater than 50% non-detectable samples; therefore no statistical trend analysis was conducted (Figure 27).

Dicamba

Dicamba was below detection for most years at most stations with the exception of Wabash Creek near Pibroch (AESRD station AB07BC0540) which had a few detectable samples but still had greater than 50% non-detectable samples; therefore no statistical trend analysis was conducted (Figure 28). Dicamba detection limits have decreased almost 10-fold from 0.02μg/L in the 1990s to 0.005 μg/L in the 2000s.

3.4.5 Herbicides in Sediment

3.4.5.1 2012 Spatial Comparisons

Given only 2008 data were available for herbicides in sediments, spatial comparisons were not conducted.

3.4.5.2 Compilation of Current Herbicides in Sediment and Comparison with Guidelines

All herbicides measured in sediments were below detection (i.e., <0.005 to <2 mg/kg) for all four AESRD LTRN stations (Table 17). No CCME guidelines were available for the herbicide species measured.

3.4.5.3 Historical Trend Analysis

Historical trend analysis was not conducted on any AESRD sediment stations, given that only one year of herbicide data was available.

3.4.6 Insecticides in Water

3.4.6.1 2012 Spatial Comparisons

Given all 2012 data for insecticides in surface waters were below detection (i.e., <0.005 to <0.2µg/L) for all stations, spatial comparisons were not conducted.

3.4.6.2 Compilation of Current Insecticides in Water and Comparison with Guidelines

All insecticides in surface water were below detection (i.e., <0.005 to <0.2µg/L) for all AESRD stations (Table 18). No guidelines were exceeded for any insecticides at any station.

3.4.6.3 Historical Trend Analysis

One insecticide was listed as a top agricultural active ingredients sold in Alberta (with available historical data): Chlorpyrifos. Historical data for Chlorpyrifos were plotted for each station and statistical trend analysis was conducted on stations with fewer than 50% non-detectable values.

Chlorpyrifos was below detection for all years at all stations (Figure 29) and therefore no statistical trend analysis was conducted.

3.4.7 Insecticides in Sediment

3.4.7.1 2012 Spatial Comparisons

Given that only 2008 data were available for insecticides in sediments, spatial comparisons were not conducted.

3.4.7.2 Compilation of Current Insecticides in Sediment and Comparison with Guidelines

All insecticides measured in sediments were below detection (i.e., <0.005 to <2 mg/kg) for all four AESRD LTRN stations, with the exception of N,N-Diethyl-M-Toluamide (DEET), which was detectable in two of three samples taken from the Athabasca River upstream of Fort McMurray (AB07CC0030) (Table 19). No CCME guidelines exist for the insecticide species measured.

3.4.7.3 Historical Trend Analysis

Given that insecticides were only measured in 2008, historical trend analysis was not conducted on any AESRD sediment stations.

3.4.8 Overall Assessment: Pesticides

- Most surface water and sediment pesticide data were obtained from sub-watersheds in the upper half of the Athabasca watershed indicating a general gap in sampling of pesticides throughout the lower half of the Athabasca watershed.

- Sediment data were particularly sparse for pesticides in the Athabasca watershed given that only 2008 data were available for the current period.

- All fungicides and insecticides in surface waters were below detection at all stations.

- Concentrations of nine herbicides were detected in at least one sample at AESRD station Wabash Creek near Pibroch (AB07BC0540). This station is located in an area of heavy agricultural land use within the Pembina sub-watershed and was last sampled in 2008.

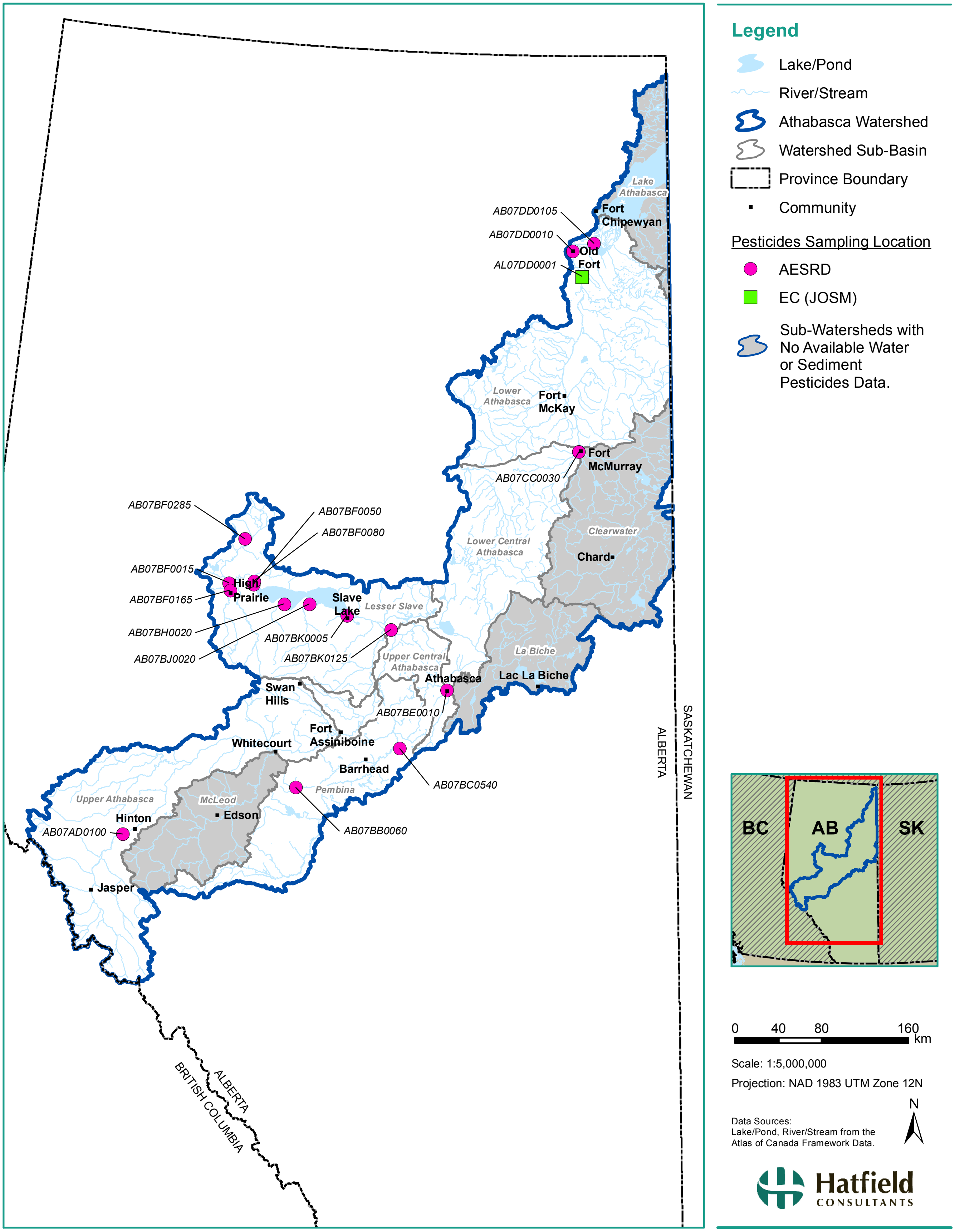
- Only two of the top pesticides sold in Alberta showed significant trends over time: 2,4-D (dichlorophenoxyacetic acid) and MCPA showed significant decreasing trends over time at AESRD station Wabash Creek near Pibroch (AB07BC0540).

- All fungicides and herbicides in sediments were below detection at all stations.

- The insecticide DEET—commonly used in lotions and sprays for human protection against mosquitoes—was detectable in the majority of sediment samples at the Athabasca River upstream of Fort McMurray (AB07CC0030) which is located downstream of most of the areas of heavy agricultural use in Alberta.

- No guidelines were exceeded for any pesticides at any station.

Figure 20 Sampling locations for pesticides in water and sediment.



Scale: 1:5,000,000

Projection: NAD 1983 UTM Zone 12N

Data Sources:
Lake/Pond, River/Stream from the Atlas of Canada Framework Data.

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Table 14 Fungicides in surface water at AESRD stations with at least one year of current data available.

Analyte	Guidelines (µg/L)			Common Detection Limit (µg/L)	Station												
					Upper Athabasca	Pembina		Upper Central Athabasca	Lesser Slave							Lower Central Athabasca	Lower Athabasca
	AESRD (2013)	CCME	BC		AB07AD0100	AB07BB0060	AB07BC0540	AB07BE0010	AB07BF0015	AB07BF0050	AB07BF0080	AB07BF0165	AB07BF0285	AB07BH0020	AB07BJ0020	AB07CC0030	AB07DD0010
Carbathiin (Carboxin)	-	-	-	0.10	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=23 ○	n=26 ○
Chlorothalonil	0.18	-	-	0.005	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=23 ○	n=26 ○
Hexaconazole	-	-	-	0.05	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=23 ○	n=26 ○
Iprodione	-	-	-	0.02	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=23 ○	n=26 ○
Metalaxyl-M	-	-	-	0.01	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=23 ○	n=26 ○
Oxycarboxin	-	-	-	0.05	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=23 ○	n=26 ○
Propiconazole	-	-	-	0.05	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=23 ○	n=26 ○
Vinclozolin	-	-	-	0.01	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=23 ○	n=26 ○

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes.

Legend

○ = All data below detection limit
◔ = 0-25% of data above detection
◑ = 26-50% of data above detection
◕ = 51-75% of data above detection
● = 76-100% of data above detection

Red highlighting indicates guideline exceedence.

Table 15 Fungicides in sediments at AESRD stations with at least one year of current data available.

Analyte	Guideline		Common Detection Limit (mg/kg)	Station			
				Upper Athabasca	Upper Central Athabasca	Lower Central Athabasca	Lower Athabasca
	CCME - ISQG	CCME - PEL		AB07AD0100	AB07BE0010	AB07CC0030	AB07DD0010
Carbathiin (Carboxin)	-	-	0.005	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Chlorothalonil	-	-	0.005	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Hexaconazole	-	-	0.05	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Iprodione	-	-	0.02	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Metalaxyl-M	-	-	0.01	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Oxycarboxin	-	-	0.05	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Propiconazole	-	-	0.05	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Vinclozolin	-	-	0.01	n=1 ○	n=1 ○	n=3 ○	n=1 ○

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes.

Legend

○ = All data below detection limit
◔ = 1-25% of data above detection
◑ = 26-50% of data above detection
◕ = 51-75% of data above detection
● = 76-100% of data above detection

Red highlighting indicates guideline exceedence.

Table 16 Herbicides in surface water at AESRD and EC (JOSM) stations with at least one year of current data available.

Analyte	Guideline (µg/L)			Common Detection Limit (µg/L)	Station															
	AESRD (2013)	CCME	BC		Upper Athabasca	Pembina		Upper Central Athabasca	Lesser Slave								Lower Central Athabasca	Lower Athabasca		
					AB07AD0100	AB07BB0060	AB07BC0540	AB07BE0010	AB07BF0015	AB07BF0050	AB07BF0165	AB07BF0285	AB07BH0020	AB07BJ0020	AB07BK0005	AB07BK0125	AB07CC0030	AB07DD0010	AB07DD0105	AL07DD0001
2,4 & 2,5-Dichlorophenol	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	n=2 ○	-	-	-	-
2,4-D (dichlorophenoxyacetic acid)	4	4	-	0.005	n=23 ○	n=22 ○	n=13 ◑	n=23 ◔	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
2,4-DB	560, 25	-	-	0.0	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
2,4-Dichlorophenol	0.2	0.2	-	0.1	n=54 ○	n=44 ○	n=26 ○	n=54 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ○	n=2 ○	n=4 ○	n=2 ○	n=2 ○	n=54 ○	n=48 ○	n=12 ○	-
4-Chloro-2-methylphenol	-	-	-	0.01	n=42 ○	n=44 ○	n=26 ○	n=42 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ○	n=2 ○	n=4 ○	-	-	n=42 ○	n=48 ○	-	-
Aminomethyl phosphonic acid	-	-	-	1	-	n=22 ○	n=12 ○	-	-	-	-	-	-	-	-	-	-	-	-	-
Aminopyralid	-	-	-	0.01	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
Atrazine	1.8	1.8	-	0.005	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
Bentazon	-	-	-	0.005	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
Bromacil	5	5	-	0.03	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
Bromoxynil	5	5	-	0.005	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
Clodinafop acid metabolite	-	-	-	0.02	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
Clodinafop-propargyl	-	-	-	0.04	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
Clopyralid (Lontrel)	-	-	-	0.02	n=23 ○	n=22 ○	n=13 ◔	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
Cyanazine	2	2	-	0.05	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
Desethyl Atrazine	-	-	-	0.05	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
Desisopropyl Atrazine	-	-	-	0.05	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
Dicamba (Banvel)	10	10	-	0.005	n=23 ○	n=22 ○	n=13 ◔	n=23 ◔	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
Dichlorprop (2,4-DP)	-	-	-	0.005	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
Diclofop-methyl (Hoegrass)	6.1	6.1	-	0.02	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
Diuron	-	-	-	0.2	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
Ethalfluralin (Edge)	-	-	-	0.005	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
Ethofumesate	-	-	-	0.005	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
Fenoxaprop-p-ethyl	-	-	-	0.04	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes

*All values were below the common detection limit, but common detection limit value is higher than published guideline. Samples with concentrations greater than the guideline are highlighted in red

Legend

○ = All data below detection limit
◔ = 1-25% of data above detection
◑ = 26-50% of data above detection
◕ = 51-75% of data above detection
● = 76-100% of data above detection

Red highlighting indicates guideline exceedence.

Table 16 (Cont'd.)

Analyte	Guideline (µg/L)			Common Detection Limit (µg/L)	Station															
					Upper Athabasca	Pembina		Upper Central Athabasca	Lesser Slave								Lower Central Athabasca	Lower Athabasca		
	AESRD (2013)	CCME	BC		AB07AD0100	AB07BB0060	AB07BC0540	AB07BE0010	AB07BF0015	AB07BF0050	AB07BF0165	AB07BF0285	AB07BH0020	AB07BJ0020	AB07BK0005	AB07BK0125	AB07CC0030	AB07DD0010	AB07DD0105	AL07DD0001
Fluazifop	-	-	-	0.01	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
Fluroxypyr	-	-	-	0.01	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
Glufosinate	-	-	-	1	-	n=22 ○	n=12 ○	-	-	-	-	-	-	-	-	-	-	-	-	-
Glyphosate (Roundup)	-	-	-	0.2	-	n=21 ○	n=12 ◑	-	-	-	-	-	-	-	-	-	-	-	-	-
Guthion (Azinphos methyl) (azinphos ethyl)	0.01	-	-	0.2*	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	n=1 ○
Imazamethabenz-methyl	-	-	-	0.05	n=23 ○	n=22 ○	n=13 ◑	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
Imazamox	-	-	-	0.02	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
Imazethapyr	-	-	-	0.02	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
Linuron	7	7	-	0.02	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
MCPA	2.6	-	-	0.005	n=23 ○	n=22 ○	n=13 ◑	n=23 ◔	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ◔	n=26 ○	-	-
MCPB	-	-	-	0.02	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
MCPP (Mecoprop)	1000, 13	-	-	0.005	n=23 ○	n=22 ○	n=13 ◕	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
Metolachlor	7.8	7.8	-	0.005	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
Metribuzin	1	1	-	0.01	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
Napropamide	-	-	-	0.02	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
Picloram (Tordon)	29	29	-	0.005	n=23 ○	n=22 ○	n=13 ◕	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
Quinclorac	-	-	-	0.005	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
Quizalofop	-	-	-	0.030	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
Simazine	10	10	-	0.01	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
Triallate (Avadex bw)	0.24	0.24	-	0.005	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
Triclopyr	-	-	-	0.01	n=23 ○	n=22 ◔	n=13 ◑	n=23 ◔	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-
Trifluralin (Treflan)	0.2	0.2	-	0.005	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-	-

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes

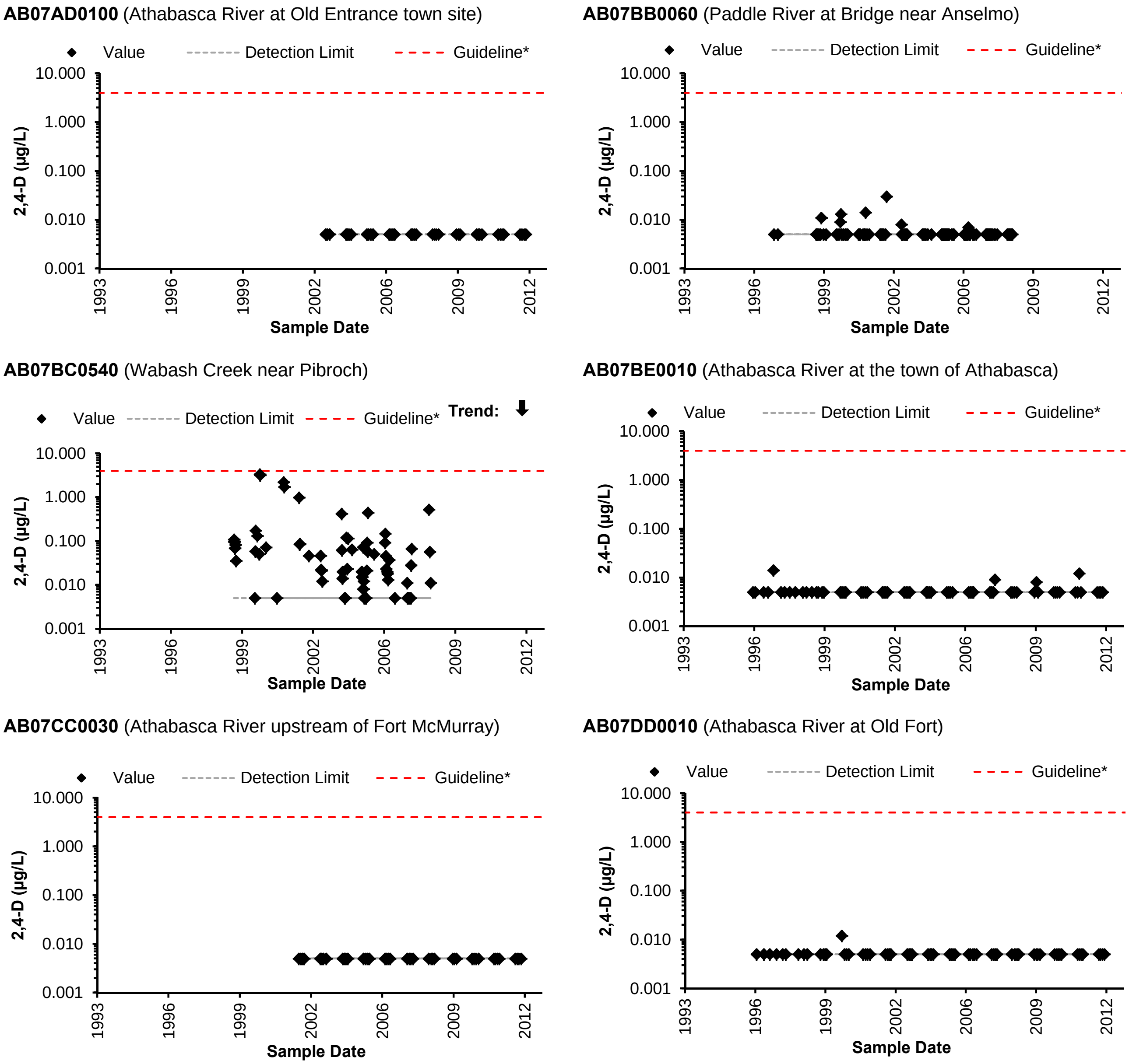
*All values were below the common detection limit, but common detection limit value is higher than published guideline. Samples with concentrations greater than the guideline are highlighted in red

Legend

○ = All data below detection limit
◔ = 1-25% of data above detection
◑ = 26-50% of data above detection
◕ = 51-75% of data above detection
● = 76-100% of data above detection

Red highlighting indicates guideline exceedence.

Figure 21 2, 4-D (dichlorophenoxyacetic acid) (Log Scale) in surface water at AESRD stations with historical datasets.



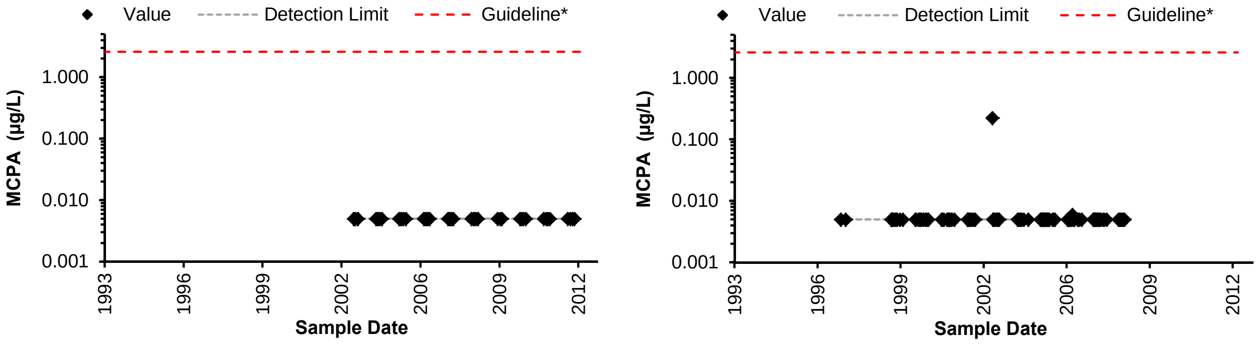
Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

*Guideline value is from CCME (2011) and AESRD (2013a) guidelines for the protection of aquatic life.

Figure 22 MCPA (Log Scale) in surface water at AESRD stations with historical datasets.

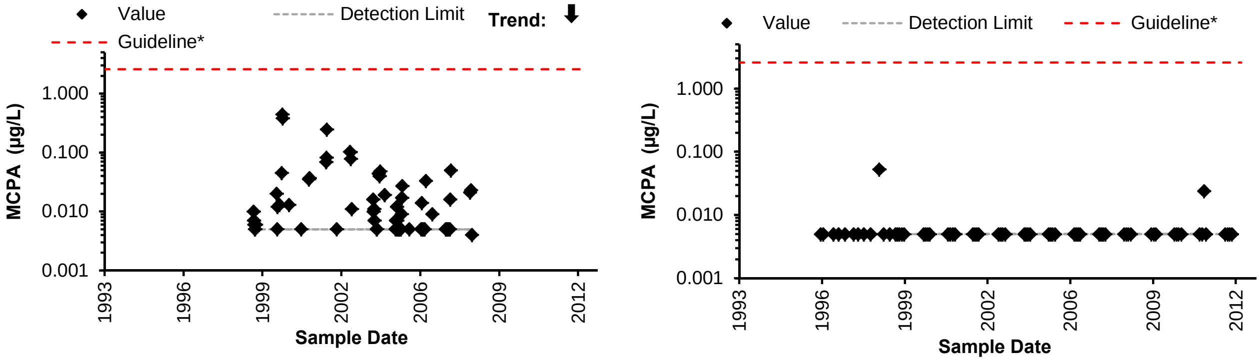
AB07AD0100 (Athabasca River at Old Entrance town site)

AB07BB0060 (Paddle River at Bridge near Anselmo)



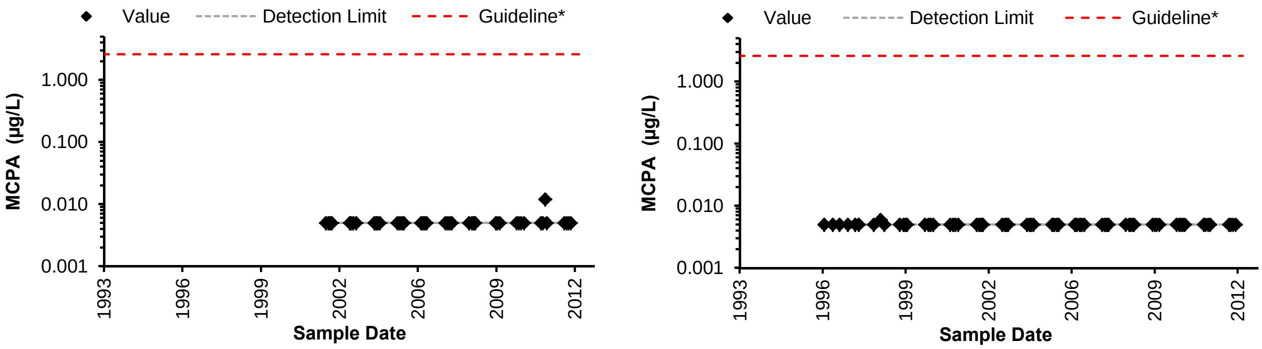
AB07BC0540 (Wabash Creek near Pibroch)

AB07BE0010 (Athabasca River at the town of Athabasca)



AB07CC0030 (Athabasca River upstream of Fort McMurray)

AB07DD0010 (Athabasca River at Old Fort)

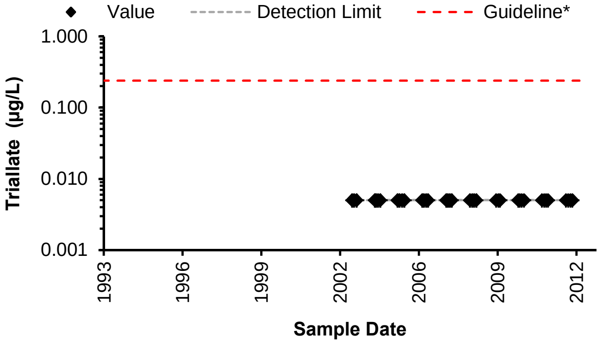


Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

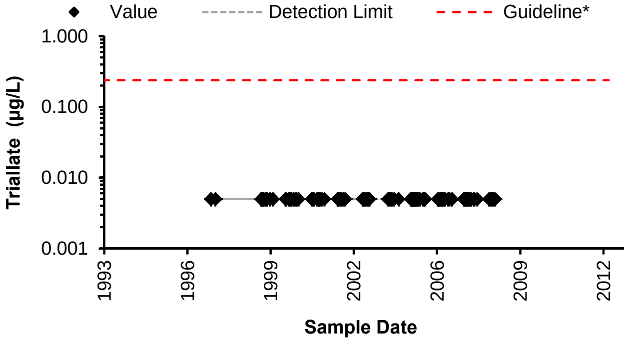
*Guideline value is from AESRD (2013a) guidelines for the protection of aquatic life.

Figure 23 Triallate (Log Scale) in surface water at AESRD stations with historical datasets.

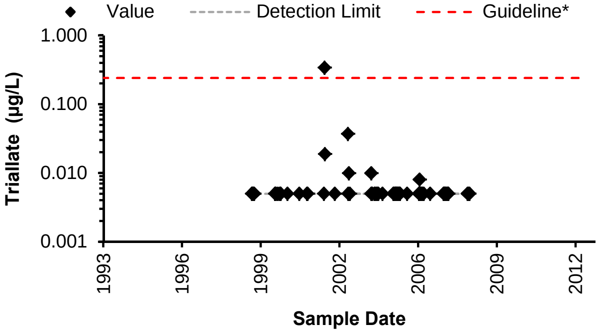
AB07AD0100 (Athabasca River at Old Entrance town site)



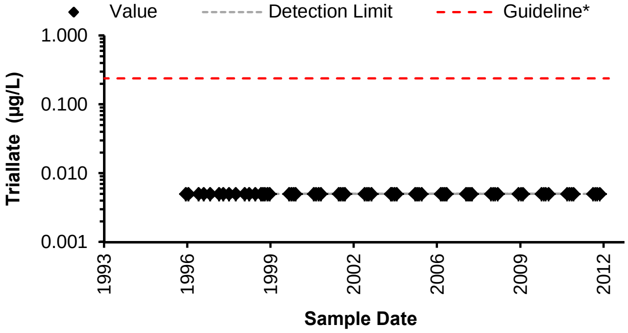
AB07BB0060 (Paddle River at Bridge near Anselmo)



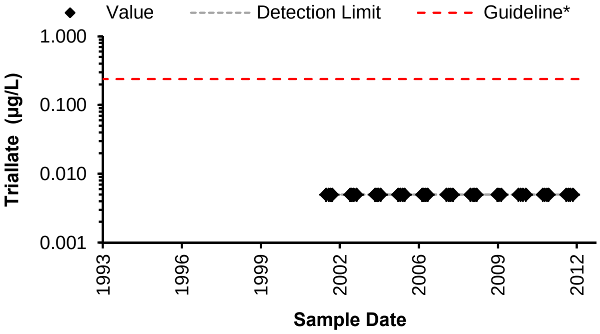
AB07BC0540 (Wabash Creek near Pibroch)



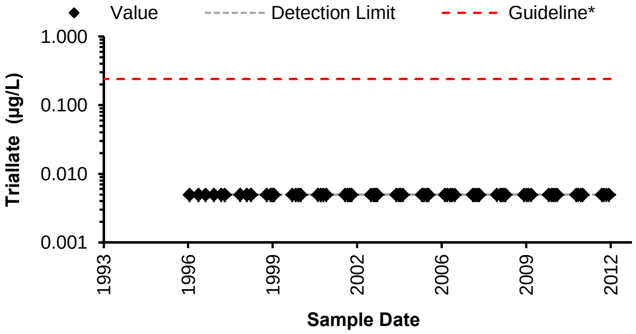
AB07BE0010 (Athabasca River at the town of Athabasca)



AB07CC0030 (Athabasca River upstream of Fort McMurray)



AB07DD0010 (Athabasca River at Old Fort)

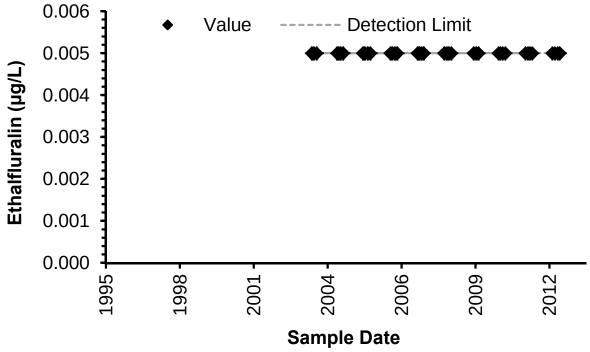


Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

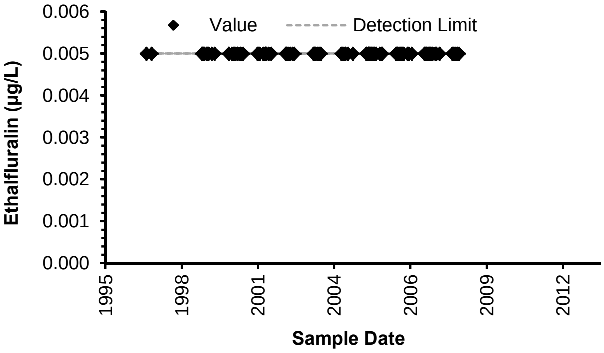
*Guideline value is from CCME (2011) and AESRD (2013a) guidelines for the protection of aquatic life.

Figure 24 Ethalfuralin in surface water at AESRD stations with historical datasets.

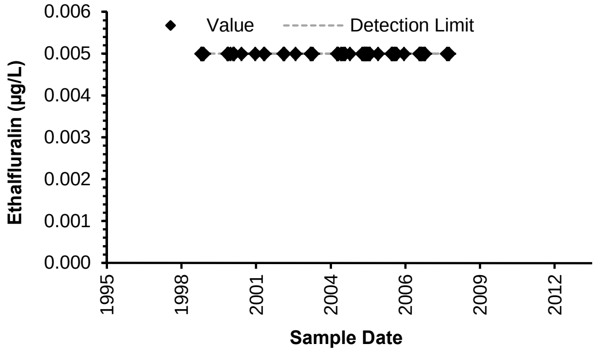
AB07AD0100 (Athabasca River at Old Entrance town site)



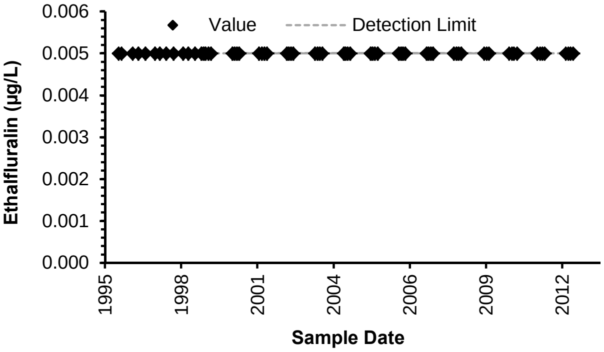
AB07BB0060 (Paddle River at Bridge near Anselmo)



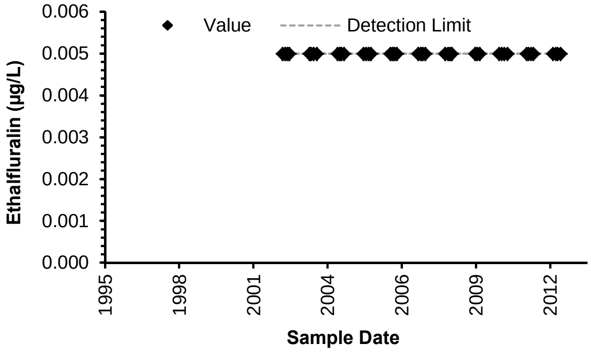
AB07BC0540 (Wabash Creek near Pibroch)



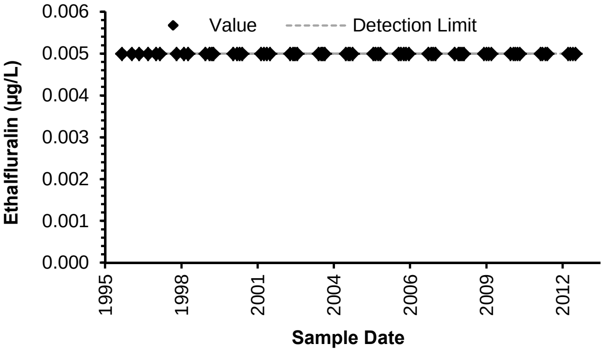
AB07BE0010 (Athabasca River at the town of Athabasca)



AB07CC0030 (Athabasca River upstream of Fort McMurray)



AB07DD0010 (Athabasca River at Old Fort)

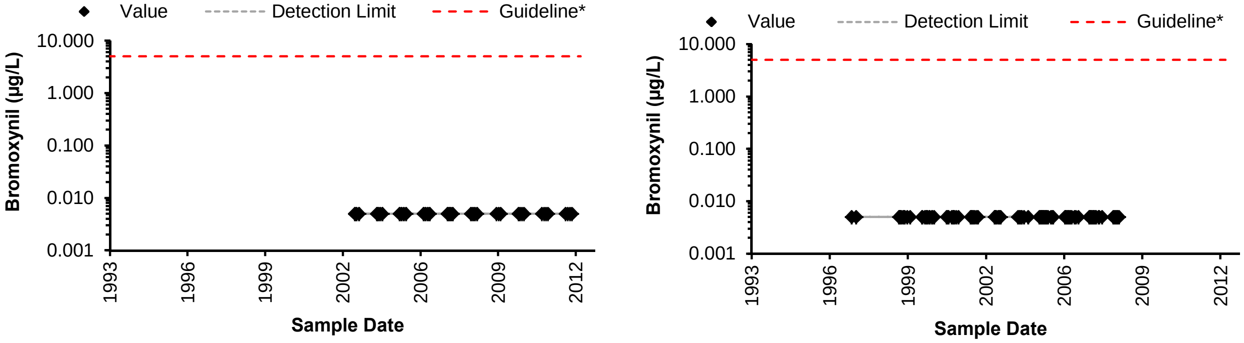


Note: No guideline available for Ethalfuralin.

Figure 25 Bromoxynil (Log Scale) in surface water at AESRD stations with historical datasets.

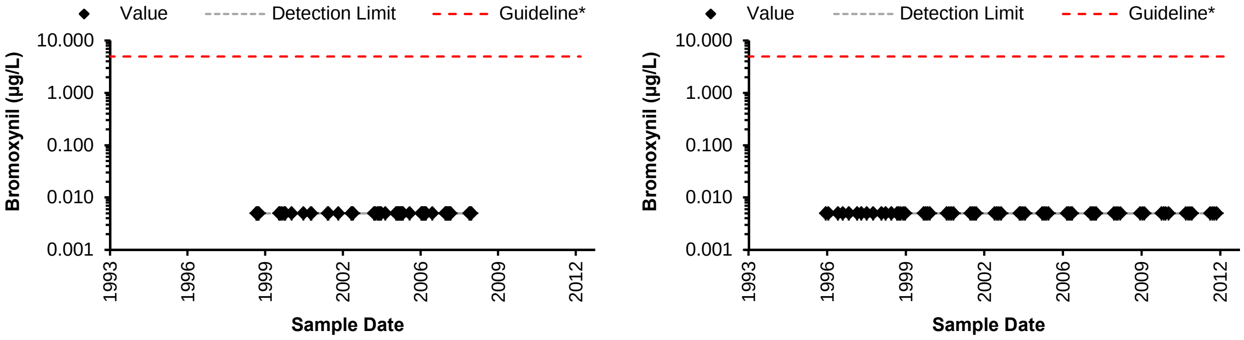
AB07AD0100 (Athabasca River at Old Entrance town site)

AB07BB0060 (Paddle River at Bridge near Anselmo)



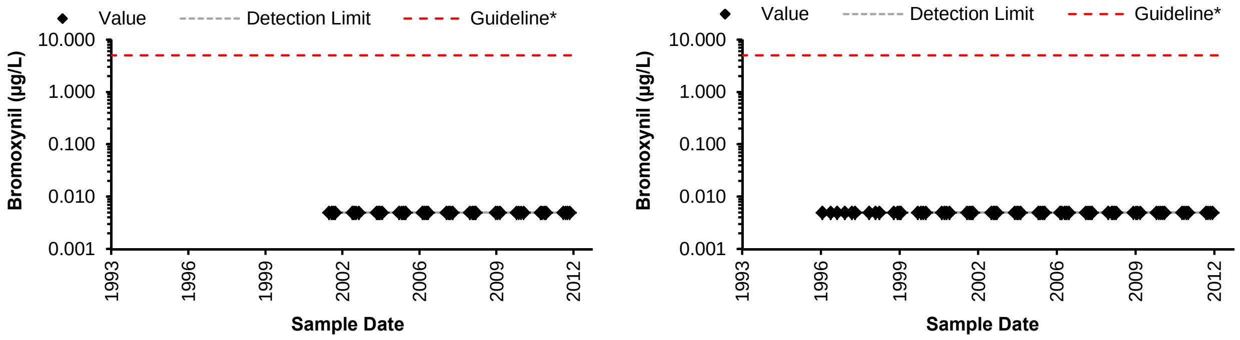
AB07BC0540 (Wabash Creek near Pibroch)

AB07BE0010 (Athabasca River at the town of Athabasca)



AB07CC0030 (Athabasca River upstream of Fort McMurray)

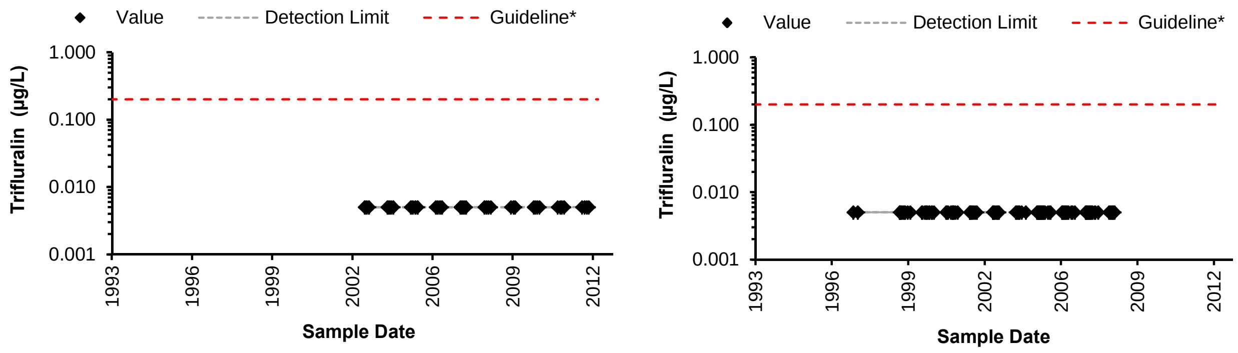
AB07DD0010 (Athabasca River at Old Fort)



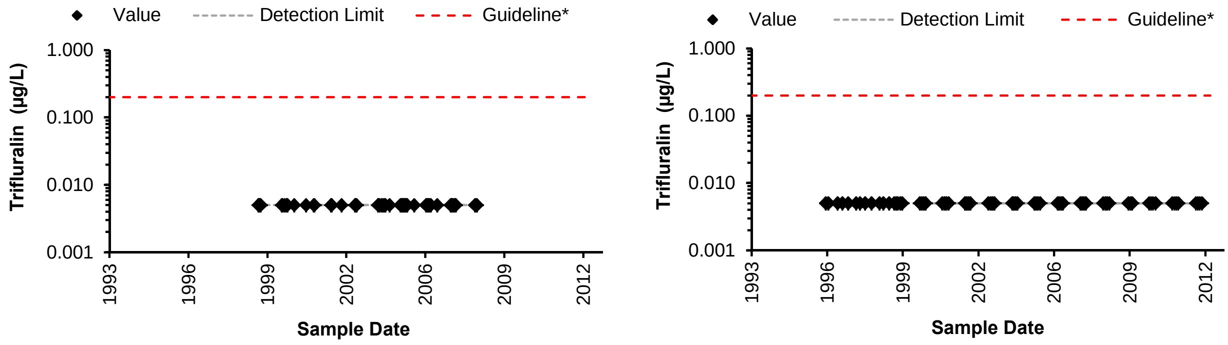
Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

*Guideline value is from CCME (2011) and AESRD (2013a) guidelines for the protection of aquatic life.

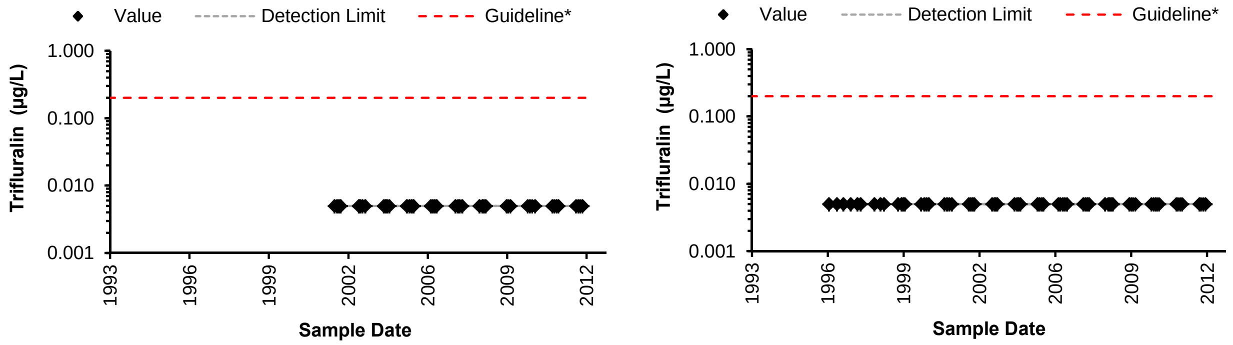
Figure 26 Trifluralin (Log Scale) in surface water at AESRD stations with historical datasets.


AB07AD0100 (Athabasca River at Old Entrance town site)

AB07BB0060 (Paddle River at Bridge near Anselmo)


AB07BC0540 (Wabash Creek near Pibroch)

AB07BE0010 (Athabasca River at the town of Athabasca)


AB07CC0030 (Athabasca River upstream of Fort McMurray)

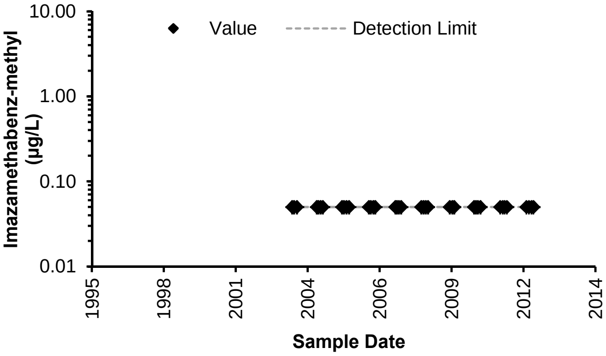
AB07DD0010 (Athabasca River at Old Fort)

Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

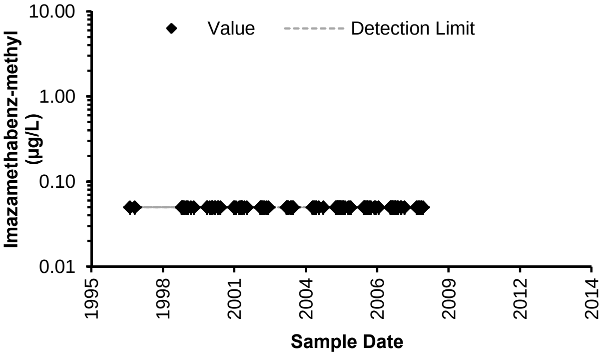
*Guideline value is from CCME (2011) and AESRD (2013a) guidelines for the protection of aquatic life.

Figure 27 Imazamethabenz-methyl (Log Scale) in surface water at AESRD stations with historical datasets.

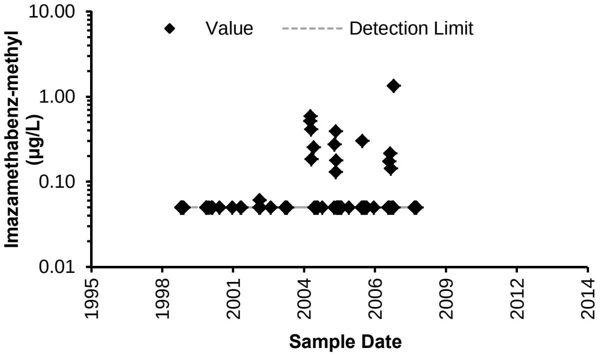
AB07AD0100 (Athabasca River at Old Entrance town site)



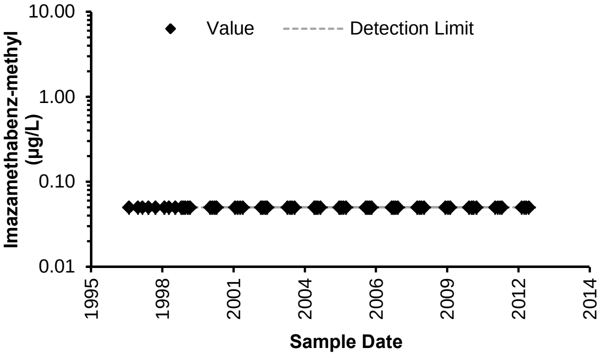
AB07BB0060 (Paddle River at Bridge near Anselmo)



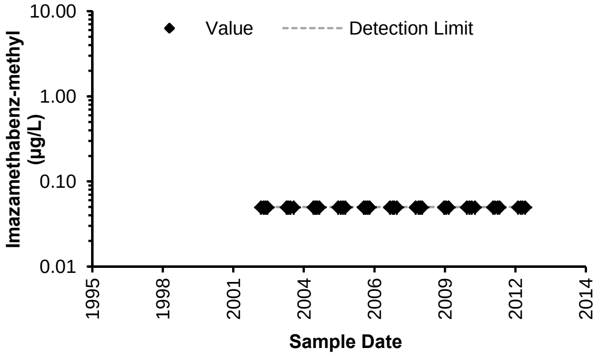
AB07BC0540 (Wabash Creek near Pibroch)



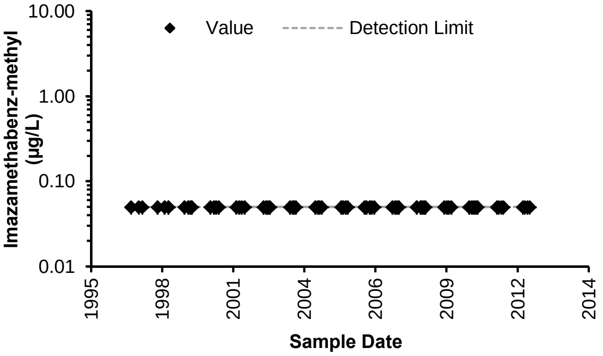
AB07BE0010 (Athabasca River at the town of Athabasca)



AB07CC0030 (Athabasca River upstream of Fort McMurray)



AB07DD0010 (Athabasca River at Old Fort)

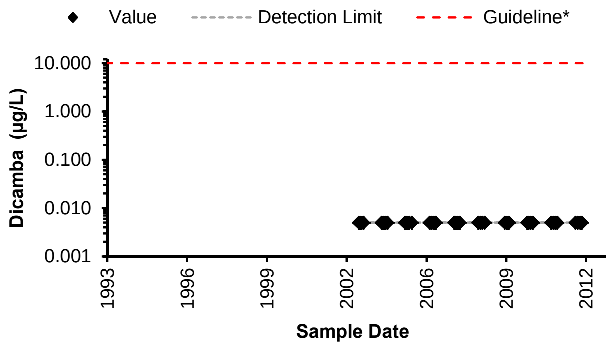


Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

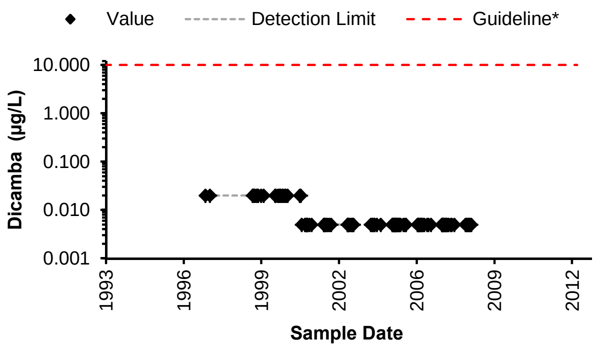
Note: No guideline available for Imazamethabenz-methyl.

Figure 28 Dicamba (Log Scale) in surface water at AESRD stations with historical datasets.

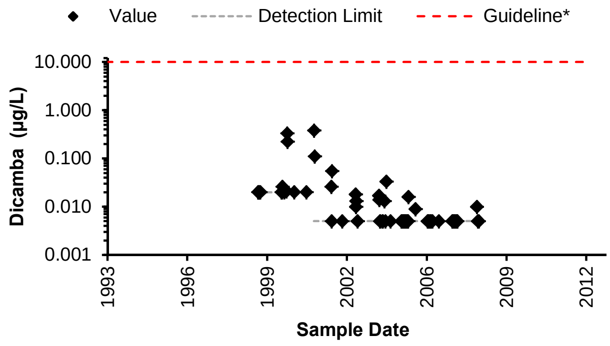
AB07AD0100 (Athabasca River at Old Entrance town site)



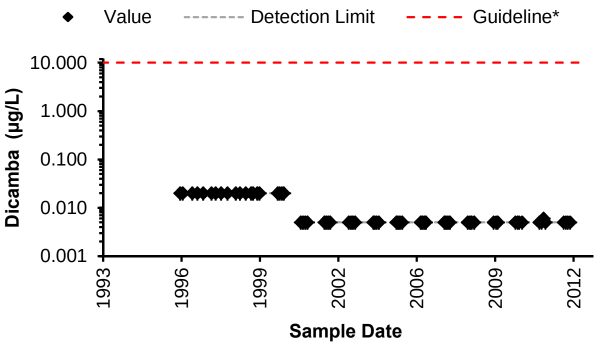
AB07BB0060 (Paddle River at Bridge near Anselmo)



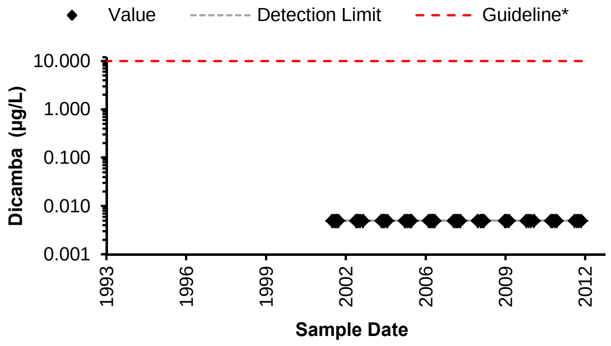
AB07BC0540 (Wabash Creek near Pibroch)



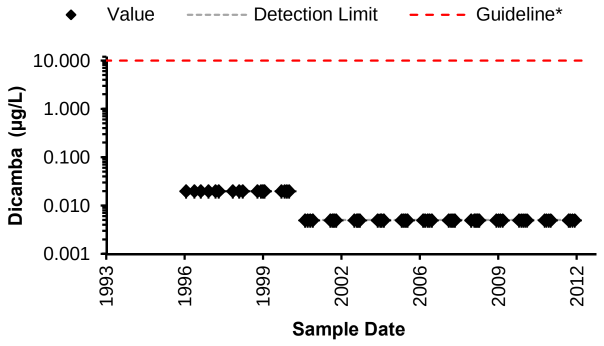
AB07BE0010 (Athabasca River at the town of Athabasca)



AB07CC0030 (Athabasca River upstream of Fort McMurray)



AB07DD0010 (Athabasca River at Old Fort)



Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

*Guideline value is from CCME (2011) and AESRD (2013a) guidelines for the protection of aquatic life.

Table 17 Herbicides in sediments at AESRD stations with at least one year of current data available.

Analyte	Guideline		Common Detection Limit (mg/kg)	Station			
				Upper Athabasca	Upper Central Athabasca	Lower Central Athabasca	Lower Athabasca
	CCME - ISQG	CCME - PEL		AB07AD0100	AB07BE0010	AB07CC0030	AB07DD0010
2,4-D (Dichlorophenoxyacetic Acid)	-	-	0.005	n=1 ○	n=1 ○	n=3 ○	n=1 ○
2,4-DB	-	-	0.005	n=1 ○	n=1 ○	n=3 ○	n=1 ○
2,4-Dichlorophenol	-	-	2	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Alachlor	-	-	0.01	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Atrazine	-	-	0.005	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Bentazon	-	-	0.005	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Bromacil	-	-	0.03	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Bromoxynil	-	-	0.005	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Chlodinafop Acid Metabolite	-	-	0.02	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Chlodinafop-propargyl	-	-	0.04	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Clopyralid (Lontrel)	-	-	0.02	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Cyanazine	-	-	0.05	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Desethyl atrazine	-	-	0.05	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Desisopropyl atrazine	-	-	0.05	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Dicamba (Banvel)	-	-	0.02	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Dichlorprop (2,4-DP)	-	-	0.005	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Diclofop-methyl (Hoegrass)	-	-	0.02	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Diuron	-	-	0.2	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Ethalfluralin (Edge)	-	-	0.005	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Ethofumesate	-	-	0.005	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Fenoxaprop-p-ethyl	-	-	0.04	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Fluazifop	-	-	0.01	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Fluroxypyr	-	-	0.01	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Guthion (Azinphos methyl)	-	-	0.2	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Imazamethabenz-methyl	-	-	0.05	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Imazamox	-	-	0.005	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Imazethapyr	-	-	0.02	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Linuron	-	-	0.02	n=1 ○	n=1 ○	n=3 ○	n=1 ○
MCPA	-	-	0.005	n=1 ○	n=1 ○	n=3 ○	n=1 ○
MCPB	-	-	0.02	n=1 ○	n=1 ○	n=3 ○	n=1 ○
MCPP (Mecoprop)	-	-	0.005	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Metolachlor	-	-	0.005	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Metribuzin	-	-	0.01	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Picloram (Tordon)	-	-	0.005	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Quinclorac	-	-	0.005	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Quinzalofop	-	-	0.03	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Simazine	-	-	0.01	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Triallate (Avadex BW)	-	-	0.005	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Triclopyr	-	-	0.01	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Trifluralin (Treflan)	-	-	0.005	n=1 ○	n=1 ○	n=3 ○	n=1 ○

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes.

Legend

○ = All data below detection limit
◔ = 1-25% of data above detection
◑ = 26-50% of data above detection
◕ = 51-75% of data above detection
●

Red highlighting indicates guideline exceedence.

Table 18 Insecticides in surface water for AESRD stations with at least one year of current data available.

Analyte	Guideline (µg/L)			Common Detection Limit (µg/L)	Station														
					Upper Athabasca	Pembina		Upper Central Athabasca	Lesser Slave									Lower Central Athabasca	Lower Athabasca	
	AESRD(2013)	CCME	BC		AB07AD0100	AB07BB0060	AB07BC0540	AB07BE0010	AB07BF0015	AB07BF0050	AB07BF0080	AB07BF0165	AB07BF0285	AB07BH0020	AB07BJ0020	AB07BK0005	AB07BK0125	AB07CC0030	AB07DD0010	AB07DD0105
Aldicarb	1	1	-	0.1	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-
Aldrin	-	-	-	0.005	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-
Alpha-benzenehexachloride (BHC)	-	-	-	0.005	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-
Alpha-endosulfan	-	-	-	0.005	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-
Chlorpyrifos-ethyl (Dursban)	0.02, 0.002	0.002	-	0.005*	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-
Diazinon	0.17	0.17	-	0.005	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-
Dieldrin	-	-	-	0.005	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-
Dimethoate (Cygon)	6.2	6.2	-	0.05	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-
Disulfoton (Di-Syston)	-	-	-	0.2	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-
Ethion	-	-	-	0.1	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-
Gamma-benzenehexachloride (Lindane)	-	-	-	0.005	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-
Malathion	0.1	-	-	0.05	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-
Methomyl	-	-	-	0.1	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-
Methoxychlor (P,P'-methoxychlor)	0.3	-	-	0.03	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-
Parathion	0.065, 0.013	-	-	0.01	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-
Pentachlorophenol	-	0.5	-	0.1	n=6 ○	-	-	n=6 ○	-	-	-	-	-	-	-	n=1 ○	n=4 ○	n=6 ○	-	n=6 ○
Phorate (Thimet)	-	-	-	0.005	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-
Pyridaben	-	-	-	0.02	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-
Terbufos	-	-	-	0.03	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-
Thiamethoxam	-	-	-	0.05	n=23 ○	n=22 ○	n=13 ○	n=23 ○	n=1 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	n=1 ○	n=2 ○	-	-	n=23 ○	n=26 ○	-

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes.

*All values were below the common detection limit, but common detection limit value is higher than published guideline. Samples with concentrations greater than the guideline are highlighted in red.

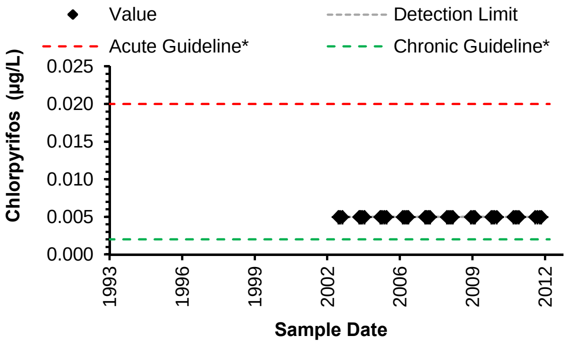
Legend

○	= All data below detection limit
◔	= 1-25% of data above detection
◑	= 26-50% of data above detection
◕	= 51-75% of data above detection
●	= 76-100% of data above detection

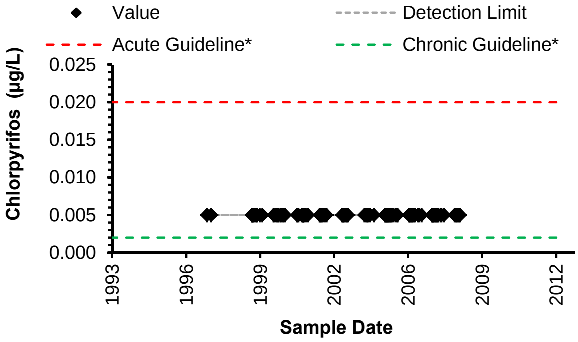
Red highlighting indicates guideline exceedence.

Figure 29 **Chlorpyrifos-ethyl in surface water at AESRD stations with historical datasets.**

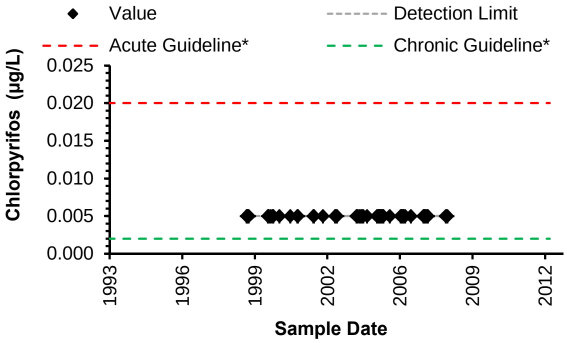
AB07AD0100 (Athabasca River at Old Entrance town site)



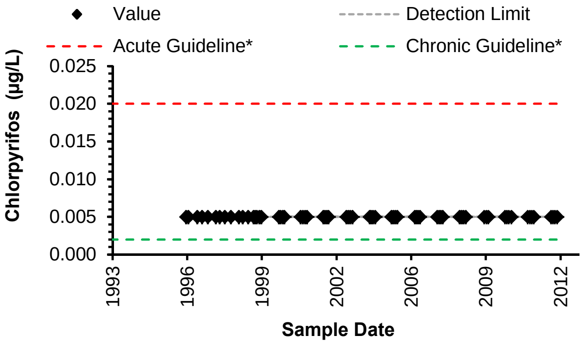
AB07BB0060 (Paddle River at Bridge near Anselmo)



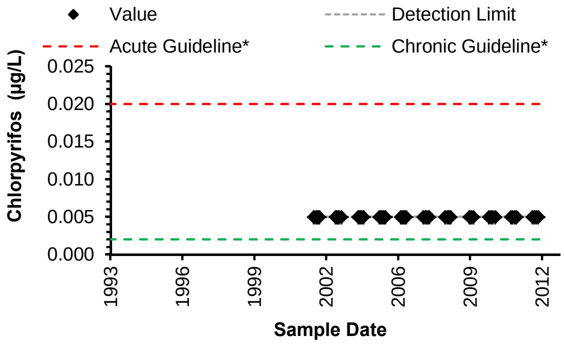
AB07BC0540 (Wabash Creek near Pibroch)



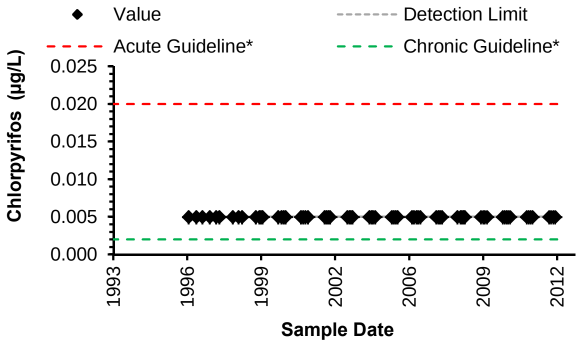
AB07BE0010 (Athabasca River at the town of Athabasca)



AB07CC0030 (Athabasca River upstream of Fort McMurray)



AB07DD0010 (Athabasca River at Old Fort)



*Guideline value is from AESRD (2013a) guidelines for the protection of aquatic life.

Table 19 Insecticides in sediment at AESRD stations with at least one year of current data available.

Analyte	Guideline		Common Detection Limit (mg/kg)	Station			
				Upper Athabasca	Upper Central Athabasca	Lower Central Athabasca	Lower Athabasca
	CCME - ISQG	CCME - PEL		AB07AD0100	AB07BE0010	AB07CC0030	AB07DD0010
Aldicarb	-	-	0.01	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Aldrin	-	-	0.005	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Alpha BHC	-	-	0.005	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Alpha-chlordane	-	-	0.01	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Alpha-endosulfan	-	-	0.005	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Beta-endosulfan	-	-	0.01	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Chlorpyrifos-ethyl (Dursban)	-	-	0.005	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Diazinon	-	-	0.005	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Dieldrin	-	-	0.005	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Dimethoate (Cygon)	-	-	0.005	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Disulfoton (Di-syston)	-	-	0.2	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Ethion	-	-	0.1	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Gamma-Benzenehexachloride (Lindane)	-	-	0.005	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Gamma-chlordane	-	-	0.01	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Heptachlor	-	-	0.01	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Heptachlor Epoxide	-	-	0.01	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Malathion	-	-	0.05	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Methoxychlor (P,P'-Methoxychlor)	-	-	0.03	n=1 ○	n=1 ○	n=3 ○	n=1 ○
N,N-Diethyl-M-Toluamide (DEET)	-	-	0.005	n=1 ○	n=1 ○	n=3 ◕	n=1 ○
O,P'-DDD	-	-	0.01	n=1 ○	n=1 ○	n=3 ○	n=1 ○
O,P'-DDE	-	-	0.01	n=1 ○	n=1 ○	n=3 ○	n=1 ○
O,P'-DDT	-	-	0.01	n=1 ○	n=1 ○	n=3 ○	n=1 ○
P,P'-DDD (TDP)	-	-	0.01	n=1 ○	n=1 ○	n=3 ○	n=1 ○
P,P'-DDE	-	-	0.01	n=1 ○	n=1 ○	n=3 ○	n=1 ○
P,P'-DDT	-	-	0.01	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Parathion	-	-	0.01	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Pentachlorophenol	-	-	2	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Phorate (Thimet)	-	-	0.005	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Pyridaben	-	-	0.02	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Terbufos	-	-	0.03	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Thiamethoxam	-	-	0.05	n=1 ○	n=1 ○	n=3 ○	n=1 ○

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes.

Legend

○ = All data below detection limit
◔ = 1-25% of data above detection
◑ = 26-50% of data above detection
◕ = 51-75% of data above detection
● = 76-100% of data above detection

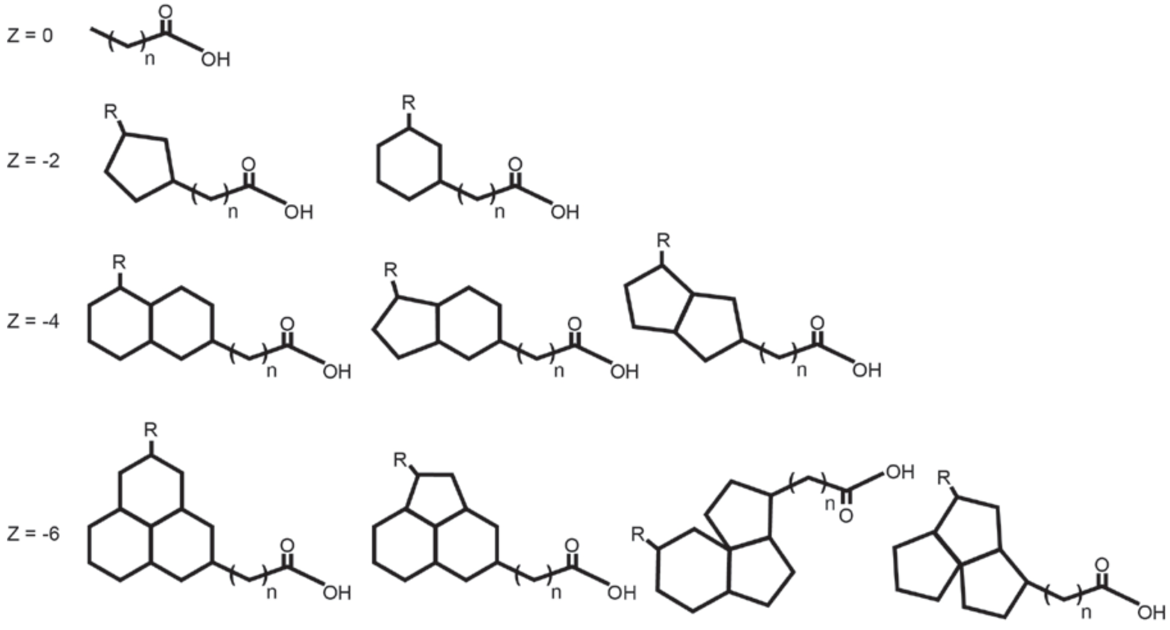
Red highlighting indicates guideline exceedence.

3.5 ORGANIC ACIDS

3.5.1 Naphthenic Acids and Oil Sands Acid Extractable Organics

Naphthenic acids are a complex group of carboxylic acids described by the chemical formula $C_nH_{2n+Z}O_2$, where n is the number of carbon atoms (typically between 10 and 20), and Z is a negative number corresponding to twice the number of rings in the molecule (i.e., 0, -2, -4, etc.) (Figure 30). Naphthenic acids in aquatic ecosystems can originate naturally from from erosion of bituminous geological formations, or they can be released by seeping through tailings ponds dykes or foundations into groundwater aquifers (Ferguson et al. 2009, Young et al. 2008).

Figure 30 Structural formula for naphthenic acids $C_nH_{2n+Z}O_2$.



Naphthenic acids are of interest in oil sands monitoring because they have potential to be good indicators of any process water influence on local surface waters. However, recent studies using high-resolution methods (e.g., Grewer et al. 2010) have shown that the majority of acid-extractable organic compounds previously measured as “naphthenic acids” in oil sands process water, river waters, and commercial naphthenic acids preparations are not actually naphthenic acids, but a combination of various other organic acids.

For example, fewer than 10% of acid-extractable organics measured by Grewer et al. (2010) in river water samples from various locations in Alberta were classic naphthenic acids, with ≥70% of these compounds being aliphatic (non-cyclic) fatty acids, particularly palmitic and stearic acids, which are common components of biological cell membranes and routinely found in river waters.

Accordingly, Grewer et al. (2010) suggested the replacement of the term "naphthenic acids" for these analyses with something more representative of the range of compounds measured, such as "oil sands tailings water acid-extractable organics (OSTWAEO)"; however, the use of the term "oil sands" is a misnomer given many of these constituent compounds also are present in surface waters outside the oil sands region. Currently, multiple commercial, academic and government laboratories are developing or using high-resolution analytical techniques for quantification and speciation of naphthenic acids mixtures in water (see Special Studies Section 6 in the RAMP 2011 Technical Report (RAMP 2012) for further discussion). Since 2011, RAMP and AESRD have contracted AITF (formerly ARC, Vegreville, AB) to measure oil sands acid extractable organics, and naphthenic acids (which is considered a subset of oil sands acid extractable organics) in ambient water quality samples.

3.5.1.1 Water Quality Data Availability

Current data for naphthenic acids and oil sands acid extractable organics (oil sands extractable) in surface water were available from six AESRD stations and 57 RAMP stations (Figure 31). Given that the laboratory methods and detection limits for naphthenic acids and oil sands extractable were consistent between both RAMP and AESRD for 2011 and 2012, only data from 2011 and 2012 were included in this assessment. No data were available for naphthenic acids and oil sands extractable in surface water for the Upper Athabasca, McLeod, Pembina, Lesser Slave, La Biche, or Lake Athabasca sub-watersheds.

3.5.1.2 Sediment Quality Data Availability

Only one sediment sample from 2010 was available for naphthenic acids from one AESRD station (Luscar Creek Settling Pond Discharge-AB07AF0470) (Figure 31). No data were available for oil sands extractable in sediment. Sediment data were only available for the McLeod sub-watershed.

3.5.2 Naphthenic Acids and Oil Sands Extractable in Water

3.5.2.1 2012 Spatial Comparisons

Given that naphthenic acids are a subset of the oil sands extractable fraction, fall 2012 data from RAMP and AESRD stations were plotted for both naphthenic acids and oil sands extractable in Figure 32. Naphthenic acids are plotted as red bubbles, or circles, within the green circles representing oil sands extractable for each station. Detection limits for naphthenic acids and oil sands extractable were the same for both AESRD and RAMP stations. Fall 2012 data were available for only three AESRD stations.

Naphthenic acid concentrations ranged from 0.02 mg/L at the RAMP station on the Athabasca River downstream of development (ATR-DD-W) and the AESRD station at the town of Athabasca (AB07BE0010) to 1.26 mg/L in the lower Beaver River (BER-1) (Figure 32). Oil sands extractable concentrations ranged from 0.09 mg/L at the RAMP station on the Athabasca River Upstream of Steepbank River (ATR-SR-W) to 1.29 mg/L at the mouth of Stanley Creek (STC-1)

(Figure 32). Both naphthenic acid and oil sands extractable concentrations were generally lowest upstream of Fort McMurray and at stations on the Athabasca and major tributaries downstream of Fort McKay. Naphthenic acids and oil sands extractable were generally highest between Fort McMurray and Fort McKay around Beaver River and McLean Creek and northeast of Fort McKay around the Muskeg River, but concentrations decreased further downstream of the major oil sands developments.

Since naphthenic acids are a subset of the oil sands extractable fraction, naphthenic acid concentrations should generally be lower than oil sands extractable concentrations, however; two RAMP stations, lower Beaver River (BER-1) and Wapasu Creek (WAC-1) showed higher naphthenic acids concentrations than their corresponding oil sands extractable fractions. The laboratory (AITF) which conducted these analyses using the GC/MS-ion-trapping, 2011 standard analytical method re-ran the Beaver River samples and double-checked all calculations and found the same result and could not provide any explanation as to why this result occurred (pers comm. D. Humphries, AITF 2012).

3.5.2.2 Compilation of Current Naphthenic Acids and Oil sands Extractable in Water and Comparison with Guidelines

All AESRD and all RAMP stations had at least one detectable (i.e., ≥20 µg/L) sample of naphthenic acids (Table 20 and Table 21). No guideline was available for naphthenic acids in surface water.

Concentrations of oil sands extractable were detected (i.e., ≥100 µg/L) in at least one sample at all AESRD and RAMP stations, with the exception of a RAMP station on the Athabasca River upstream of the Steepbank River (ATR-SR-W) (Table 20 and Table 21). No guideline was available for oil sands extractable in surface water.

3.5.2.3 Historical Trend Analysis

Given this assessment only considered naphthenic acids and oil sands extractable measured in 2011 and 2012, historical trend analysis was not conducted on any surface water stations.

3.5.3 Naphthenic Acids and Oil sands Extractable in Sediment

3.5.3.1 2012 Spatial Comparisons

Given only one sample was available for analysis, spatial comparisons were not conducted.

3.5.3.2 Compilation of Current Naphthenic Acids in Sediment and Comparison with Guidelines

The concentration of naphthenic acids in sediments at the AESRD station- Luscar Creek Settling Pond Discharge (AB07AF0470) was detectable (i.e., >0.01 mg/kg). No guidelines are available for naphthenic acids in sediment.

3.5.3.3 Historical Trend Analysis

Statistical trend analysis was not conducted, given there was only one sample available for analysis.

3.5.4 Overall Assessment: Naphthenic Acids and Oil sands Extractable

- To maintain consistency with laboratory methods and detection limits for naphthenic acids and oil sands extractable between both RAMP and AESRD, only data from 2011 and 2012 were included in this assessment.

- The majority of surface water data for naphthenic acids and oil sands extractable were obtained from stations in the Lower Athabasca sub-watershed, indicating a general gap in sampling of naphthenic acids and oil sands extractable throughout the rest of the Athabasca watershed.

- Sediment data were very sparse for naphthenic acids in the Athabasca watershed given that only one sample from one station in 2010 was available for the current period. No sediment data were available for oil sands extractable at any stations within the Athabasca watershed.

- The majority of naphthenic acid and oil sands extractable concentrations in surface water were detected at all AESRD and RAMP stations.

- The only sediment sample available for naphthenic acids was detectable.

3.5.5 Resin and Fatty Acids

Resin and fatty acids are acidic organic compounds which originate naturally in the environment as coniferous tree extractives. Resin acids are found in tree resin, frequently referred to as 'sap', and protect wood against microbial and insect damage. Fatty acids are common components of biological cell membranes and naturally found in river waters. Resin and fatty acids are commonly released from wood during the pulping process and discharged as effluent (McMaster et al. 2003).

During pulpmill effluent treatment processes, resin and fatty acids are reduced, but not eliminated, and have historically been associated with effluent acute toxicity in aquatic organisms (Hewitt et al. 2006, McMaster et al. 2003, McCubbin & Folke 1993). However, since the late 1980s, improved technologies (e.g., chlorine substitution) have led to the reduction of contaminants in pulpmill effluent in Canada including resin and fatty acids (NRBS 1996).

As mentioned above, the majority of acid-extractable organic compounds previously measured as "naphthenic acids" in oil-sands process water, river waters, and commercial naphthenic acids preparations are not actually naphthenic acids, but a combination of various other organic acids including resin and fatty acids.

3.5.5.1 Water Quality Data Availability

Current data for resin and fatty acids in surface waters were available from five AESRD stations (Figure 31). However, station AB07BK0125 was only sampled in 2011 and 2012 and results were provided in different units from the rest of the stations and detection limits were at least ten-fold larger than those sampled at other stations in previous years. No clarification was received from AESRD regarding this station prior to the submission of this assessment; therefore, only data from the four LTRN stations (AB07AD0100, AB07BE0010, AB07CC0030, AB07DD0105) were included in this assessment. No data were available for resin and fatty acids in surface water for the Lesser Slave, McLeod, Pembina, La Biche, Clearwater, or Lake Athabasca sub-watersheds.

3.5.5.2 Sediment Quality Data Availability

No current data were available for resin and fatty acids in sediment from any AESRD, EC (JOSM), or RAMP stations, therefore no data were available for resin and fatty acids in sediment for any of the sub-watersheds of the Athabasca watershed (Figure 31).

3.5.6 Resin and Fatty Acids in Water

3.5.6.1 2012 Spatial Comparisons

Given no 2012 data for resin and fatty acids in surface waters were available, spatial comparisons were not conducted.

3.5.6.2 Compilation of Current Resin and Fatty Acids in Water and Comparison with Guidelines

All resin and fatty acids measured in surface water were below common detection limits (i.e., <0.2 to <10 μg/L) for all four AESRD stations with the exception of one stearic acid sample, which was detected at station AB07BE0010 (Table 20). No guidelines were available for the resin and fatty acids measured.

3.5.6.3 Historical Trend Analysis

The sum total of resin and fatty acids were plotted for each station and statistical trend analysis was conducted on stations with fewer than 50% non-detectable values. The majority of total resin and fatty acids concentrations were below detection for all years at all stations (Figure 33); therefore no statistical trend analysis was conducted.

3.5.7 Overall Assessment: Resin and Fatty Acids

- All surface water resin and fatty acids data were obtained from four LTRN stations located in the Upper Athabasca, Upper Central Athabasca, Lower Central Athabasca, and Lower Athabasca sub-watersheds, indicating a general gap in sampling of resin and fatty acids throughout the rest of the Athabasca watershed.

- No sediment data were available for resin and fatty acids for any of the sub-watersheds of the Athabasca watershed.
- All resin and fatty acids in surface waters were below common detection limits at all stations.
- No statistical trend analysis was conducted on total resin and fatty acids in surface water given the majority of total resin and fatty acids concentrations were below detection for all years at all stations.

3.5.8 Non-chlorinated Phenols and Total Phenols

Phenols are a large, complex group of acidic compounds that are hydroxyl derivatives of aromatic hydrocarbons. Phenols are found everywhere in the environment and can originate as by-products from pulp and paper, mineral, steel and metal, and petroleum industries and are also used as disinfectants, biocides, preservatives, dyes, and pesticides (CCME 1999c). Phenols are also produced naturally from the decomposition of aquatic vegetation (CCME 1999c).

Toxicity of phenols to aquatic life varies widely with the type of aquatic organism (DeGraeve et al. 1980) as well as the dissolved oxygen content and water temperature (CCME 1999c). Elevated concentrations of phenol, for example, are a concern for early life stages of sensitive aquatic species (CEPA 2000) and have been found to cause reduced growth in early life stages of rainbow trout (DeGraeve et al. 1980).

3.5.8.1 Water Quality Data Availability

Current data for non-chlorinated phenols and total phenols in surface waters were available from six AESRD stations and 64 RAMP stations (Figure 31). No data were available for non-chlorinated phenols and total phenols in surface water for the McLeod, Pembina, La Biche, or Lake Athabasca sub-watersheds.

3.5.8.2 Sediment Quality Data Availability

Non-chlorinated phenols and total phenols data for sediments were obtained from four AESRD LTRN stations (Figure 31). No data were available for non-chlorinated phenols and total phenols in sediment for the McLeod, Pembina, Lesser Slave, La Biche, Clearwater, or Lake Athabasca sub-watersheds.

3.5.9 Non-chlorinated Phenols and Total Phenols in Water

3.5.9.1 2012 Spatial Comparisons

Total phenols concentrations ranged from 0.0028 mg/L at two RAMP stations on the Athabasca River upstream of the Steepbank River west bank (ATR-SR-W) and east bank (ATR-SW-E) to 0.0177 mg/L at the lower Calumet River (CAR-1) (Figure 34). Total phenols concentrations were generally lowest at certain stations along the Athabasca mainstem and at the mouth of major tributaries of the Athabasca River. Concentrations of total phenols were generally highest between Fort McMurray and Fort McKay around Poplar Creek and at the Steepbank River stations and northeast of Fort McKay around the Muskeg River.

3.5.9.2 Compilation of Non-chlorinated Phenols and Total Phenols in Water and Comparison with Guidelines

All non-chlorinated phenols in surface water were below common detection limits (i.e., <0.1 to <0.2µg/L) for all six AESRD stations. No guidelines were exceeded for non-chlorinated phenols, although only one guideline was available (Table 20).

Total phenols were routinely detectable (i.e., ≥4 µg/L) at most RAMP stations, regardless of their proximity to industrial development (Table 21). Values above (usually <2x) the CCME and AESRD guidelines for the protection of aquatic life for phenols of 4 µg/L were common at most stations. However, these guidelines are specific to mono- and dihydric phenols (i.e., those with one or two hydroxyl groups), while the total phenols measure used by RAMP incorporates a wider range of compounds and therefore may include more species (i.e., polyhydric species) that are not relevant to the CCME and AESRD guidelines. Thus, even though initial screening showed concentrations of total phenols exceeded the CCME and AESRD guidelines in at least one sample at most RAMP stations, these guidelines may not be applicable to the RAMP variable and were therefore not used in this assessment. Given the similar range of total phenol concentrations among RAMP baseline and test stations, it is likely that this observed range of values is representative of regional background conditions.

3.5.9.3 Historical Trend Analysis

Statistical trend analysis was conducted on total phenols in surface waters for 40 RAMP stations where there were at least seven years of water quality data. Concentrations of total phenols increased significantly over time at 19 RAMP stations throughout the Lower Athabasca sub-watershed, including stations upstream and downstream of oil sands disturbance; all other stations showed no significant trends over time (Figure 35).

Sixteen RAMP stations had less than four years of data and were therefore excluded from both qualitative and quantitative trend analysis. Historical total phenols concentrations for eight additional RAMP stations (CHR-1, CLR-2, FIR-2, HAR-1, IYC-1, JAC-2, MAR-2A, SHC-1) were plotted, but were excluded from statistical trend analysis because these stations either had less than seven years of data, or had greater than 50% non-detectable values (Figure 35).

3.5.10 Non-chlorinated Phenols in Sediment

3.5.10.1 2012 Spatial Comparisons

Given only 2008 data were available for non-chlorinated phenols in sediments, spatial comparisons were not conducted. Total phenols were not measured in sediments.

3.5.10.2 Compilation of Non-chlorinated Phenols in Sediment and Comparison with Guidelines

All non-chlorinated phenols measured in sediments were below detection (i.e., <2 to <4 mg/kg) for all four AESRD LTRN stations (Table 22). No CCME guidelines were available for the non-chlorinated phenols species measured.

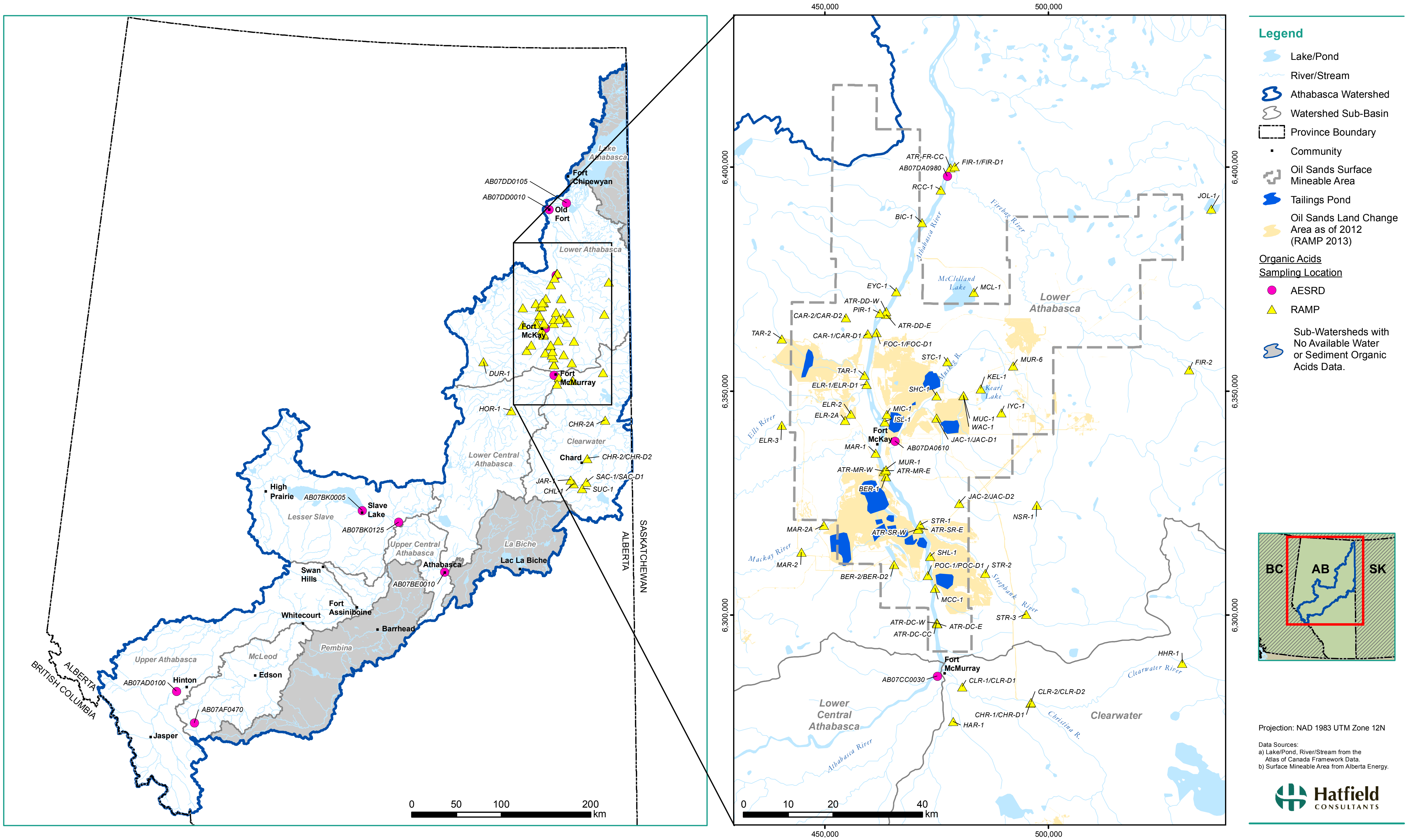
3.5.10.3 Historical Trend Analysis

Historical trend analysis was not conducted on any AESRD sediment stations, given only one year of non-chlorinated phenols data were available.

3.5.11 Overall Assessment: Non-Chlorinated Phenols and Total Phenols

- The majority of surface water data for total phenols were obtained from stations in the Lower Athabasca sub-watershed, indicating a general gap in sampling of total phenols throughout the rest of the Athabasca watershed.
- Non-chlorinated phenols data for surface water were obtained from stations in half of the Athabasca sub-watersheds, indicating a general gap in sampling of non-chlorinated phenols throughout half of the Athabasca watershed.
- Sediment data were sparse for non-chlorinated phenols in the Athabasca watershed given that only 2008 data were available for the current period. No sediment data were available for total phenols at any stations within the Athabasca watershed.
- All non-chlorinated phenols in surface waters and sediments were below common detection limits and guidelines at all stations.
- Concentrations of total phenols were measurable in almost all samples at all RAMP stations and increased significantly over time at 19 RAMP stations.

Figure 31 Sampling locations for organic acids in water and sediment.



Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Lake/Pond, River/Stream from the Atlas of Canada Framework Data.
b) Surface Mineable Area from Alberta Energy.

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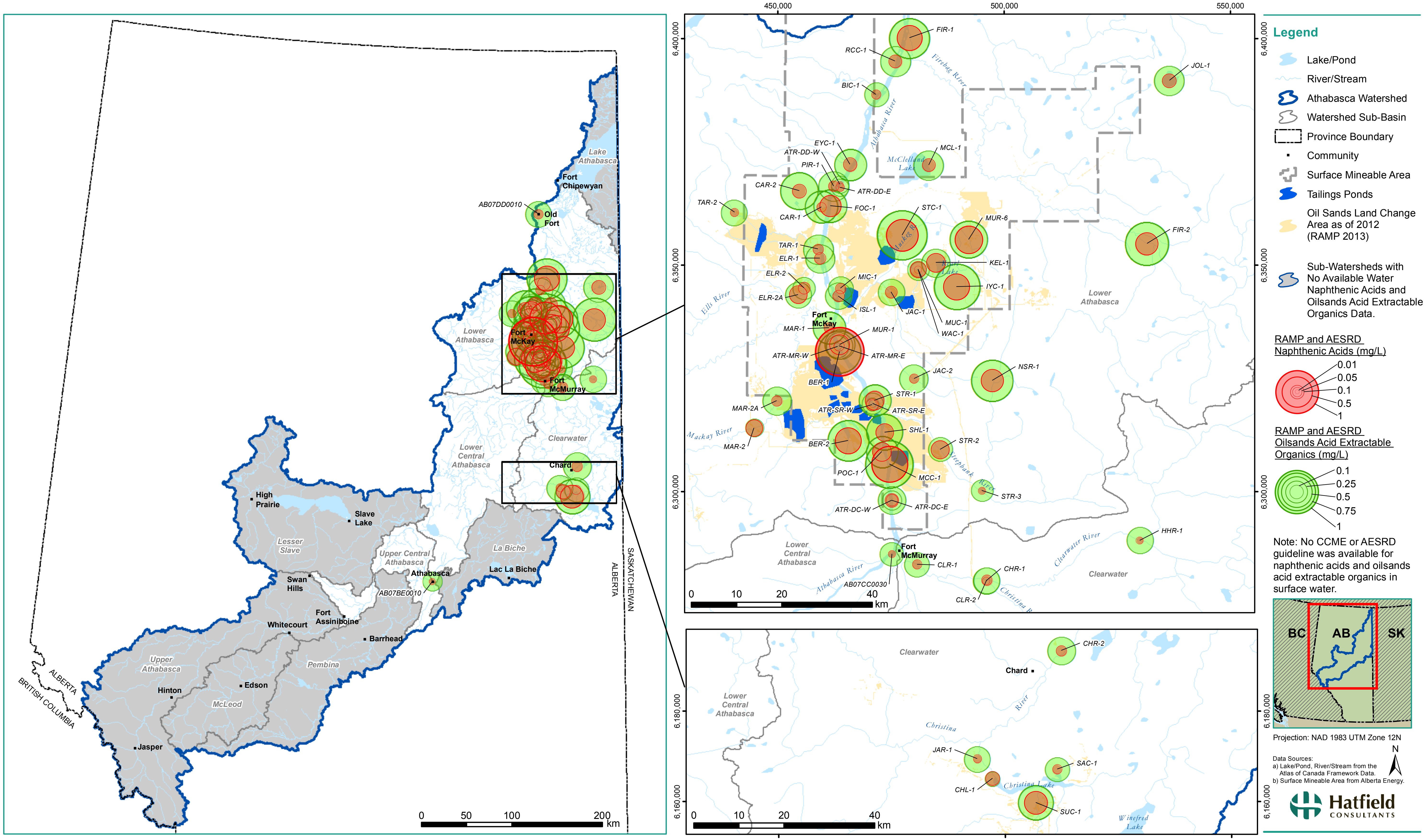
Figure 32 Naphthenic acids and oilsands acid extractable organics in surface water (mg/L), fall 2012.



Note: No CCME or AESRD guideline was available for naphthenic acids and oilsands acid extractable organics in surface water.

Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Lake/Pond, River/Stream from the Atlas of Canada Framework Data.
b) Surface Mineable Area from Alberta Energy.

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Table 20 Organic acids in surface water at AESRD stations with at least one year of current data available.

Analyte	Guideline (µg/L)			Common Detection Limit (µg/L)	Station								
					Upper Athabasca	Upper Central Athabasca	Lesser Slave		Lower Central Athabasca	Lower Athabasca			
	AESRD (2013)	CCME	BC		AB07AD0100	AB07BE0010	AB07BK0005	AB07BK0125	AB07CC0030	AB07DA0610	AB07DA0980	AB07DD0010	AB07DD0105
Resin Acids													
Abietic Acid	-	-	-	1	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	-	n=3 ○
Dehydroabietic acid	-	-	-	0.2	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	-	n=3 ○
Isopimaric Acid	-	-	-	0.2	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	-	n=3 ○
Levopimaric Acid	-	-	-	2	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	-	n=3 ○
Neoabietic Acid	-	-	-	2	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	-	n=3 ○
Palustric Acid	-	-	-	2	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	-	n=3 ○
Pimaric Acid	-	-	-	0.2	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	-	n=3 ○
Sandaracopimaric Acid	-	-	-	0.3	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	-	n=3 ○
Fatty Acids													
Arachidic Acid	-	-	-	1	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	-	n=3 ○
Linoleic Acid	-	-	-	1	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	-	n=3 ○
Linolenic Acid	-	-	-	1	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	-	n=3 ○
Myristic Acid	-	-	-	2	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	-	n=3 ○
Oleic Acid	-	-	-	2	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	-	n=3 ○
Palmitic Acid	-	-	-	10	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	-	n=3 ○
Stearic Acid	-	-	-	5	n=3 ○	n=3 ◑	-	-	n=3 ○	-	-	-	n=3 ○
Naphthenic acids	-	-	-	20	-	n=9 ●	-	-	n=24 ◕	n=24 ●	n=22 ●	n=14 ●	n=9 ●
Oilsands Acid Extractable	-	-	-	100	-	n=9 ●	-	-	n=23 ●	n=23 ●	n=22 ●	n=14 ●	n=8 ●
Non-chlorinated Phenols and Total Phenols													
2,4-dimethylphenol	-	-	-	0.2	n=3 ○	n=3 ○	n=1 ○	n=2 ○	n=3 ○	-	-	-	n=3 ○
2,4-dinitrophenol	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	n=2 ○	n=3 ○	-	-	-	n=3 ○
2-methyl-4,6-dinitrophenol	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	n=2 ○	n=3 ○	-	-	-	n=3 ○
2-nitrophenol	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	n=2 ○	n=3 ○	-	-	-	n=3 ○
4-nitrophenol	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	n=2 ○	n=3 ○	-	-	-	n=3 ○
Phenol	4	4	-	0.1	n=3 ○	n=3 ○	n=1 ○	n=2 ○	n=3 ○	-	-	-	n=3 ○

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes.

Legend

○ = All data below detection limit
◔ = 1-25% of data above detection
◑ = 26-50% of data above detection
◕ = 51-75% of data above detection
● = 76-100% of data above detection

Red highlighting indicates guideline exceedence.

Table 21 Organic acids in surface water at RAMP stations with at least one year of current data available.

Analyte	Guideline (µg/L)			Common Detection	Station																		
	AESRD (2013)	CCME	BC	Limit (µg/L)	ATR-DC-CC	ATR-DC-E	ATR-DC-W	ATR-DD-E	ATR-DD-W	ATR-FR-CC	ATR-MR-E	ATR-MR-W	ATR-SR-E	ATR-SR-W	BER-1	BER-2	BIC-1	CAR-1	CAR-2	CHL-1	CHR-1	CHR-2	CHR-2A
Naphthenic Acids	-	-	-	20	-	n=8 ●	n=8 ◕	n=8 ◕	n=8 ◕	-	n=2 ●	n=2 ◑	n=2 ●	n=2 ◑	n=2 ●	n=2 ●	n=6 ●	n=2 ●	n=2 ●	n=3 ●	n=2 ◑	n=2 ●	-
Oilsands Acid Extractable	-	-	-	100	-	n=8 ●	n=8 ◕	n=8 ●	n=8 ●	-	n=2 ●	n=2 ◑	n=2 ●	n=2 ○	n=2 ●	n=2 ●	n=6 ●	n=2 ●	n=2 ●	n=3 ●	n=2 ●	n=2 ●	-
Non-chlorinated Phenols and Total Phenols																							
Total Phenolics	[a]	[a]	-	4	n=1 ●	n=17 ◕	n=17 ◑	n=24 ◑	n=24 ◑	n=4 ◑	n=6 ◑	n=6 ◑	n=6 ◑	n=6 ◑	n=6 ●	n=13 ●	n=6 ●	n=6 ●	n=9 ●	n=3 ●	n=7 ◕	n=7 ◕	n=2 ◑

Analyte	Guideline (µg/L)			Common Detection	Station																		
	AESRD (2013)	CCME	BC	Limit (µg/L)	CLR-1	CLR-2	DUR-1	ELR-1	ELR-2	ELR-2A	ELR-3	EYC-1	FIR-1	FIR-2	FOC-1	HAR-1	HHR-1	HOR-1	ISL-1	IYC-1	JAC-1	JAC-2	JAR-1
Naphthenic Acids	-	-	-	20	n=2 ●	n=2 ◑	-	n=2 ●	n=2 ●	n=5 ●	n=2 ●	n=8 ●	n=2 ●	n=2 ●	n=2 ●	-	n=6 ●	-	n=2 ●	n=2 ◑	n=2 ●	n=2 ●	n=3 ●
Oilsands Acid Extractable	-	-	-	100	n=2 ●	n=2 ●	-	n=2 ●	n=2 ●	n=5 ●	n=2 ●	n=8 ●	n=2 ●	n=2 ●	n=2 ●	-	n=6 ●	-	n=2 ●	n=2 ●	n=2 ●	n=2 ●	n=3 ●
Non-chlorinated Phenols and Total Phenols																							
Total Phenolics	[a]	[a]	-	4	n=8 ◕	n=6 ◑	n=1 ●	n=6 ●	n=8 ●	n=6 ●	n=2 ●	n=7 ●	n=6 ◕	n=6 ●	n=6 ◑	n=4 ◕	n=7 ◕	n=1 ●	n=8 ●	n=6 ●	n=6 ●	n=5 ●	n=3 ◕

Analyte	Guideline (µg/L)			Common Detection	Station																		
	AESRD (2013)	CCME	BC	Limit (µg/L)	JOL-1	KEL-1	MAR-1	MAR-2	MAR-2A	MCC-1	MCL-1	MIC-1	MUC-1	MUR-1	MUR-6	NSR-1	PIR-1	POC-1	RCC-1	SAC-1	SHC-1	SHL-1	STC-1
Naphthenic Acids	-	-	-	20	n=7 ●	n=2 ●	n=2 ●	n=2 ●	n=7 ●	n=2 ●	n=2 ●	n=2 ●	n=2 ●	n=2 ●	n=2 ●	n=2 ●	n=6 ●	n=2 ●	n=6 ●	n=3 ●	-	n=2 ●	n=2 ●
Oilsands Acid Extractable	-	-	-	100	n=7 ●	n=2 ●	n=2 ●	n=2 ●	n=7 ●	n=2 ●	n=2 ●	n=2 ●	n=2 ●	n=2 ●	n=2 ●	n=2 ●	n=6 ●	n=2 ●	n=6 ●	n=3 ●	-	n=2 ●	n=2 ●
Non-chlorinated Phenols and Total Phenols																							
Total Phenolics	[a]	[a]	-	4	n=7 ◕	n=7 ●	n=12 ●	n=12 ●	n=13 ●	n=6 ●	n=6 ◕	n=3 ○	n=7 ●	n=6 ●	n=6 ●	n=6 ●	n=6 ●	n=6 ●	n=6 ◕	n=3 ●	n=2 ◑	n=8 ●	n=6 ◕

Analyte	Guideline (µg/L)			Common Detection	Station						
	AESRD (2013)	CCME	BC	Limit (µg/L)	STR-1	STR-2	STR-3	SUC-1	TAR-1	TAR-2	WAC-1
Naphthenic Acids	-	-	-	20	n=4 ●	n=2 ●	n=2 ●	n=3 ●	n=2 ●	n=2 ◑	n=2 ●
Oilsands Acid Extractable	-	-	-	100	n=4 ●	n=2 ●	n=2 ●	n=3 ◕	n=2 ●	n=2 ●	n=2 ●
Non-chlorinated Phenols and Total Phenols											
Total Phenolics	[a]	[a]	-	4	n=11 ◕	n=6 ●	n=8 ●	n=3 ●	n=8 ●	n=10 ◕	n=6 ●

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes.

[a] CCME and AESRD guideline for total phenols is specific for mono- and dihydric phenols (i.e., those with one or two hydroxyl groups), and is therefore not applicable to the RAMP water quality variable, which encompasses a wide variety of phenolic compounds, including polyhydric species. See Section 3.5.9 for more details.

Legend

○ = All data below detection limit
◔ = 1-25% of data above detection
◑ = 26-50% of data above detection
◕ = 51-75% of data above detection
● = 76-100% of data above detection

Red highlighting indicates guideline exceedence.

Table 22 Organic acids in sediments at AESRD stations with at least one year of current data available.

Analyte	Guideline		Common Detection Limit (mg/kg)	Station				
				Upper Athabasca	McLeod	Upper Central Athabasca	Lower Central Athabasca	Lower Athabasca
	CCME - ISQG	CCME - PEL		AB07AD0100	AB07AF0470	AB07BE0010	AB07CC0030	AB07DD0010
Naphthenic Acids	-	-	10	-	n=1 ●	-	-	-
Non-chlorinated Phenols and Total Phenols								
2,4-dimethylphenol	-	-	4	n=1 ○	-	n=1 ○	n=3 ○	n=1 ○
2,4-dinitrophenol	-	-	2	n=1 ○	-	n=1 ○	n=3 ○	n=1 ○
2-methyl-4,6-dinitrophenol	-	-	2	n=1 ○	-	n=1 ○	n=3 ○	n=1 ○
2-nitrophenol	-	-	2	n=1 ○	-	n=1 ○	n=3 ○	n=1 ○
4-nitrophenol	-	-	2	n=1 ○	-	n=1 ○	n=3 ○	n=1 ○
Phenol	-	-	2	n=1 ○	-	n=1 ○	n=3 ○	n=1 ○

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes.

Legend

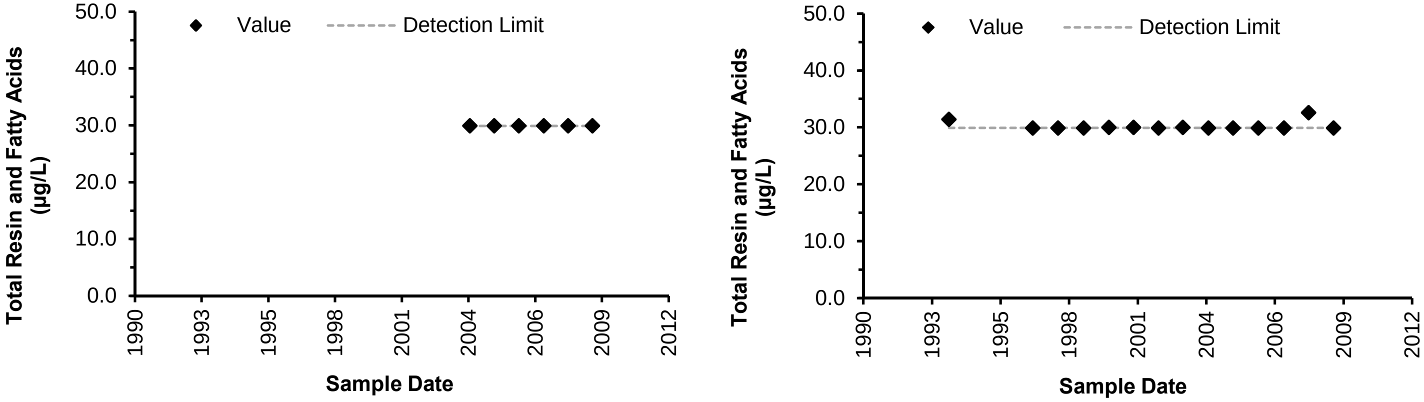
○ = All data below detection limit
◔ = 1-25% of data above detection
◑ = 26-50% of data above detection
◕ = 51-75% of data above detection
● = 76-100% of data above detection

Red highlighting indicates guideline exceedence.

Figure 33 Total resin and fatty acids in surface water for AESRD stations with historical datasets.

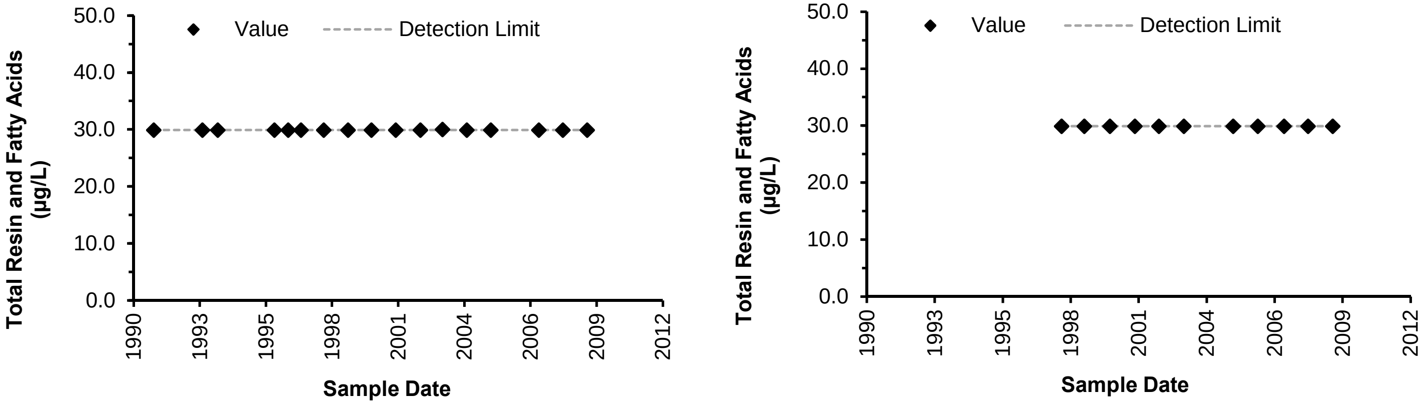
AB07AD0100 (Athabasca River at Old Entrance town site)

AB07BE0010 (Athabasca River at the town of Athabasca)



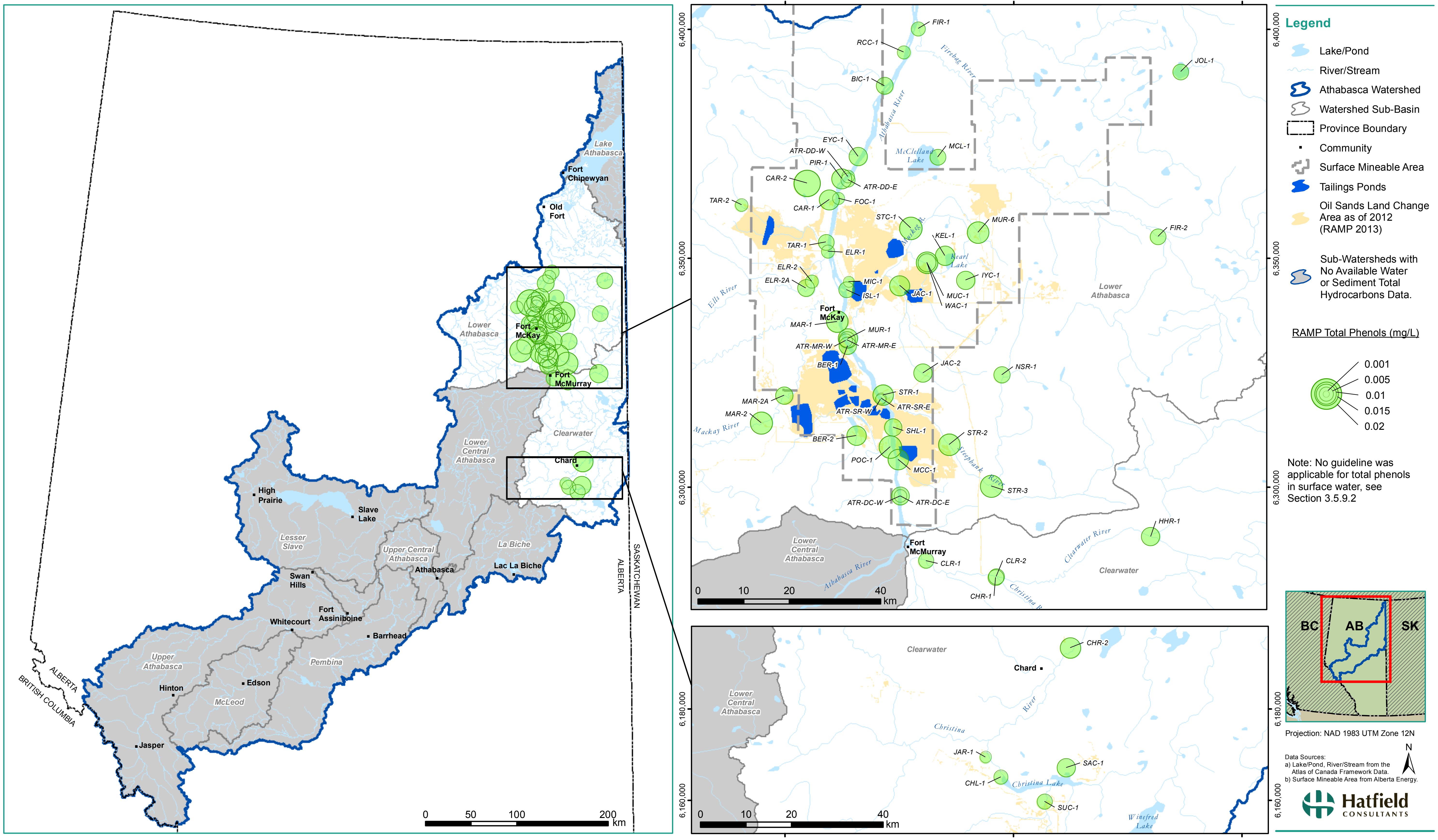
AB07CC0030 (Athabasca River upstream of Fort McMurray)

AB07DD0105 (Athabasca River downstream of Devils Elbow)



Note: No guideline available for total resin and fatty acids in surface water.

Figure 34 Total phenols in surface water (mg/L), fall 2012.

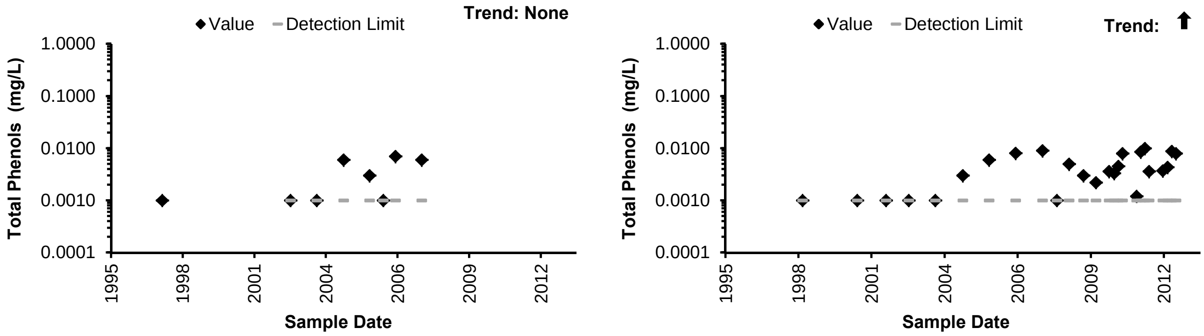


K:\Data\Project\AWPAC6511\GIS_MXD\AWPAC6511_Bub03_TotalPhenols_20140128_ss.mxd

Figure 35 Total phenols (Log Scale) in surface water at RAMP stations with historical datasets.

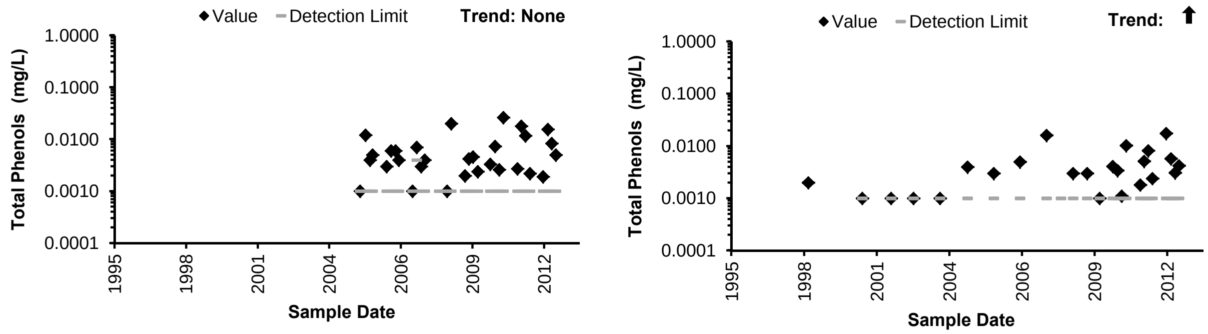
ATR-DC-CC (Athabasca River Upstream of Donald Creek (cross channel))

ATR-DC-E (Athabasca River Upstream of Donald Creek (east bank))



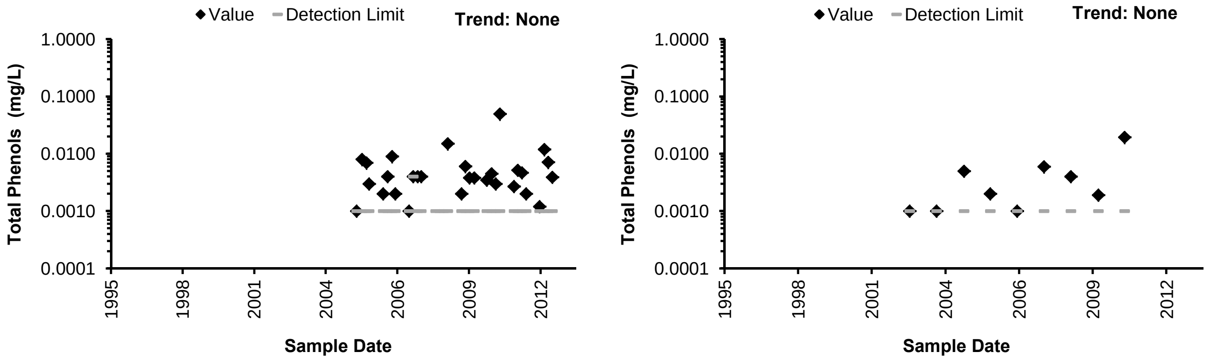
ATR-DD-E (Athabasca River Downstream of Development (east bank))

ATR-DC-W (Athabasca River Upstream of Donald Creek (west bank))



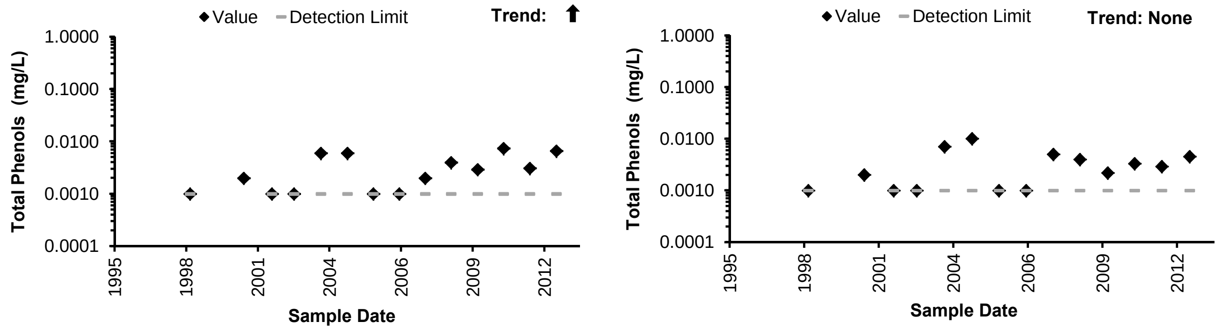
ATR-DD-W (Athabasca River Downstream of Development (west bank))

ATR-FR-CC (Athabasca River Upstream of Mouth of Firebag River (cross channel))



ATR-MR-E (Athabasca River Upstream of Muskeg River (east bank))

ATR-MR-W (Athabasca River Upstream of Muskeg River (west bank))



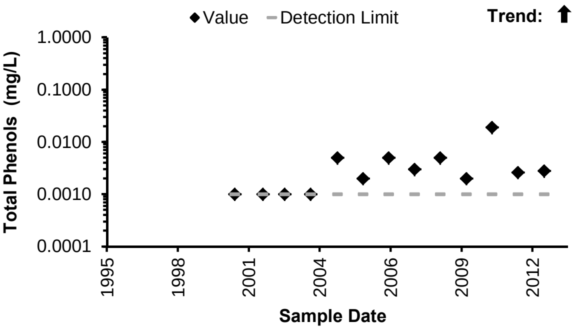
Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

Note: Detection limits are indicated by a grey dash, absence of a grey dash indicates that detection limits were not provided for these data points.

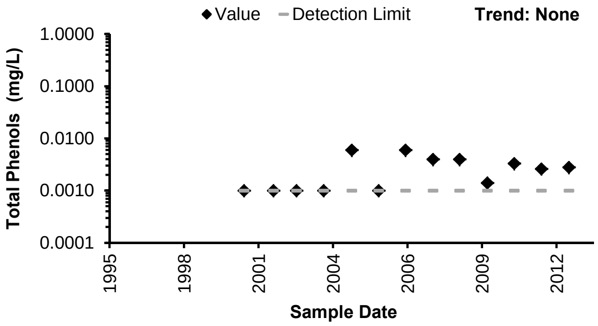
No guideline was applicable for total phenols in surface water, see Section 3.5.9.2.

Figure 35 (Cont'd.)

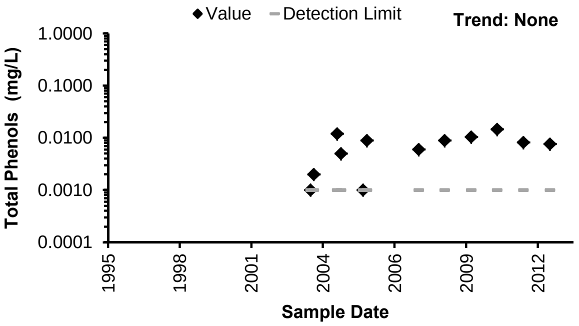
ATR-SR-E (Athabasca River Upstream of Steepbank River (east bank))



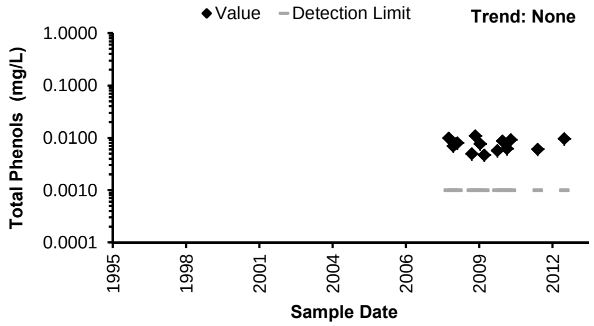
ATR-SR-W (Athabasca River Upstream of Steepbank River (west bank))



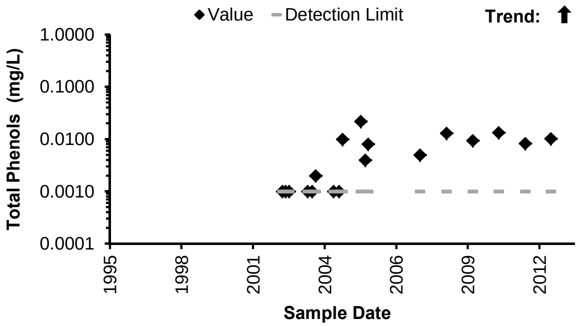
BER-1 (Beaver River)



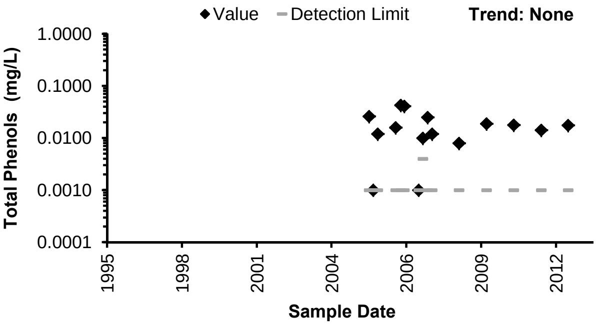
BER-2 (Beaver River)



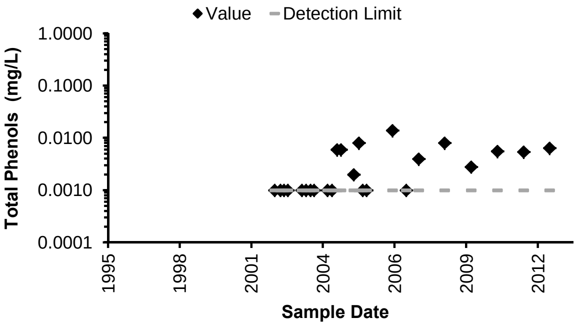
CAR-1 (Calumet River)



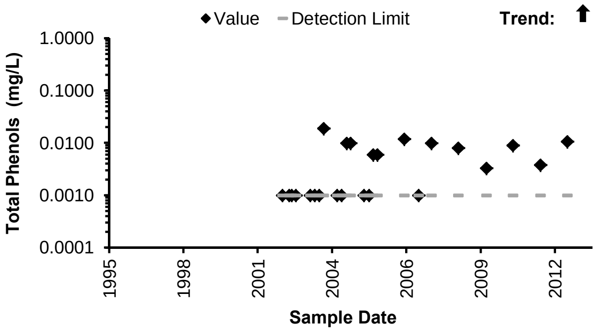
CAR-2 (Calumet River)



CHR-1 (Christina River)



CHR-2 (Christina River)



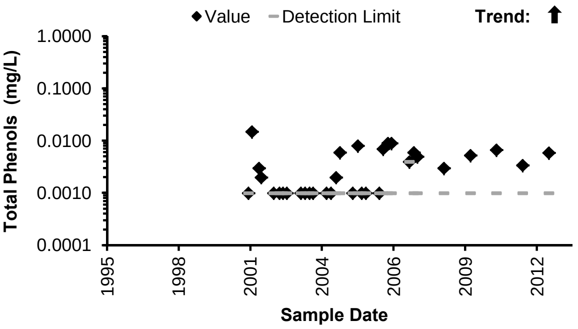
Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

Note: Detection limits are indicated by a grey dash, absence of a grey dash indicates that detection limits were not provided for these data points.

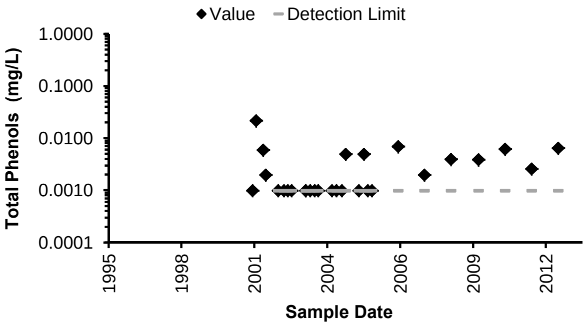
No guideline was applicable for total phenols in surface water, see Section 3.5.9.2.

Figure 35 (Cont'd.)

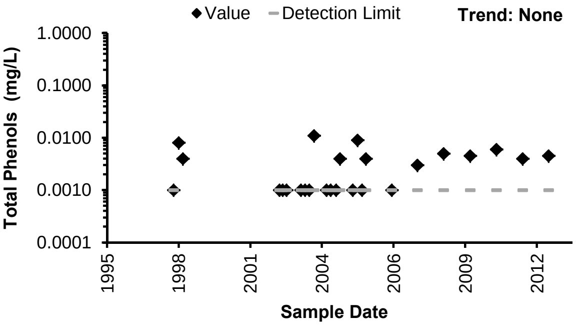
CLR-1 (Clearwater River)



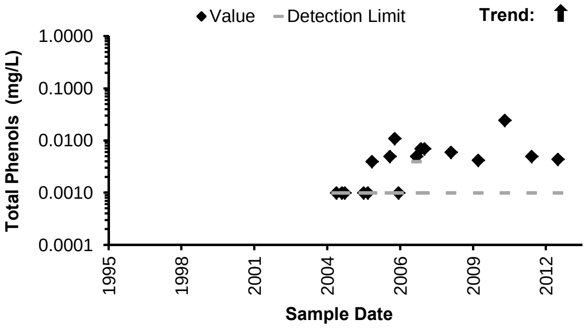
CLR-2 (Clearwater River)



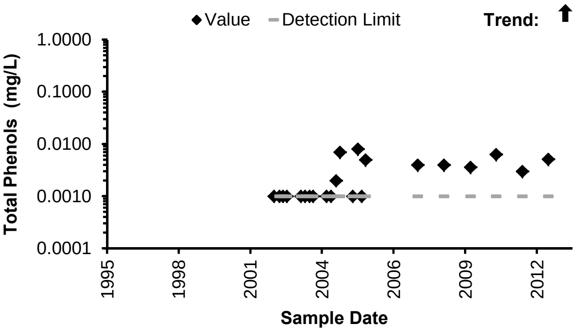
ELR-1 (Ells River)



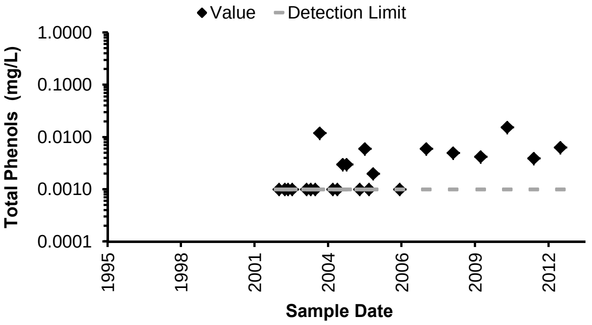
ELR-2 (Ells River)



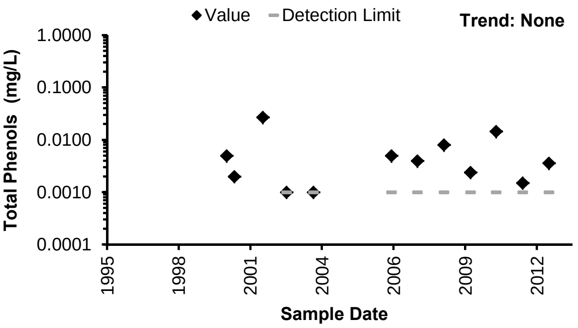
FIR-1 (Firebag River)



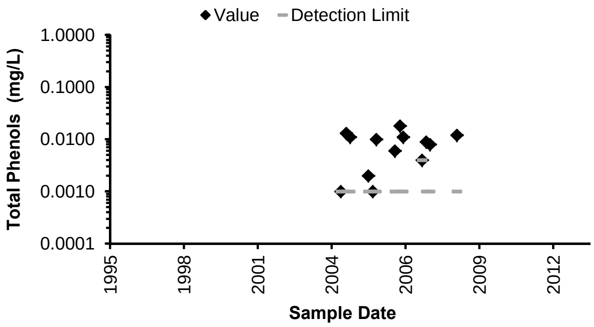
FIR-2 (Firebag River)



FOC-1 (Fort Creek)



HAR-1 (Hangingstone River)



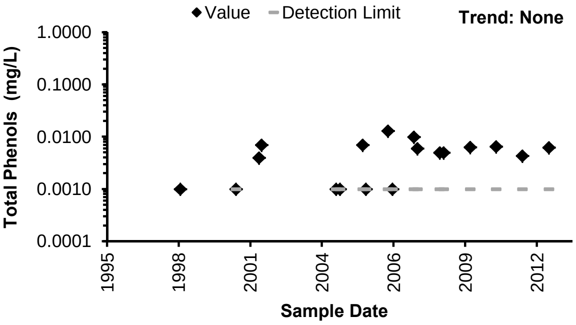
Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

Note: Detection limits are indicated by a grey dash, absence of a grey dash indicates that detection limits were not provided for these data points.

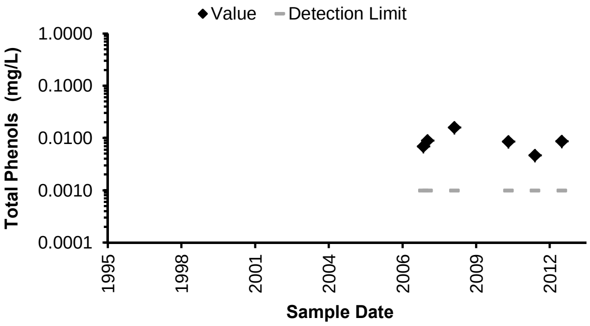
No guideline was applicable for total phenols in surface water, see Section 3.5.9.2.

Figure 35 (Cont'd.)

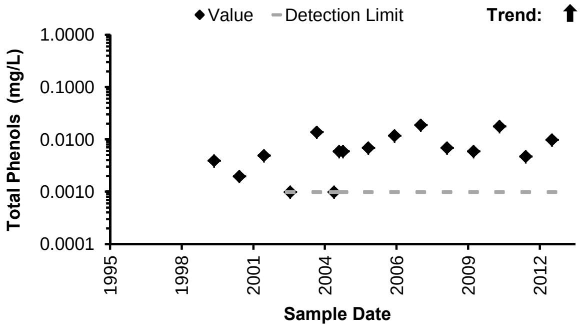
ISL-1 (Isadore's Lake)



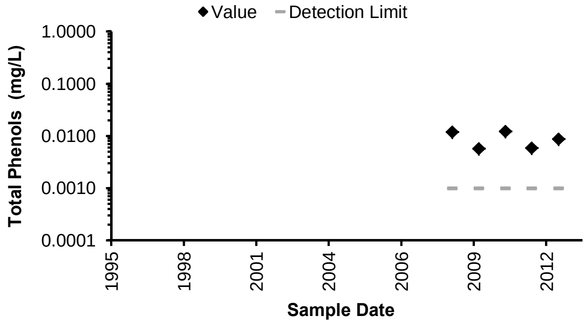
IYC-1 (Iyinimin Creek)



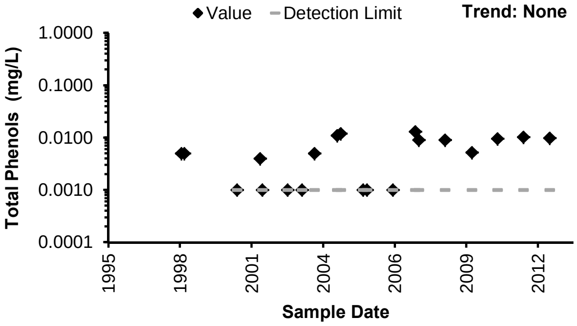
JAC-1 (Jackpine Creek)



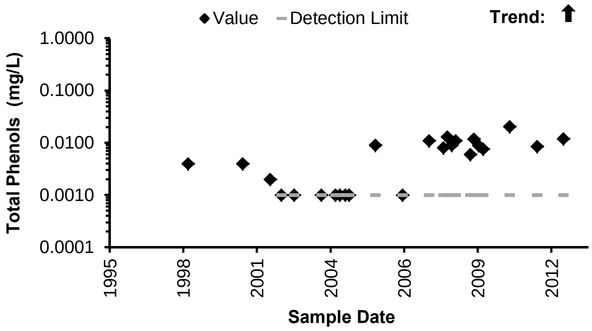
JAC-2 (Jackpine Creek)



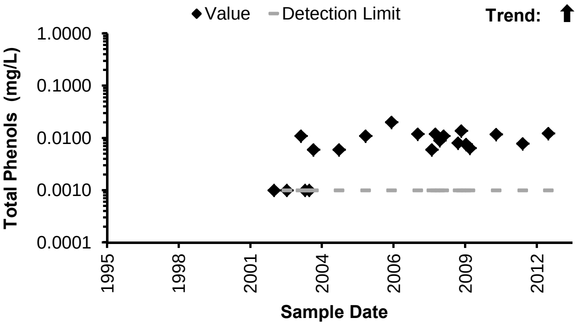
KEL-1 (Kearl Lake)



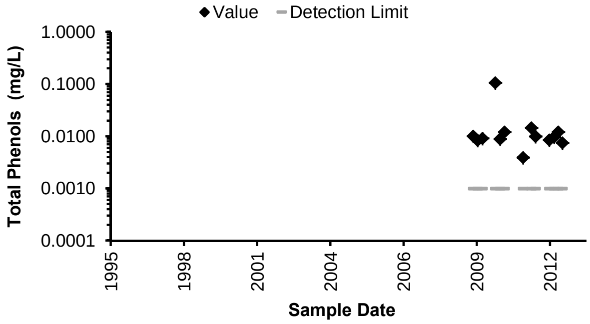
MAR-1 (Mackay River)



MAR-2 (Mackay River)



MAR-2A (Mackay River)



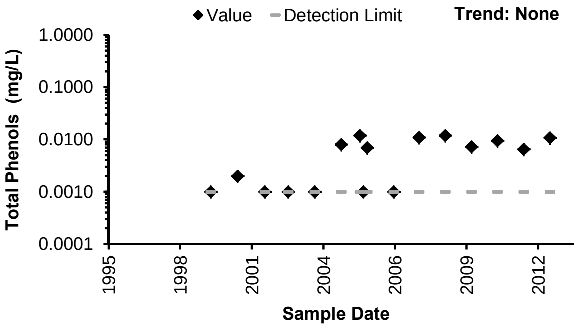
Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

Note: Detection limits are indicated by a grey dash, absence of a grey dash indicates that detection limits were not provided for these data points.

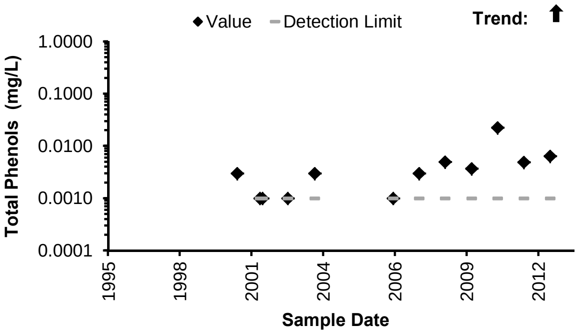
No guideline was applicable for total phenols in surface water, see Section 3.5.9.2.

Figure 35 (Cont'd.)

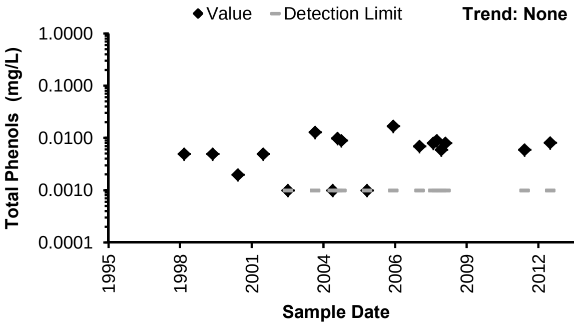
MCC-1 (McLean Creek)



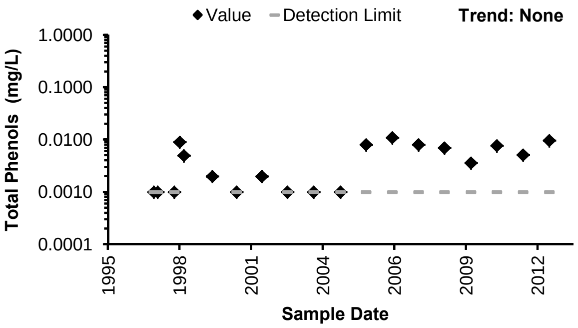
MCL-1 (McClelland Lake)



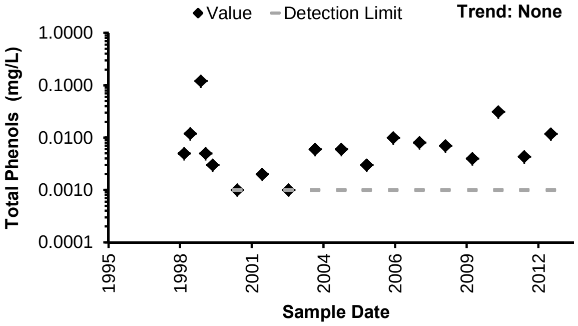
MUC-1 (Muskeg Creek)



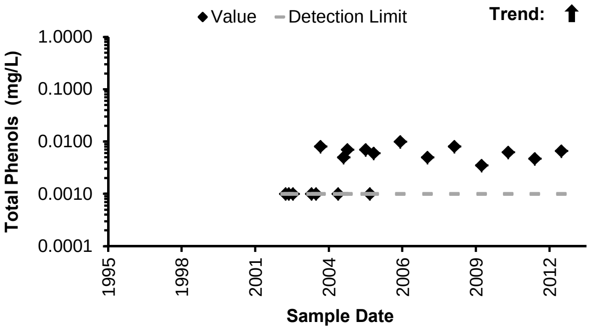
MUR-1 (Muskeg River)



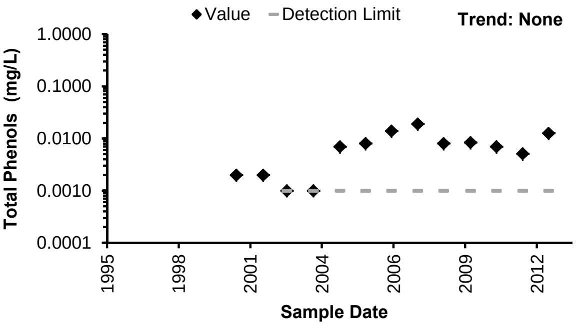
MUR-6 (Muskeg River)



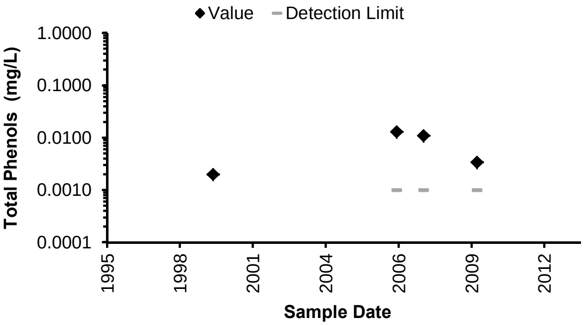
NSR-1 (North Steepbank River)



POC-1 (Poplar Creek)



SHC-1 (Shelley Creek)



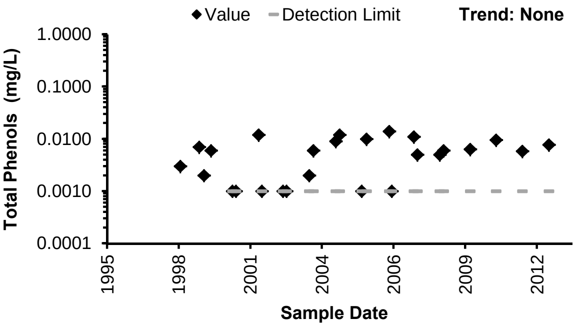
Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

Note: Detection limits are indicated by a grey dash, absence of a grey dash indicates that detection limits were not provided for these data points.

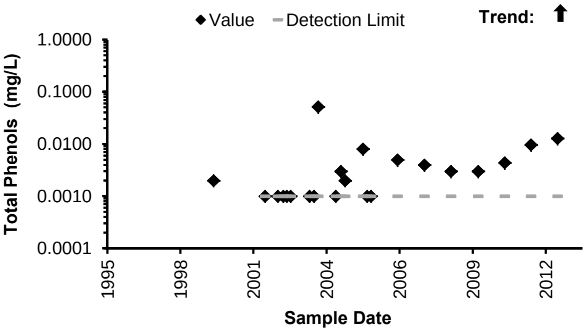
No guideline was applicable for total phenols in surface water, see Section 3.5.9.2.

Figure 35 (Cont'd.)

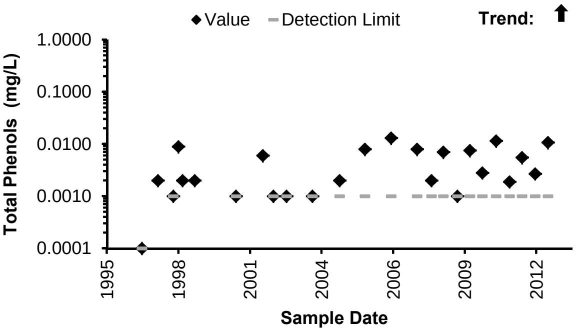
SHL-1 (Shipyard Lake)



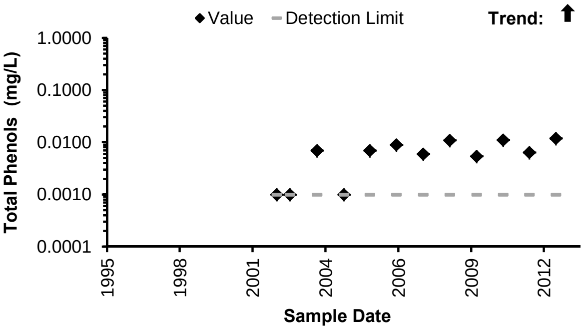
STC-1 (Stanley Creek)



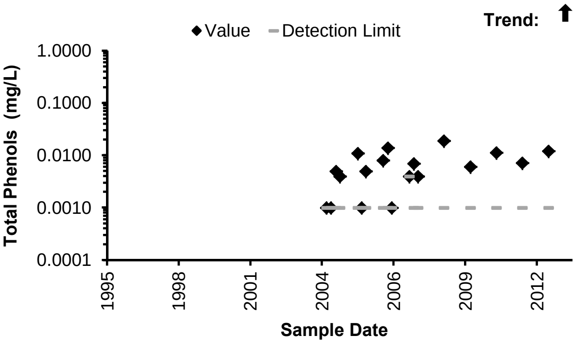
STR-1 (Steepbank River)



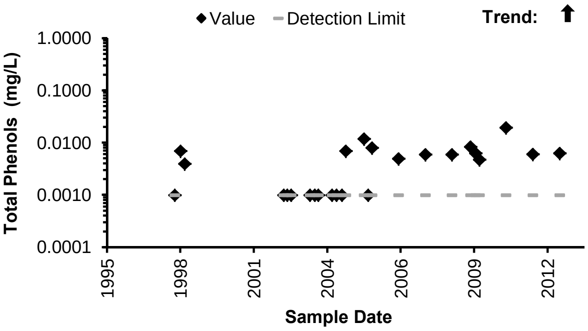
STR-2 (Steepbank River)



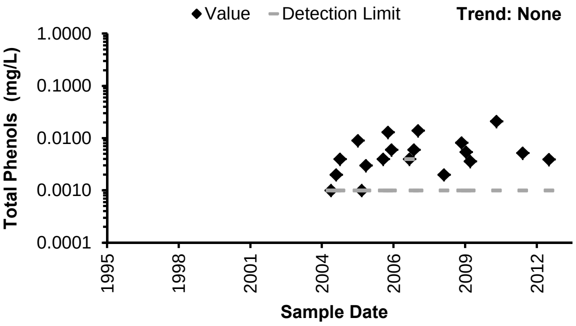
STR-3 (Steepbank River)



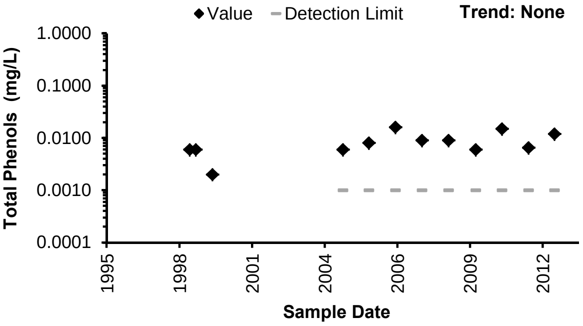
TAR-1 (Tar River)



TAR-2 (Tar River)



WAC-1 (Wapasu Creek)



Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

Note: Detection limits are indicated by a grey dash, absence of a grey dash indicates that detection limits were not provided for these data points.

No guideline was applicable for total phenols in surface water, see Section 3.5.9.2.

3.6 ORGANOCHLORINES AND ADSORBABLE ORGANIC HALIDES (AOX)

Organochlorines, or chlorinated organic compounds, are organic compounds that contain one or more covalently bonded chlorine atoms. Organochlorines in the environment can originate from wastewater and pulpmill effluent discharge, disinfectants, pesticides, dyes, wood preservatives, wood processing and treatment plants, and agricultural operations (Sanderson et al. 1997).

Adsorbable organic halides (AOX) are a measure of the total amount of organic chemicals containing halogen atoms (i.e., chlorine, bromine, iodine, fluorine) that adsorb from a water sample onto organic carbon. Chemicals measured in AOX are typically chlorinated organic compounds, formed through chlorination of lignin compounds during bleaching processes in pulpmills.

Chlorinated organic compounds are of interest due to their toxicity, bioaccumulation potential, and persistence in the environment, as well as their potential to cause tainting of fish tissue and odour problems (McCarthy et al. 1997), although these characteristics depend on the chemical structure of the chlorinated organic compound. Chlorinated organic compounds found in elemental-chlorine-free (ECF) pulpmill effluent (including, for example, chlorinated phenols, catechols, guaiacols, vanillins, and syringaldehydes) have been shown to affect the survival, health, reproduction or development of fish at concentrations between approximately 0.1 and 2.6 mg/L (Bright et al. 1997). However, concentrations of these compounds in actual treated effluents at ECF pulpmills typically occur at concentrations of less than 0.001 mg/L (Roberts et al. 2007).

Before the introduction of industrial process changes in Canada, significant quantities of chlorinated organic compounds were produced during the chlorinated bleaching process in pulpmills (Bright et al. 1997), and were released into the environment as effluent discharge. Following implementation of the Pulp and Paper Effluent Regulations (PPER) in 1992, pulpmill effluents were required to be not acutely toxic (as measured with rainbow trout and *Daphnia magna*). These requirements led to the elimination of elemental-chlorine bleaching, and installation of secondary treatment systems at all Canadian pulpmills (Halliburton and Maddison 2004), thereby resulting in significantly lower concentrations of chlorinated organic compounds in pulpmill effluent (Fisher et al. 1996, Stromberg et al. 1996, Lehtinen 2004).

3.6.1 Data Availability

3.6.1.1 Water Quality

Organochlorine data for surface waters were obtained from six AESRD stations, (Figure 36). However, station AB07BK0125 was only sampled in 2011 and 2012 and detection limits at this station were highly variable with some ranging from five to fifty times larger than those sampled at other stations in previous years. No clarification was received from AESRD regarding this station prior to the submission of this assessment; therefore, only data from five AESRD stations (AB07AD0100, AB07BE0010, AB07BK0005, AB07CC0030, AB07DD0105) were included in the assessment of organochlorine data; data for station AB07BK0125 were provided in Appendix A1. AOX data were available from seven AESRD stations within the Athabasca watershed. No data were available for organochlorines and AOX in surface water for the McLeod, Pembina, La Biche, Clearwater, or Lake Athabasca sub-watersheds.

3.6.1.2 Sediment Quality

Only one year of current data (i.e., 2008) were available for organochlorines in sediments from four AESRD LTRN stations (Figure 36). No data were available for organochlorines in sediment for the McLeod, Pembina, Lesser Slave, La Biche, Clearwater, or Lake Athabasca sub-watersheds.

No data were available for AOX in sediments for any of the sub-watersheds of the Athabasca watershed.

3.6.2 Organochlorines and AOX in Water

3.6.2.1 2012 Spatial comparisons

Given 2012 data for organochlorines and AOX in surface water were only available from one sample at one station (AB07BK0125), spatial comparisons were not conducted.

3.6.2.2 Compilation of Current Organochlorines and AOX in Water and Comparison with Guidelines

All organochlorines in surface water were below common detection limits (i.e., <0.02 to <2µg/L) for all AESRD stations (Table 23). No guidelines were exceeded for any organochlorines at any station.

Concentrations of AOX in surface water were detected (i.e., ≥20 µg/L) in at least one sample at six of the seven AESRD stations with available data. No guidelines were available for AOX.

3.6.2.3 Historical Trend Analysis

Statistical trend analysis was conducted on AOX in surface waters for six AESRD stations where there were at least seven years of water quality data. Concentrations of AOX at the Athabasca River downstream of Devil's Elbow (AB07DD0105) increased significantly over time; all other stations showed no significant trends over time (Figure 37). AOX is typically discharged into aquatic systems as part of pulpmill effluent; however, this increasing trend observed in the Lower Athabasca sub-watershed indicates that AOX may also be released from other sources such as municipal wastewater which contain sources of AOX in waste from cleaning agents and disinfectants from housekeeping, hospitals and canteen kitchens (Schulz & Hahn 1998).

Detection limits were not provided for AESRD AOX data prior to 1996 and are therefore not included in Figure 37. One AESRD station (AB07DA0980) had less than four years of data and was therefore excluded from both qualitative and quantitative trend analysis.

3.6.3 Organochlorines in Sediment

3.6.3.1 2012 Spatial Comparisons

Given that only 2008 data were available for organochlorines in sediments, spatial comparisons were not conducted. AOX was not measured in sediments.

3.6.3.2 Compilation of Current Organochlorines in Sediment and Comparison with Guidelines

All organochlorines measured in sediments were below detection (i.e., <2 to <5 mg/kg) for all four AESRD LTRN stations (Table 24). No CCME guidelines were available for the organochlorines measured.

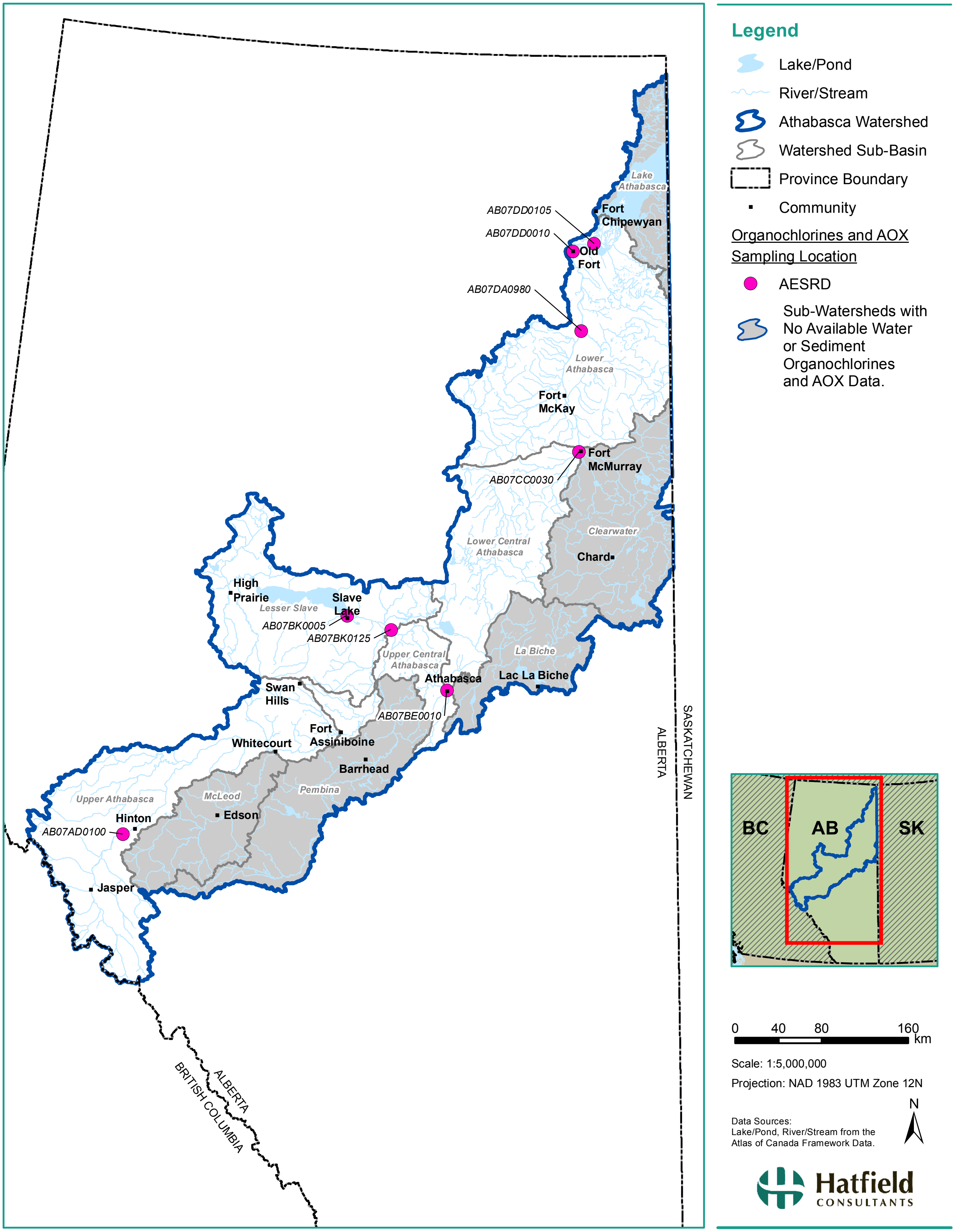
3.6.3.3 Historical Trend Analysis

Historical trend analysis was not conducted on any AESRD sediment stations, given that only one year of organochlorines data were available.

3.6.4 Overall Assessment: Organochlorines and AOX

- All surface water organochlorines and AOX data were obtained from stations in half of the Athabasca sub-watersheds, indicating a general gap in sampling of organochlorines and AOX in recent years throughout half of the Athabasca watershed.
- Sediment data were sparse for organochlorines in the Athabasca watershed given that only 2008 data were available for the current period.
- No AOX sediment data were available for the current period.
- All organochlorines in surface waters and sediments were below common detection limits and guidelines at all stations.
- Concentrations of AOX in surface water were detected in at least one sample in six of the seven AESRD stations with available data.
- No significant trends were observed in AOX at AESRD surface water stations except for station AB07DD0105 on the Athabasca River downstream of Devil's Elbow which showed an increasing trend in AOX over time. This trend may be attributed to the release of AOX from other sources such as municipal wastewater which contain sources of AOX in waste from cleaning agents and disinfectants from housekeeping, hospitals and canteen kitchens (Schulz & Hahn 1998).

Figure 36 Sampling locations for organochlorines and AOX in water and sediment.



Scale: 1:5,000,000

Projection: NAD 1983 UTM Zone 12N

Data Sources: Lake/Pond, River/Stream from the Atlas of Canada Framework Data.

K:\Data\Project\AWPAC6511\GIS_MXD\AWPAC6511_Loc05_Organochlorine_20140127_ss.mxd

Table 23 Organochlorines and AOX in surface water at AESRD stations with at least one year of current data available.

Analyte	Guideline (µg/L)			Common Detection Limit (µg/L)	Station							
					Upper Athabasca	Upper Central Athabasca	Lesser Slave		Lower Central Athabasca	Lower Athabasca		
	AESRD (2013)	CCME	BC		AB07AD0100	AB07BE0010	AB07BK0005	AB07BK0125	AB07CC0030	AB07DA0980	AB07DD0010	AB07DD0105
Adsorbable Organic Halides (AOX)	-	-	-	20	n=5 ◑	n=5 ◑	-	n=2 ○	n=5 ◕	n=2 ●	n=2 ●	n=3 ●
1,1,1,2-tetrachloroethane	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
1,1,1-trichloroethane	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
1,1,2,2-tetrachloroethane	110	110	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
1,1,2-trichloroethane	21	21	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
1,1-dichloroethane	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
1,1-dichloroethylene	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
1,1-dichloropropylene	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
1,2,3-trichlorobenzene	8	8	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
1,2,3-trichloropropane	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
1,2,4-trichlorobenzene	24	24	-	0.1	n=6 ○	n=6 ○	n=2 ○	-	n=6 ○	-	-	n=6 ○
1,2-dibromo-3-chloropropane	-	-	-	0.3	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
1,2-dibromoethane	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
1,2-dichlorobenzene	0.7	0.7	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
1,2-dichloroethane	100	100	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
1,2-dichloropropane	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes.

Legend

○ = All data below detection limit
◔ = 1-25% of data above detection
◑ = 26-50% of data above detection
◕ = 51-75% of data above detection
● = 76-100% of data above detection

Red highlighting indicates guideline exceedence.

Table 23 (Cont'd.)

Analyte	Guideline (µg/L)			Common Detection Limit (µg/L)	Station							
					Upper Athabasca	Upper Central Athabasca	Lesser Slave		Lower Central Athabasca	Lower Athabasca		
	AESRD (2013)	CCME	BC		AB07AD0100	AB07BE0010	AB07BK0005	AB07BK0125	AB07CC0030	AB07DA0980	AB07DD0010	AB07DD0105
1,3-dichlorobenzene	150	150	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
1,3-dichloropropane	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
1,4-dichlorobenzene	26	26	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
12,14-dichlorodehydroabietic acid	-	-	-	0.2	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	n=3 ○
12-chlorodehydroaibetic acid	-	-	-	0.2	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	n=3 ○
14-chlorodehydroaibetic acid	-	-	-	0.2	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	n=3 ○
2,2-dichloropropane	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
2,3,4,6-tetrachlorophenol	1	1	-	0.1	n=6 ○	n=6 ○	n=1 ○	-	n=6 ○	-	-	n=6 ○
2,3,6-trichlorophenol	18	18	-	0.02	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	n=3 ○
2,4,6-trichlorophenol	18	18	-	0.1	n=6 ○	n=6 ○	n=1 ○	-	n=6 ○	-	-	n=6 ○
2-chloroethylvinylether	-	-	-	0.4	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
2-chlorophenol	7	7	-	0.2	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes.

Legend

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●= 76-100% of data above detection

Red highlighting indicates guideline exceedence.

Table 23 (Cont'd.)

Analyte	Guideline (µg/L)			Common Detection Limit (µg/L)	Station							
					Upper Athabasca	Upper Central Athabasca	Lesser Slave		Lower Central Athabasca	Lower Athabasca		
	AESRD (2013)	CCME	BC		AB07AD0100	AB07BE0010	AB07BK0005	AB07BK0125	AB07CC0030	AB07DA0980	AB07DD0010	AB07DD0105
2-chlorotoluene	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
3,4,5-trichlorocatecol	-	-	-	0.02	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	n=3 ○
3,4,5-trichloroguaiacol	-	-	-	0.02	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	n=3 ○
3,4,5-trichloroveratrol	-	-	-	0.02	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	n=3 ○
3,4,6-trichlorocatechol	-	-	-	0.02	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	n=3 ○
3,4,6-trichloroguaiacol	-	-	-	0.02	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	n=3 ○
3,4-dichlorocatechol	-	-	-	0.02	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	n=3 ○
3,5-dichlorocatechol	-	-	-	0.02	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	n=3 ○
4,5,6-trichloroguaiacol	-	-	-	0.02	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	n=3 ○
4,5,6-trichlorosyringol	-	-	-	0.02	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	n=3 ○
4,5-dichlorocatechol	-	-	-	0.02	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	n=3 ○
4,5-dichloroguaiacol	-	-	-	0.02	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	n=3 ○
4,5-dichloroveratrole	-	-	-	0.02	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	n=3 ○
4,6-dichloroguaiacol	-	-	-	0.02	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	n=3 ○

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes.

Legend

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◔ = 1-25% of data above detection

◑ = 26-50% of data above detection

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● = 76-100% of data above detection

Red highlighting indicates guideline exceedence.

Table 23 (Cont'd.)

Analyte	Guideline (µg/L)			Common Detection Limit (µg/L)	Station							
					Upper Athabasca	Upper Central Athabasca	Lesser Slave		Lower Central Athabasca	Lower Athabasca		
	AESRD (2013)	CCME	BC		AB07AD0100	AB07BE0010	AB07BK0005	AB07BK0125	AB07CC0030	AB07DA0980	AB07DD0010	AB07DD0105
4-chloro-3-methylphenol	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
4-chlorocatechol	-	-	-	0.02	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	n=3 ○
4-chloroguaiacol	-	-	-	0.02	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	n=3 ○
4-chlorophenol	7	7	-	0.02	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	n=3 ○
4-chlorophenyl phenyl ether	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
4-chlorotoluene	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
9,10-dichlorostearic acid	-	-	-	1	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	n=3 ○
Bis(2-chloroethoxy)methane	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
Bis(2-chloroethyl)ether	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
Bis(2-chloroisopropyl)ether	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
Bromoform	-	-	-	0.5	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
Bromomethane	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
Carbon tetrachloride	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes.

Legend

○= All data below detection limit

◔= 1-25% of data above detection

◑= 26-50% of data above detection

◕= 51-75% of data above detection

●= 76-100% of data above detection

Red highlighting indicates guideline exceedence.

Table 23 (Cont'd.)

Analyte	Guideline (µg/L)			Common Detection Limit (µg/L)	Station							
					Upper Athabasca	Upper Central Athabasca	Lesser Slave		Lower Central Athabasca	Lower Athabasca		
	AESRD (2013)	CCME	BC		AB07AD0100	AB07BE0010	AB07BK0005	AB07BK0125	AB07CC0030	AB07DA0980	AB07DD0010	AB07DD0105
Chlorobenzene	1.3	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
Chloroethane	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
Chloroform	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
Chloromethane	-	-	-	0.5	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
Cis-1,2-dichloroethene	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
Cis-1,3-dichloropropene	-	-	-	0.3	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
Dibromochloromethane	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
Dibromomethane	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
Dichlorobromomethane	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
Hexachlorobenzene	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
Hexachlorobutadiene	1.3	1.3	-	0.5	n=6 ○	n=6 ○	n=2 ○	-	n=6 ○	-	-	n=6 ○
Hexachlorocyclopentadiene	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
Hexachloroethane	-	-	-	0.5	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
Methylene chloride (Dichloromethane)	-	-	-	2.0	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
Tetrachlorocatecol	-	-	-	0.02	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	n=3 ○
Tetrachloroethylene	-	-	-	0.3	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
Tetrachlorguaiacol	-	-	-	0.02	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	n=3 ○

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes.

Legend

○ = All data below detection limit

◔ = 1-25% of data above detection

◑ = 26-50% of data above detection

◕ = 51-75% of data above detection

● = 76-100% of data above detection

Red highlighting indicates guideline exceedence.

Table 23 (Cont'd.)

Analyte	Guideline (µg/L)			Common Detection Limit (µg/L)	Station							
					Upper Athabasca	Upper Central Athabasca	Lesser Slave		Lower Central Athabasca	Lower Athabasca		
	AESRD (2013)	CCME	BC		AB07AD0100	AB07BE0010	AB07BK0005	AB07BK0125	AB07CC0030	AB07DA0980	AB07DD0010	AB07DD0105
Tetrachloroveratrol	-	-	-	0.02	n=3 ○	n=3 ○	-	-	n=3 ○	-	-	n=3 ○
Trans-1,2-dichloroethene	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
Trans-1,3-dichloropropene	-	-	-	0.3	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
Trichloroethylene	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
Trichlorofluoromethane	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
Trihalomethanes	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○
Vinyl chloride	-	-	-	0.5	n=3 ○	n=3 ○	n=1 ○	-	n=3 ○	-	-	n=3 ○

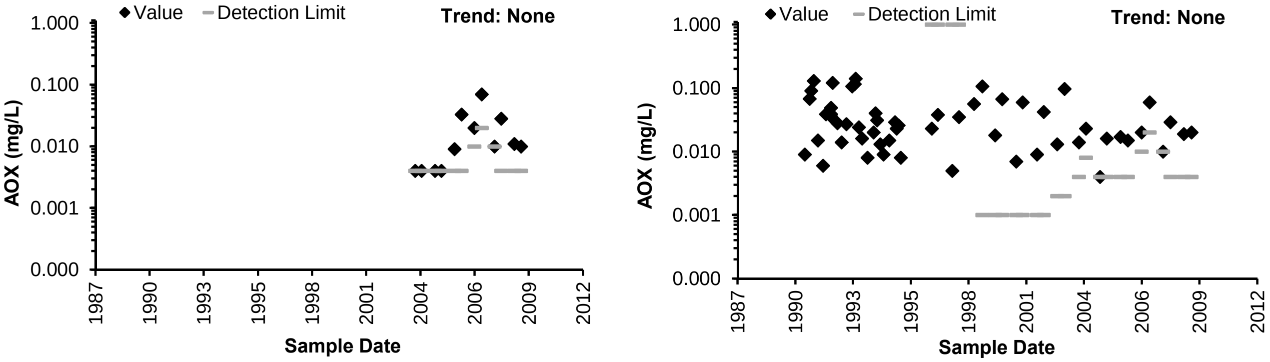
Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes.

Legend

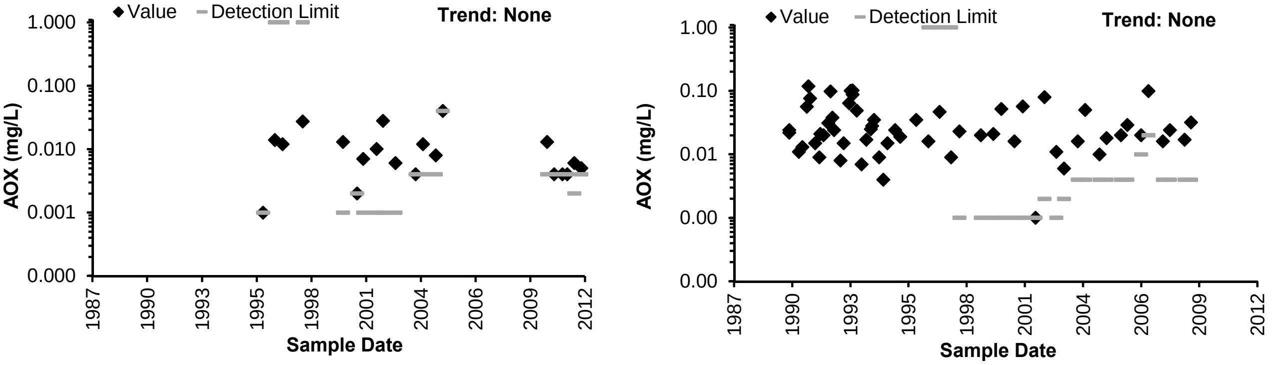
○ = All data below detection limit
◔ = 1-25% of data above detection
◑ = 26-50% of data above detection
◕ = 51-75% of data above detection
● = 76-100% of data above detection

Red highlighting indicates guideline exceedence.

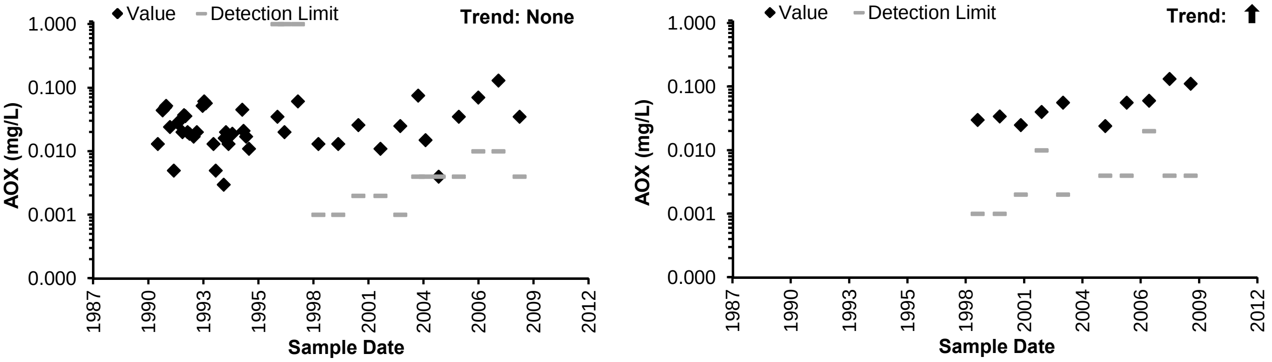
Figure 37 **Adsorbable Organic Halide (AOX) (Log Scale)in surface water at AESRD stations with historical datasets.**


AB07AD0100 (Athabasca River at Old Entrance town site)

AB07BE0010 (Athabasca River at the town of Athabasca)


AB07BK0125 (Lesser Slave River)

AB07CC0030 (Athabasca River upstream of Fort McMurray)


AB07DD0010 (Athabasca River at Old Fort)

AB07DD0105 (Athabasca River downstream of Devils Elbow)

Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values.

Note: Detection limits were not provided for AOX data prior to 1996. No guideline was available for AOX in surface water.

Table 24 Organochlorines in sediments at AESRD stations with at least one year of current data available.

Analyte	Guideline		Common Detection Limit (mg/kg)	Station			
				Upper Athabasca	Upper Central Athabasca	Lower Central Athabasca	Lower Athabasca
	CCME - ISQG	CCME - PEL		AB07AD0100	AB07BE0010	AB07CC0030	AB07DD0010
1,2,4-trichlorobenzene	-	-	2	n=1 ○	n=1 ○	n=3 ○	n=1 ○
2,3,4,6-tetrachlorophenol	-	-	2	n=1 ○	n=1 ○	n=3 ○	n=1 ○
2,4,6-trichlorophenol	-	-	2	n=1 ○	n=1 ○	n=3 ○	n=1 ○
2-chlorophenol	-	-	4	n=1 ○	n=1 ○	n=3 ○	n=1 ○
4-chloro-3-methylphenol	-	-	2	n=1 ○	n=1 ○	n=3 ○	n=1 ○
4-chlorophenyl phenyl ether	-	-	2	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Bis(2-chloroethoxy)methane	-	-	2	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Bis(2-chloroethyl)ether	-	-	2	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Bis(2-chloroisopropyl)ether	-	-	2	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Hexachlorobenzene	-	-	2	n=2 ○	n=2 ○	n=6 ○	n=2 ○
Hexachlorobutadiene	-	-	5	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Hexachlorocyclopentadiene	-	-	2	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Hexachloroethane	-	-	5	n=1 ○	n=1 ○	n=3 ○	n=1 ○

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes.

Legend

○ = All data below detection limit
◔ = 1-25% of data above detection
◑ = 26-50% of data above detection
◕ = 51-75% of data above detection
● = 76-100% of data above detection

Red highlighting indicates guideline exceedence.

3.6.5 Dioxins and Furans

Dioxins (polychlorinated dibenzo-p-dioxins, PCDDs) and furans (polychlorinated dibenzofurans, PCDFs) are a group of 210 distinct chlorinated organic compounds. Dioxins and furans in the environment can originate from the large-scale incineration of municipal and medical waste, pulp and paper mill processes using elemental chlorine, steel and iron production, the burning of fuel and wood, electrical power generation, tobacco smoke, and natural processes such as forest fires and volcanic eruptions (Health Canada 2005, McCarthy et al. 1997).

Dioxins and furans are persistent in the environment, hydrophobic and lipophilic (i.e., fat-soluble), and therefore have a strong affinity for sediments in freshwater ecosystems and a high potential for accumulating in biological tissues of aquatic organisms (CEPA 1990). Dioxins and furans can also be transported far from their original source via air pollutants (CCME 2001b).

Under the *Canadian Environmental Protection Act*, dioxins and furans are considered toxic (CEPA 1990). Some dioxin and furan congeners are more toxic than others, and relative concentrations of each in the environment differ depending on the original source as well as the industrial processes applied to it (MacDonald et al. 1998, Bright et al. 1999). The most toxic of these compounds is 2,3,7,8-tetrachlorodibenzodioxin, or TCDD. Historically, the use of elemental chlorine in bleached kraft pulpmills led to the release of dioxins and furans to the environment through pulpmill effluent; however, regulations that came into effect in 1992 prohibit the discharge of measurable concentrations of the most toxic dioxin and furan congeners and have significantly reduced this source (Environment Canada 2003). Over recent years, industrial production of these compounds has been subjected to regulation in Canada and dioxins and furans are facing elimination under the Canadian Environmental Protection Act (CEPA), the federal Toxic Substances Management Policy (TSMP) and the Canadian Council of Ministers of the Environment (CCME) Policy for the Management of Toxic Substances (CCME 2001b).

Dioxins and furans TCDD/TCDF were non-detectable in effluent discharged from West Fraser Timber Co.'s Hinton Pulp, and Alberta Pacific Forest Industries (AlPac) in 2013, and have been in compliance with the CEPA/Pulp and Paper Effluent Regulations (PPER) requirements for seven years (pers comm. Dan Moore, Alberta Newsprint Company, October 17, 2013).

3.7 POLYCHLORINATED BIPHENYLS

Polychlorinated biphenyls (PCBs) are synthetic, chlorine-containing compounds that have been widely used since 1929 in a variety of products including transformers, capacitors, hydraulic fluids, and as plasticizers in paints, plastics, and sealants (Webster et al. 2013, ATSDR 2001). There are 209 distinct PCB compounds, known as congeners. Each congener consists of a biphenyl molecule with attached chlorine atoms; the number and position of the chlorine atoms determines its environmental fate and toxicity as well as the congener name (e.g., 3,4,4′-Trichlorobiphenyl). PCBs were generally used commercially as mixtures of individual congeners; in North America, Aroclors (the trade name for mixtures of PCBs produced historically by Monsanto) were the most common commercial mixtures.

Originally, PCBs were released into the environment during their manufacture, use, and disposal, as well as from spills, leaks, and fires. However, due to environmental and human health concerns of PCBs, the manufacture and processing of PCBs in North America and western Europe was discontinued in the 1970s and in eastern Europe and Russia in the early 1990s. In Canada, the import, manufacture, and sale (for re-use) of PCBs was made illegal in 1977 and release of PCBs to the environment was made illegal in 1985, although Canadian legislation permits owners of PCB-containing equipment to continue using the equipment until the end of its service life (Health Canada 2005). PCBs can still enter the environment following destruction and disposal of industrial plants and equipment, emissions from construction materials, or leaching of old equipment from landfills (Webster et al. 2013). In addition, PCBs can be transported through the atmosphere and deposited in locations far from the emission source (ATSDR 2001).

PCBs are persistent in the environment, hydrophobic, and adsorb to organic particles and bottom sediments in aquatic environments. Because of their affinity for fats and their slow rate of metabolism, PCBs can bioaccumulate and biomagnify in aquatic food chains, leading to high concentrations of PCBs in aquatic birds and mammals, including humans, who consume those organisms (e.g., sport fish) (Webster et al. 2013, Hazewinkel and Noton 2004). PCBs can have numerous deleterious effects on living organisms, including toxic effects on the immune, nervous, and reproductive systems of mammals as well as acting as probable carcinogens (ATSDR 2001).

3.7.1 Data Availability

3.7.1.1 Water Quality

No current data were available for polychlorinated biphenyls in surface water from any AESRD, EC (JOSM), or RAMP stations (Figure 38). PCBs data were available from 1987-1994 at 16 AESRD stations, and all values were below detection (i.e., <0.05 to <0.2 µg/L) for all stations, however; these data were not assessed any further as they were outside of the scope of this report.

3.7.1.2 Sediment Quality

Only one year of current data (i.e., 2008) were available for polychlorinated biphenyls in sediments from four AESRD LTRN stations (Figure 38). No data were available for PCBs in sediment for the McLeod, Pembina, Lesser Slave, La Biche, Clearwater, or Lake Athabasca sub-watersheds.

3.7.2 PCBs in Sediment

3.7.2.1 2012 Spatial comparisons

Given only 2008 data were available for PCBs in sediments, spatial comparisons were not conducted.

3.7.2.2 Compilation of Current PCBs in Sediment and Comparison with Guidelines

All PCBs measured in sediments were below detection (i.e., <0.01 mg/kg) and below guidelines for all four AESRD LTRN stations (Table 25).

3.7.2.3 Historical Trend Analysis

Historical trend analysis was not conducted on any AESRD sediment stations, given only one year of PCB data were available.

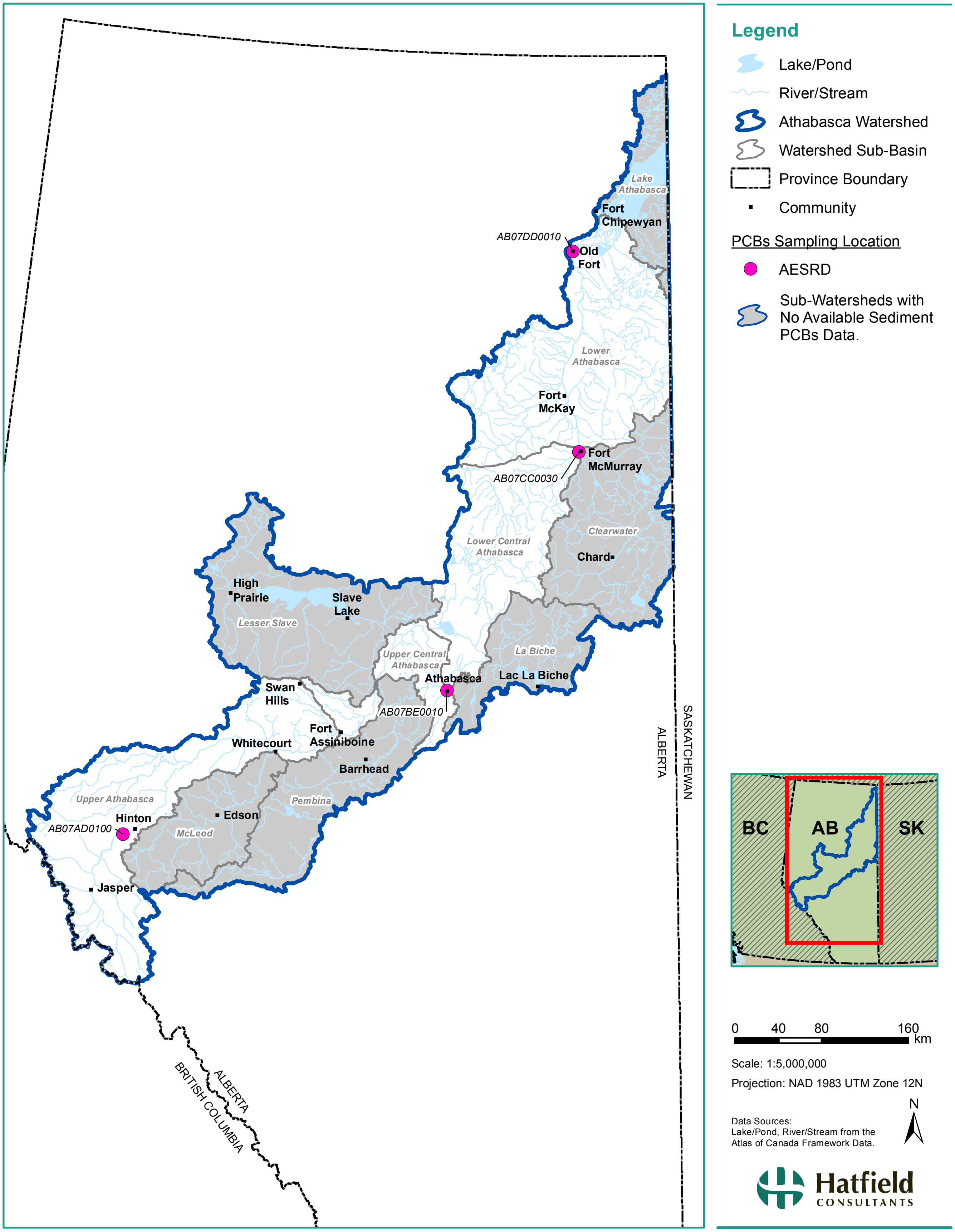
3.7.3 Overall Assessment: PCBs

- No current surface water data for PCBs in the Athabasca watershed were available, indicating a general gap in sampling of PCBs throughout the entire Athabasca watershed.

- Sediment data were sparse for PCBs in the Athabasca watershed given that only 2008 data were available for the current period.

- All PCBs in sediments were below common detection limits and guidelines at all stations.

Figure 38 Sampling locations for PCBs in sediment.



Scale: 1:5,000,000

Projection: NAD 1983 UTM Zone 12N

Data Sources:
Lake/Pond, River/Stream from the Atlas of Canada Framework Data.

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Table 25 PCB in Sediments for AESRD Stations with at least one year of current data available.

Analyte	Guideline			Common Detection Limit (mg/kg)	Station			
					Upper Athabasca	Upper Central Athabasca	Lower Central Athabasca	Lower Athabasca
	CCME-ISQG	CCME-PEL	BC Aquatic Life		AB07AD0100	AB07BE0010	AB07CC0030	AB07DD0010
Total PCBs	0.0341	0.277	0.02*	0.01	n=1 ○	n=1 ○	n=3 ○	n=1 ○

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes.
*Guideline is 0.02 at 1% organic carbon, otherwise calculated by 0.02 x1% organic carbon content

Legend

○ = All data below detection limit
◔ = 1-25% of data above detection
◑ = 26-50% of data above detection
◕ = 51-75% of data above detection
● = 76-100% of data above detection

Red highlighting indicates guideline exceedence.

3.8 TRACE METALS

Metals in the environment can originate naturally from erosion of rocks and soils, and concentrations can vary substantially by metal and by region due to different geological characteristics. Trace metals imply the occurrence of a particular metal at low (trace) concentrations in the environment (Rainbow 2006). Anthropogenic origins of trace metals in the environment include point and non-point source pollution, including the discharge of municipal and industrial effluents, mine drainage, runoff, and atmospheric deposition (i.e., via upgraders, dust from mines, etc.).

While many trace metals are required nutrients for both plant and animal life, elevated concentrations or availability of trace metals can have toxic effects on aquatic organisms (Driscoll et al. 1994). In freshwater ecosystems, there is a lack of natural elimination processes for metals, which leads to the shifting of metals between environmental compartments such as aquatic sediments, surface waters, and aquatic organisms (Chapman 1996). Due to the adsorption of metals to sediment particles, concentrations of metals in sediments are generally higher than in surface waters. Thus, a common measure of trace metals in aquatic environments is through concentration in sediments (Rainbow 2006). However, trace metals that exist as freely dissolved ions in the aqueous phase are the most bioavailable to aquatic organisms and have the greatest chance of causing adverse effects (Baker et al. 2012).

3.8.1 Data Availability

3.8.1.1 Sediment Quality

Trace metals in sediment data were obtained from 30 RAMP stations (Figure 39). Of the ten sub-watersheds in the Athabasca River watershed, sediment trace metals data were only available for only two: the Lower Athabasca and Clearwater.

Recent studies have also examined trace metals in sediments within and around the Lower Athabasca and Cold Lake oil sands regions:

- Wiklund et al. (2012) collected sediment cores from an isolated, upland lake located in a bedrock basin near Fort Chipewyan, Alberta to assess the potential dispersal of contaminants from Alberta oil sands emissions to the Peace-Athabasca delta, ~200 km to the north. They found that current industrial emissions from the Alberta oil sands are not measurably increasing airborne antimony (Sb) and arsenic (As) concentrations to the Peace-Athabasca delta, and even though current lead (Pb) and mercury (Hg) concentrations are above background levels, decreasing trends during the period of increasing oil sands production imply that the oil sands industry is not a major far-field source of airborne Pb and Hg; and

- Skierszkan et al. (2013) collected sediment cores from two lakes (Hilda and Ethel Lake) in the immediate vicinity of the Cold Lake oil field in eastern Alberta and also analysed surficial soil samples from the region to assess the impact of in-situ oil sand extraction on regional metal enrichment in soil and sediment. Based on the sediment core data, they found that metal enrichment from the in-situ oil sand facilities was not detectable at the Cold Lake oil field. Sediment core data also showed cadmium (Cd), lead (Pb), and mercury (Hg) enrichment in the early 20th Century, with concentrations peaking prior to establishment of Cold Lake operations in 1985 and declining or leveling off since then. Surficial soil samples showed minor enrichment in four trace metals (Cd, arsenic (As), nickel (Ni), vanadium (V)), but the As, Ni, and V enrichment may have been driven by adsorption to iron hydroxides. They concluded that in the absence of bitumen upgrading and surface mining activities, in situ extraction processes have not been a major source of metals emissions at Cold Lake.

3.8.2 Trace Metals in Sediment

3.8.2.1 2012 Spatial Comparisons

Spatial comparisons were conducted on all metals that exceeded CCME guidelines for the current data period, namely arsenic, copper, and mercury. Any stations that exceeded CCME guidelines in 2012 were shaded dark green on the bubble maps. If metals concentrations were below detection, half of the station marker was shaded black.

Total arsenic concentrations ranged from 0.03 mg/kg at McLelland Lake (MCL-1) to 8.9 mg/kg at the lower Tar River (TAR-D1) (Figure 40). Total arsenic concentrations were generally lowest in the Clearwater sub-watershed upstream of Fort McMurray and at certain stations northeast of Fort McKay. Concentrations of total arsenic were generally highest immediately downstream of Fort McMurray and Fort McKay around Poplar Creek and Tar River stations and further downstream in the Athabasca River delta. Total arsenic exceeded CCME guidelines (5.9 mg/kg) for sediments in one sample at five RAMP stations (EMR-2, ISL-1, POC-D1, SHL-1, and TAR-D1) in 2012.

Total copper concentrations ranged from 0.72 mg/kg at upper Christina River (CHR-D2) to 24.5 mg/kg at Isadore's Lake (ISL-1) (Figure 41). Similar to total arsenic, total copper concentrations were generally lowest in the Clearwater sub-watershed upstream of Fort McMurray and at certain stations northeast of Fort McKay. Concentrations of total copper were generally highest immediately downstream of Fort McMurray and Fort McKay around Poplar Creek and Isadore's Lake stations and further downstream in the Athabasca River delta. In 2012, no stations exceeded CCME guidelines for total copper in sediments.

Total mercury concentrations were below detection (i.e., <0.05 mg/kg) at almost all RAMP stations. Three stations (POC-D1, ISL-1, EMR-2) showed detectable concentrations of total mercury, ranging from 0.055 mg/kg at upper Embarras River (EMR-2) to 0.058 mg/kg at Isadore's Lake (ISL-1) (Figure 42). In 2012, no stations exceeded CCME guidelines for total mercury in sediments. In general the detection limit for total mercury (0.05 mg/kg) in all samples was higher than expected mercury concentrations in surface mineral soils and sediments far removed from point sources, which have been shown to have concentrations less than 0.05 mg/kg in studies from the north central USA (Nater & Grigal 1992), and from southeastern to central Alberta (Dudas & Pawluk 1976). However, this detection limit remains well below the ISQG guideline value of 0.17 mg/kg for the protection of aquatic life.

3.8.2.2 Compilation of Current Trace Metals in Sediment and Comparison with Guidelines

Most metals were detectable (i.e., ≥0.05 to ≥200 mg/kg) at all RAMP stations, with the exception of total beryllium, bismuth, cadmium, silver, and thallium, which were all below detection at all RAMP stations (Table 26). Concentrations of tin and uranium were detectable at only one station each and mercury and molybdenum were detectable at less than half of the RAMP stations.

Total arsenic exceeded CCME ISQG guidelines (5.9 mg/kg) for sediments at six RAMP stations (ELR-D1, two samples from 2010, 2011; EMR-2, two samples from 2010 and 2012; ISL-1, four samples from 2007, 2008, 2010, 2012; POC-D1, four samples from 2008, 2009, 2011, 2012; SHL-1, four samples from 2007, 2009, 2010, 2012; and TAR-D1, three samples from 2010, 2011, 2012) in the Lower Athabasca sub-watershed. Arsenic can originate naturally in surface waters from weathering of rocks and soils, and anthropogenically through pollution from smelting and refining industries (CCME 2001c).

Concentrations of copper exceeded CCME ISQG guidelines (35.7 mg/kg) at Kearl Lake (KEL-1, one sample in 2009), and concentrations of mercury exceeded CCME ISQG guidelines (0.17 mg/kg) at Isadore’s Lake (ISL-1, one sample in 2008). No CCME PEL guidelines were exceeded for any metals in sediments for the current data period.

3.8.2.3 Historical Trend Analysis

Historical trend analysis was conducted on metals that exceeded guidelines for the current data period; arsenic, copper, and mercury.

Statistical trend analysis was conducted on total arsenic in sediment for 19 RAMP stations where there were at least seven years of water quality data. Concentrations of total arsenic at four RAMP stations (ATR-ER, CHR-D2, KEL-1, MCL-1) decreased significantly over time; all other stations showed no significant trends over time. (Figure 43). Six RAMP stations (CHL-1, EMR-1, EMR-2, JOL-1, SAC-D1, SUC-D1) had less than four years of total arsenic data and were therefore excluded from both qualitative and quantitative trend analysis. Historical total arsenic concentrations for five additional RAMP stations (CAR-D1, CAR-D2, CLR-D1, CLR-D2, FIR-D1) were plotted, but were excluded from statistical trend analysis because these stations either had less than seven years of data, or had greater than 50% non-detectable values (Figure 43).

Statistical trend analysis was conducted on total copper in sediment for 18 RAMP stations where there were at least seven years of water quality data. Concentrations of total copper at four RAMP stations (ATR-ER, CHR-D2, FOC-D1, SHL-1) decreased significantly over time; all other stations showed no significant trends over time. (Figure 44). Six RAMP stations (CHL-1, EMR-1, EMR-2, JOL-1, SAC-D1, SUC-D1) had less than four years of total copper data and were therefore excluded from both qualitative and quantitative trend analysis. Historical total copper concentrations for six additional RAMP stations (BER-D2, CAR-D1, CAR-D2, CLR-D1, CLR-D2, FIR-D1) were plotted, but were excluded from statistical trend analysis because these stations either had less than seven years of data, or had greater than 50% non-detectable values (Figure 44).

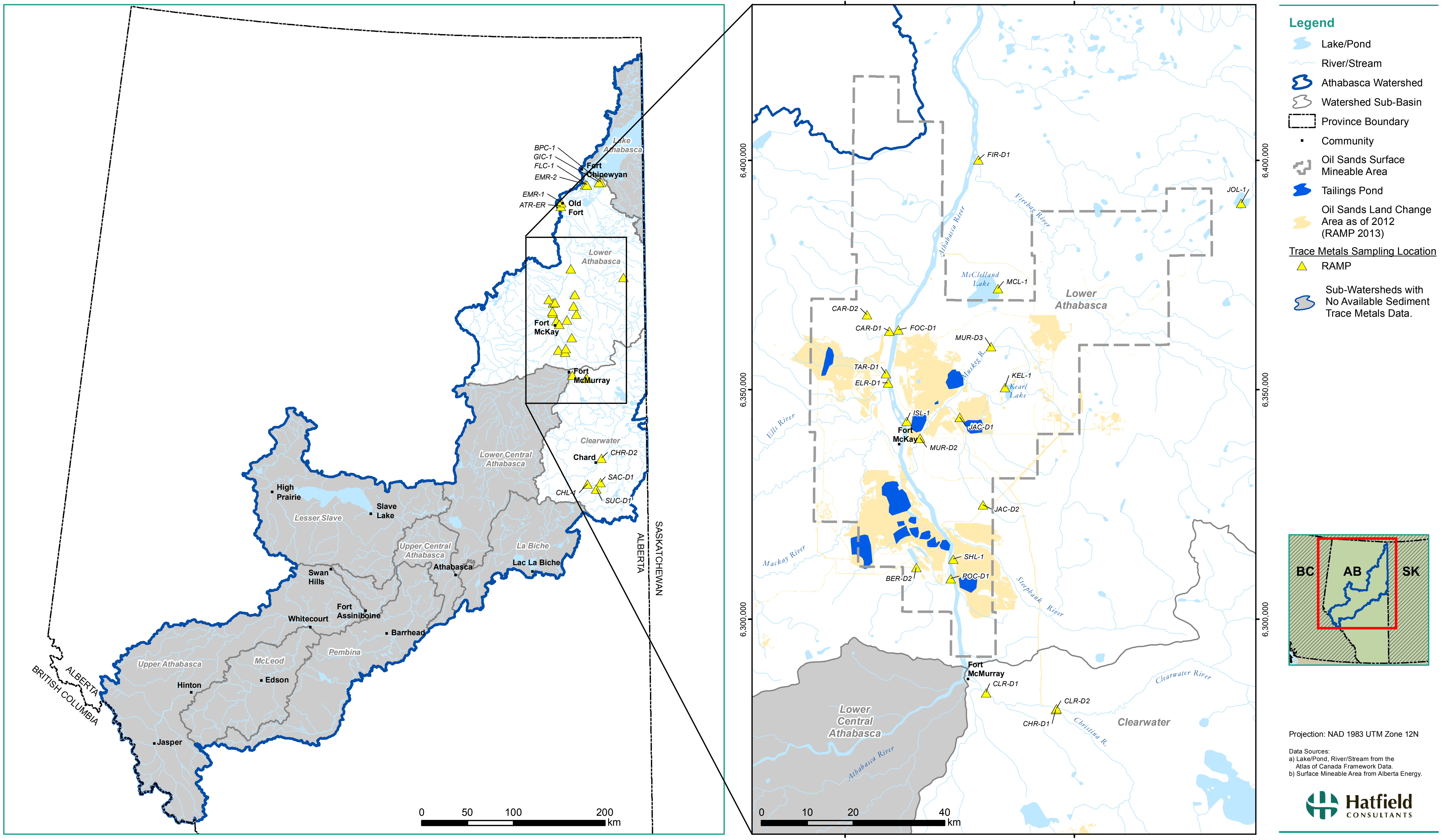
For total mercury, six RAMP stations (CHL-1, EMR-1, EMR-2, JOL-1, SAC-D1, SUC-D1) had less than four years of data and were therefore excluded from both qualitative and quantitative trend analysis. Historical total mercury concentrations for the remaining 24 RAMP stations were plotted, but were excluded from statistical trend analysis because these stations either had less than seven years of data, or had greater than 50% non-detectable values (Figure 45).

The majority of total mercury samples were below detection at all RAMP stations over all years of data.

3.8.3 Overall Assessment: Trace Metals

- All sediment trace metals data were obtained from RAMP stations in the lower Athabasca and Clearwater sub-watersheds indicating a general gap in sampling of trace metals in sediments throughout the majority of the Athabasca watershed.
- The majority of metals were measureable in at least one sediment sample at all RAMP stations.
- Concentrations of arsenic exceeded CCME ISQG guidelines at six RAMP stations in the Lower Athabasca sub-watershed; mercury and copper exceeded guidelines at one RAMP station each. No CCME PEL guidelines were exceeded for any metals in sediments for the current data period.
- Concentrations of total arsenic at four RAMP stations decreased significantly over time; all other stations showed no significant trends over time.
- Concentrations of total copper at four RAMP stations decreased significantly over time; all other stations showed no significant trends over time.
- Statistical trend analysis was not conducted for total mercury in sediments given that the majority of total mercury samples were below detection at all RAMP stations over all years of data.

Figure 39 Sampling locations for trace metals in sediment.



Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Lake/Pond, River/Stream from the Atlas of Canada Framework Data.
b) Surface Mineable Area from Alberta Energy.

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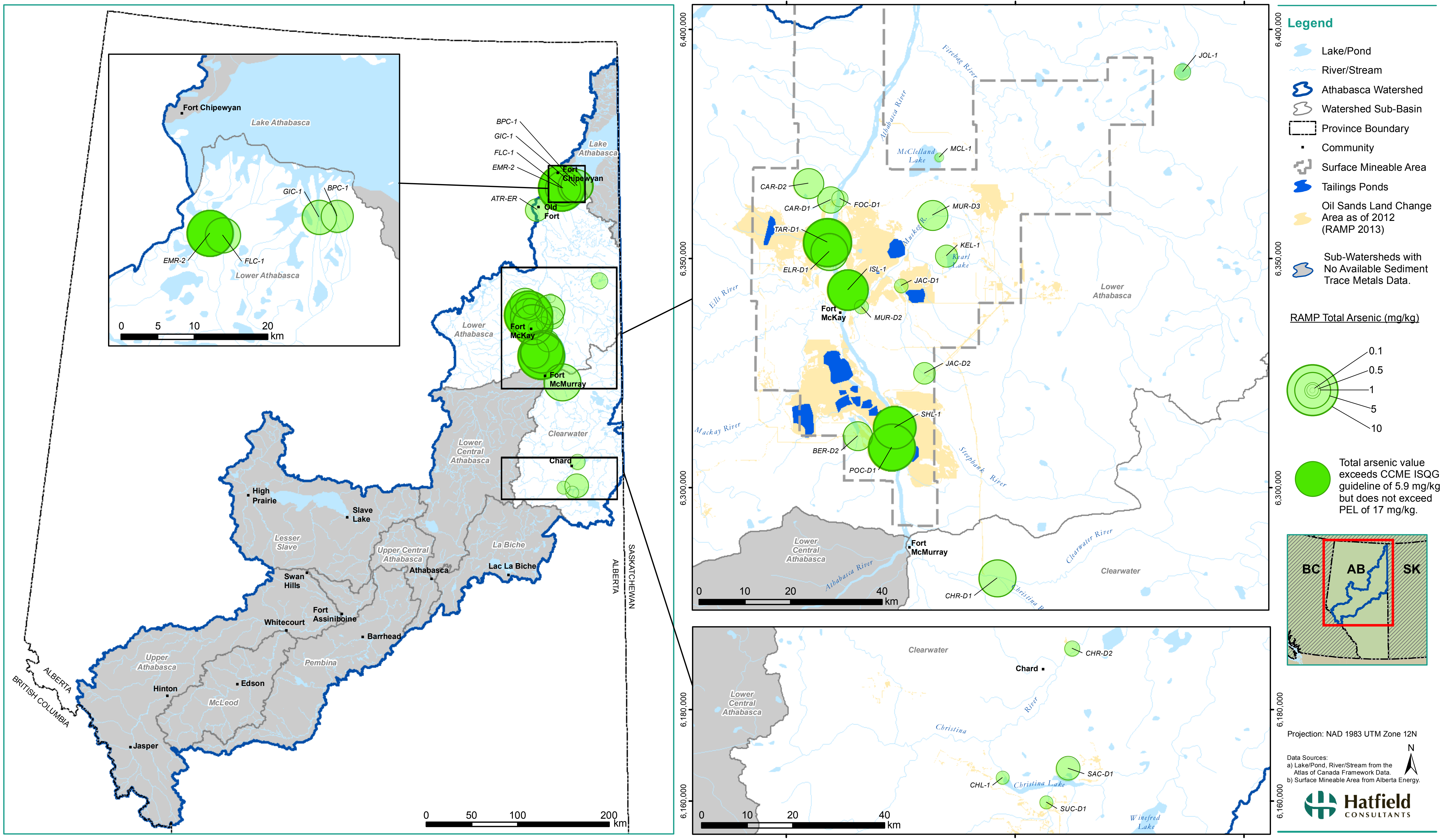
Figure 40 Total arsenic in sediment (mg/kg), fall 2012.



K:\Data\Project\AWPAC6511\GIS_MXD\AWPAC6511_Bub04_TraceMetals_Arsenic_20140127_ss.mxd

Figure 41 Total copper in sediment (mg/kg), fall 2012.

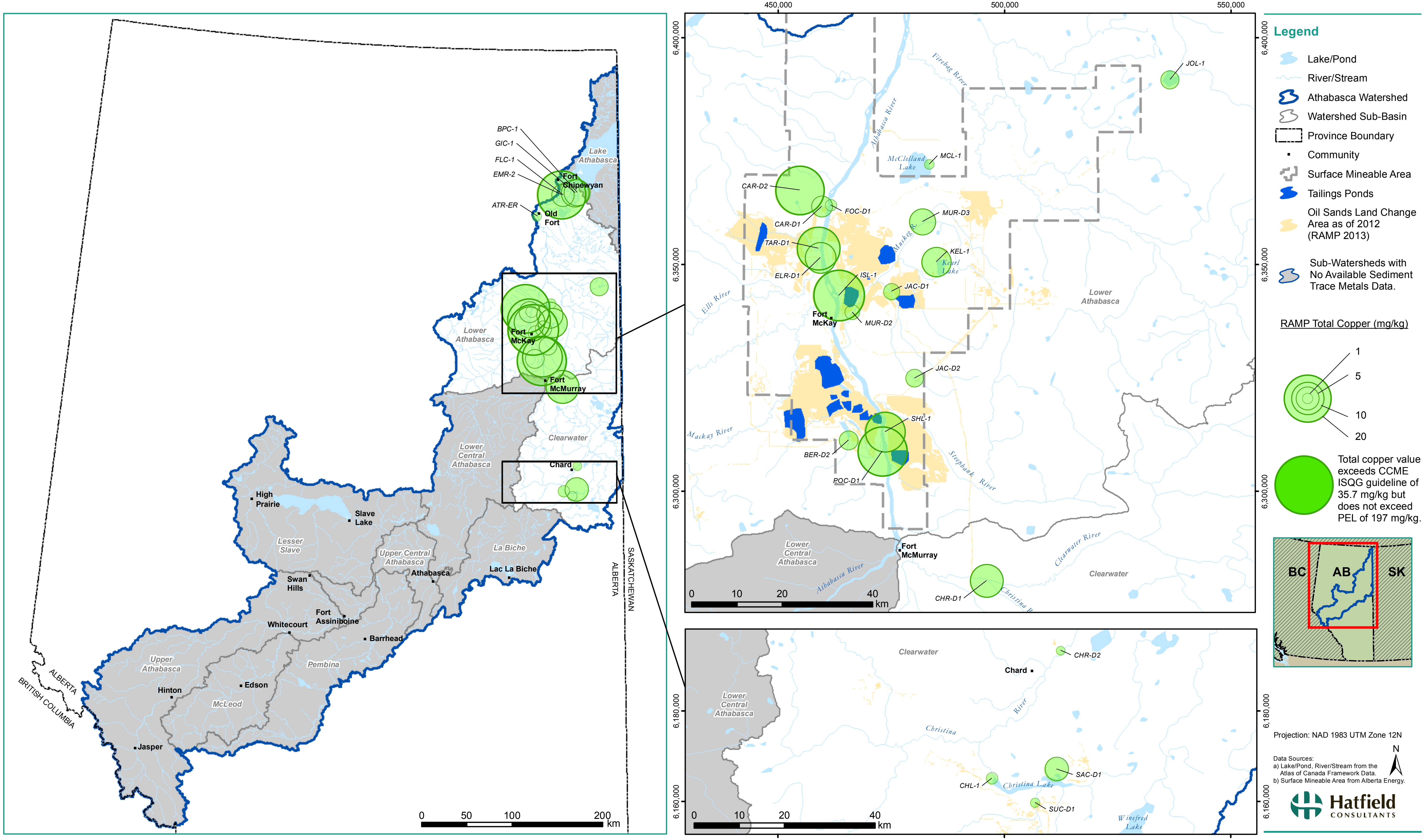


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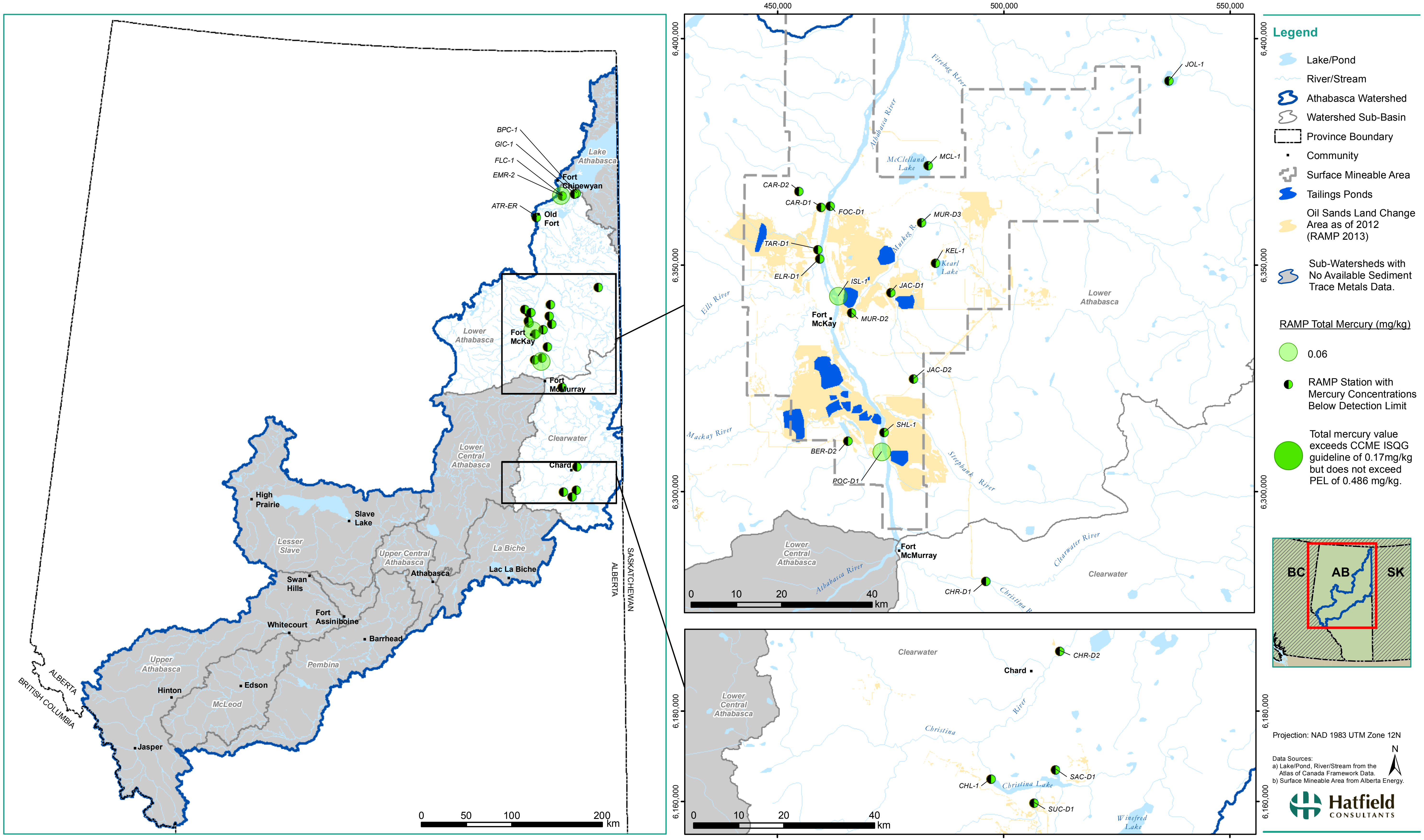
Figure 42 Total mercury in sediment (mg/kg), fall 2012.



Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Lake/Pond, River/Stream from the Atlas of Canada Framework Data.
b) Surface Mineable Area from Alberta Energy.

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Table 26 Total metals in sediments for RAMP stations with at least one year of current data available.

Analyte	Guideline (mg/kg)		Common Detection	Station																													
	CCME - ISQG	CCME - PEL	Limit (mg/kg)	ATR-ER	BER-D2	BPC-1	CAR-D1	CAR-D2	CHL-1	CHR-D1	CHR-D2	CLR-D1	CLR-D2	ELR-D1	EMR-1	EMR-2	FIR-D1	FLC-1	FOC-D1	GIC-1	ISL-1	JAC-D1	JAC-D2	JOL-1	KEL-1	MCL-1	MUR-D2	MUR-D3	POC-D1	SAC-D1	SHL-1	SUC-D1	TAR-D1
Total Aluminum (Al)	-	-	50	n=6 ●	n=5 ●	n=6 ●	n=2 ●	n=2 ●	n=1 ●	n=3 ●	n=2 ●	n=2 ●	n=2 ●	n=4 ●	n=1 ●	n=2 ●	n=2 ●	n=6 ●	n=5 ●	n=6 ●	n=6 ●	n=6 ●	n=6 ●	n=2 ●	n=5 ●	n=6 ●	n=6 ●	n=6 ●	n=5 ●	n=1 ●	n=6 ●	n=1 ●	n=4 ●
Total Antimony (Sb)	-	-	0.2	n=3 ○	n=3 ○	n=3 ◕	n=1 ●	n=1 ●	n=1 ●	n=1 ●	n=1 ●	n=1 ○	n=1 ○	n=3 ●	n=1 ○	n=2 ●	n=1 ○	n=3 ◕	n=3 ○	n=3 ◕	n=3 ◕	n=3 ◑	n=3 ○	n=2 ○	n=4 ◑	n=3 ◑	n=3 ◑	n=3 ○	n=3 ◕	n=1 ○	n=3 ●	n=1 ●	n=3 ◕
Total Arsenic (As)	5.9	17	0.2	n=6 ●	n=5 ●	n=6 ●	n=2 ●	n=2 ●	n=1 ●	n=3 ●	n=2 ●	n=2 ●	n=2 ●	n=4 ◑	n=1 ●	n=2 ●	n=2 ●	n=6 ●	n=5 ●	n=6 ●	n=6 ◕	n=6 ●	n=6 ●	n=2 ●	n=6 ●	n=6 ●	n=6 ●	n=6 ●	n=5 ●	n=1 ●	n=6 ◕	n=1 ●	n=4 ◕
Total Barium (Ba)	-	-	5	n=6 ●	n=5 ●	n=6 ●	n=2 ●	n=2 ●	n=1 ●	n=3 ●	n=2 ●	n=2 ●	n=2 ●	n=4 ●	n=1 ●	n=2 ●	n=2 ●	n=6 ●	n=5 ●	n=6 ●	n=6 ●	n=6 ●	n=6 ●	n=2 ●	n=6 ●	n=6 ●	n=6 ●	n=6 ●	n=5 ●	n=1 ●	n=6 ●	n=1 ●	n=4 ●
Total Beryllium (Be)	-	-	1	n=6 ○	n=5 ○	n=6 ○	n=2 ○	n=2 ○	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ○	n=1 ○	n=2 ○	n=2 ○	n=6 ○	n=5 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=2 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=5 ○	n=1 ○	n=6 ○	n=1 ○	n=4 ○
Total Bismuth (Bi)	-	-	0.5	n=6 ○	n=5 ○	n=6 ○	n=2 ○	n=2 ○	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ○	n=1 ○	n=2 ○	n=2 ○	n=6 ○	n=5 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=2 ○	n=5 ○	n=6 ○	n=6 ○	n=6 ○	n=5 ○	n=1 ○	n=6 ○	n=1 ○	n=4 ○
Total Boron (B)	-	-	2	n=3 ●	n=2 ●	n=3 ●	n=1 ●	n=1 ●	-	n=2 ●	n=1 ●	n=1 ○	n=1 ●	n=1 ●	-	-	n=1 ●	n=3 ●	n=2 ●	n=3 ●	n=3 ●	n=3 ◕	n=3 ◕	-	n=2 ●	n=3 ●	n=3 ◑	n=3 ●	n=2 ●	-	n=3 ●	-	n=1 ●
Total Cadmium (Cd)	0.6	3.5	0.5	n=6 ○	n=5 ○	n=6 ○	n=2 ○	n=2 ○	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ○	n=1 ○	n=2 ○	n=2 ○	n=6 ○	n=5 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=2 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=5 ○	n=1 ○	n=6 ○	n=1 ○	n=4 ○
Total Chromium (Cr)	37.3	90	0.5	n=6 ●	n=5 ●	n=6 ●	n=2 ●	n=2 ●	n=1 ●	n=3 ●	n=2 ●	n=2 ●	n=2 ●	n=4 ●	n=1 ●	n=2 ●	n=2 ●	n=6 ●	n=5 ●	n=6 ●	n=6 ●	n=6 ●	n=6 ●	n=2 ●	n=6 ●	n=6 ●	n=6 ●	n=6 ●	n=5 ●	n=1 ●	n=6 ●	n=1 ●	n=4 ●
Total Cobalt (Co)	-	-	1	n=6 ●	n=5 ●	n=6 ●	n=2 ●	n=2 ●	n=1 ○	n=3 ●	n=2 ◑	n=2 ◑	n=2 ◑	n=4 ●	n=1 ●	n=2 ●	n=2 ◑	n=6 ●	n=5 ◑	n=6 ●	n=6 ●	n=6 ◑	n=6 ●	n=2 ◑	n=6 ●	n=6 ●	n=6 ●	n=6 ●	n=5 ●	n=1 ●	n=6 ●	n=1 ○	n=4 ●
Total Copper (Cu)	35.7	197	2	n=6 ◕	n=5 ◕	n=6 ●	n=2 ◑	n=2 ●	n=1 ○	n=3 ●	n=2 ○	n=2 ○	n=2 ◑	n=4 ●	n=1 ●	n=2 ●	n=2 ◑	n=6 ●	n=5 ◔	n=6 ●	n=6 ●	n=6 ◑	n=6 ●	n=2 ●	n=6 ◔	n=6 ●	n=6 ●	n=6 ●	n=5 ●	n=1 ●	n=6 ●	n=1 ○	n=4 ●
Total Iron (Fe)	-	-	200	n=6 ●	n=5 ●	n=6 ●	n=2 ●	n=2 ●	n=1 ●	n=3 ●	n=2 ●	n=2 ●	n=2 ●	n=4 ●	n=1 ●	n=2 ●	n=2 ●	n=6 ●	n=5 ●	n=6 ●	n=6 ●	n=6 ●	n=6 ●	n=2 ●	n=5 ●	n=6 ●	n=6 ●	n=6 ●	n=5 ●	n=1 ●	n=6 ●	n=1 ●	n=4 ●
Total Lead (Pb)	35	91.3	5	n=6 ◑	n=5 ○	n=6 ●	n=2 ○	n=2 ●	n=1 ○	n=3 ◕	n=2 ○	n=2 ○	n=2 ◑	n=4 ◕	n=1 ○	n=2 ●	n=2 ○	n=6 ●	n=5 ◔	n=6 ●	n=6 ●	n=6 ○	n=6 ○	n=2 ○	n=6 ◔	n=6 ○	n=6 ○	n=6 ○	n=5 ●	n=1 ○	n=6 ●	n=1 ○	n=4 ◑
Total Lithium (Li)	-	-	0.5	n=3 ●	n=3 ●	n=3 ●	n=1 ●	n=1 ●	n=1 ○	n=1 ●	n=1 ○	n=1 ●	n=1 ○	n=3 ●	n=1 ●	n=2 ●	n=1 ●	n=3 ●	n=3 ◕	n=3 ●	n=3 ●	n=3 ◕	n=3 ●	n=2 ◑	n=3 ●	n=3 ◕	n=3 ●	n=3 ●	n=3 ●	n=1 ●	n=3 ●	n=1 ○	n=3 ●
Total Manganese (Mn)	-	-	1	n=6 ●	n=5 ●	n=6 ●	n=2 ●	n=2 ●	n=1 ●	n=3 ●	n=2 ●	n=2 ●	n=2 ●	n=4 ●	n=1 ●	n=2 ●	n=2 ●	n=6 ●	n=5 ●	n=6 ●	n=6 ●	n=6 ●	n=6 ●	n=2 ●	n=5 ●	n=6 ●	n=6 ●	n=6 ●	n=5 ●	n=1 ●	n=6 ●	n=1 ●	n=4 ●
Total Mercury (Hg)	0.17	0.486	0.05	n=6 ○	n=5 ◔	n=6 ◔	n=2 ○	n=2 ○	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ○	n=1 ○	n=2 ●	n=2 ○	n=6 ◔	n=5 ○	n=6 ○	n=6 ◔	n=6 ○	n=6 ○	n=2 ○	n=6 ◑	n=6 ○	n=6 ○	n=6 ○	n=5 ◔	n=1 ○	n=6 ◔	n=1 ○	n=4 ◔
Total Molybdenum (Mo)	-	-	1	n=6 ○	n=5 ○	n=6 ○	n=2 ○	n=2 ◑	n=1 ○	n=3 ○	n=2 ○	n=2 ◑	n=2 ○	n=4 ◔	n=1 ○	n=2 ◑	n=2 ○	n=6 ○	n=5 ○	n=6 ○	n=6 ◕	n=6 ○	n=6 ○	n=2 ◑	n=6 ◑	n=6 ○	n=6 ○	n=6 ◔	n=5 ◑	n=1 ○	n=6 ●	n=1 ○	n=4 ◑
Total Nickel (Ni)	-	-	2	n=6 ●	n=5 ●	n=6 ●	n=2 ●	n=2 ●	n=1 ○	n=3 ●	n=2 ◑	n=2 ◑	n=2 ◑	n=4 ●	n=1 ●	n=2 ●	n=2 ◑	n=6 ●	n=5 ●	n=6 ●	n=6 ●	n=6 ◑	n=6 ●	n=2 ●	n=6 ●	n=6 ●	n=6 ●	n=6 ●	n=5 ●	n=1 ●	n=6 ●	n=1 ○	n=4 ●
Total Selenium (Se)	-	-	0.2	n=6 ◑	n=5 ◔	n=6 ●	n=2 ◑	n=2 ●	n=1 ○	n=3 ◕	n=2 ○	n=2 ○	n=2 ◑	n=4 ◕	n=1 ○	n=2 ●	n=2 ◑	n=6 ●	n=5 ◔	n=6 ●	n=6 ●	n=6 ○	n=6 ◑	n=2 ●	n=6 ●	n=6 ●	n=6 ◑	n=6 ●	n=5 ●	n=1 ●	n=6 ●	n=1 ○	n=4 ●
Total Silver (Ag)	-	-	1	n=6 ○	n=5 ○	n=6 ○	n=2 ○	n=2 ○	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ○	n=1 ○	n=2 ○	n=2 ○	n=6 ○	n=5 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=2 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=5 ○	n=1 ○	n=6 ○	n=1 ○	n=4 ○
Total Strontium (Sr)	-	-	1	n=6 ●	n=5 ●	n=6 ●	n=2 ●	n=2 ●	n=1 ●	n=3 ●	n=2 ●	n=2 ●	n=2 ●	n=4 ●	n=1 ●	n=2 ●	n=2 ●	n=6 ●	n=5 ●	n=6 ●	n=6 ●	n=6 ●	n=6 ●	n=2 ●	n=5 ●	n=6 ●	n=6 ●	n=6 ●	n=5 ●	n=1 ●	n=6 ●	n=1 ●	n=4 ●
Total Thallium (Tl)	-	-	1	n=6 ○	n=5 ○	n=6 ○	n=2 ○	n=2 ○	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ○	n=1 ○	n=2 ○	n=2 ○	n=6 ○	n=5 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=2 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=5 ○	n=1 ○	n=6 ○	n=1 ○	n=4 ○
Total Tin (Sn)	-	-	5	n=6 ○	n=5 ○	n=6 ○	n=2 ○	n=2 ○	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ○	n=1 ○	n=2 ○	n=2 ◑	n=6 ○	n=5 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=2 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=5 ○	n=1 ○	n=6 ○	n=1 ○	n=4 ○
Total Titanium (Ti)	-	-	1	n=6 ●	n=5 ●	n=6 ●	n=2 ●	n=2 ●	n=1 ●	n=3 ●	n=2 ●	n=2 ●	n=2 ●	n=4 ●	n=1 ●	n=2 ●	n=2 ●	n=6 ●	n=5 ●	n=6 ●	n=6 ●	n=6 ●	n=6 ●	n=2 ●	n=5 ●	n=6 ●	n=6 ●	n=6 ●	n=5 ●	n=1 ●	n=6 ●	n=1 ●	n=4 ●
Total Uranium (U)	-	-	2	n=6 ○	n=5 ○	n=6 ○	n=2 ○	n=2 ◑	n=1 ○	n=3 ○	n=2 ○	n=2 ○	n=2 ○	n=4 ○	n=1 ○	n=2 ○	n=2 ○	n=6 ○	n=5 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=2 ○	n=6 ○	n=6 ○	n=6 ○	n=6 ○	n=5 ○	n=1 ○	n=6 ○	n=1 ○	n=4 ○
Total Vanadium (V)	123	315	1	n=6 ●	n=5 ●	n=6 ●	n=2 ●	n=2 ●	n=1 ●	n=3 ●	n=2 ●	n=2 ●	n=2 ●	n=4 ●	n=1 ●	n=2 ●	n=2 ●	n=6 ●	n=5 ●	n=6 ●	n=6 ●	n=6 ●	n=6 ●	n=2 ●	n=6 ●	n=6 ●	n=6 ●	n=6 ●	n=5 ●	n=1 ●	n=6 ●	n=1 ●	n=4 ●
Total Zinc (Zn)	-	-	10	n=6 ●	n=5 ●	n=6 ●	n=2 ◑	n=2 ●	n=1 ●	n=3 ●	n=2 ●	n=2 ○	n=2 ◑	n=4 ●	n=1 ●	n=2 ●	n=2 ◑	n=6 ●	n=5 ●	n=6 ●	n=6 ●	n=6 ◑	n=6 ●	n=2 ●	n=6 ●	n=6 ●	n=6 ◕	n=6 ●	n=5 ●	n=1 ●	n=6 ●	n=1 ○	n=4 ●

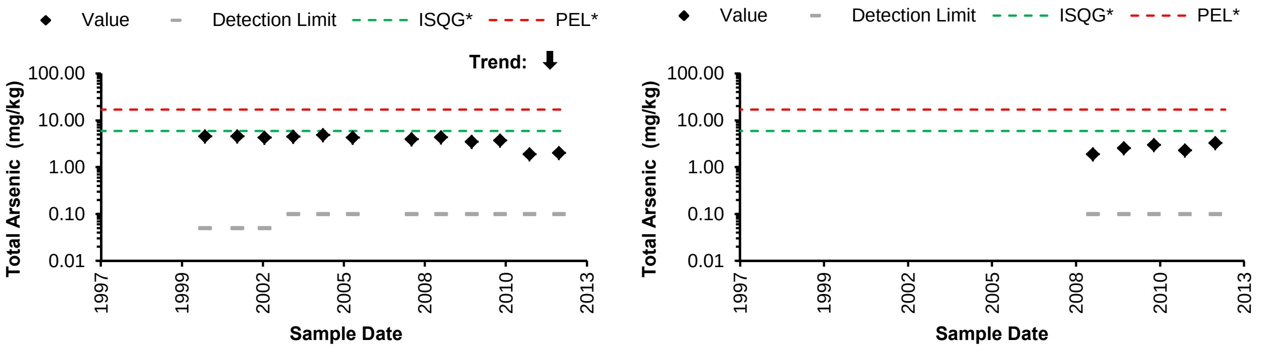
Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes.

Legend

○ = All data below detection limit
◔ = 1-25% of data above detection
◑ = 26-50% of data above detection
◕ = 51-75% of data above detection
● = 76-100% of data above detection

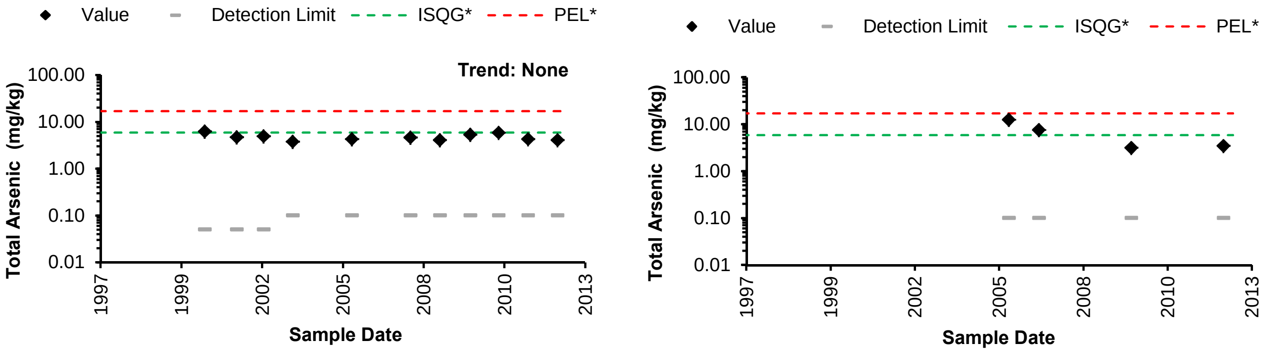
Red highlighting indicates guideline exceedance.

Figure 43 Total arsenic (Log Scale) in sediments at RAMP stations with historical data.



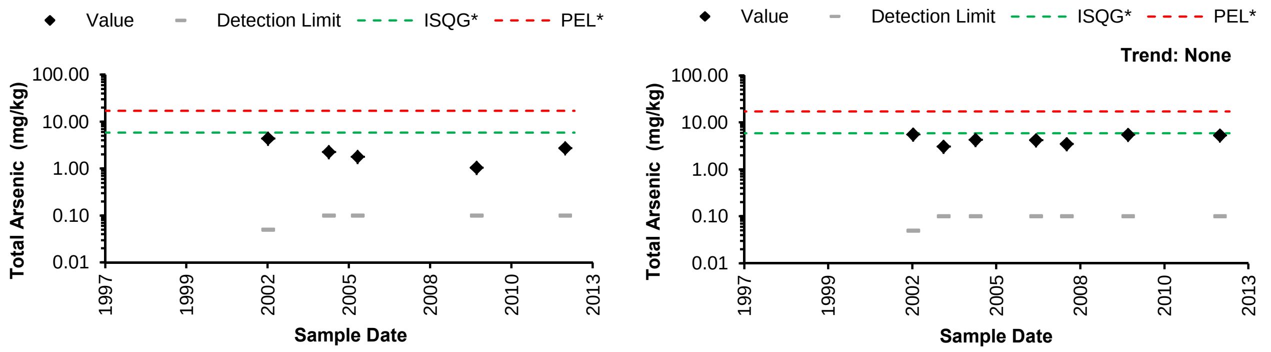
ATR-ER (Athabasca River)

BER-D2 (Beaver River)



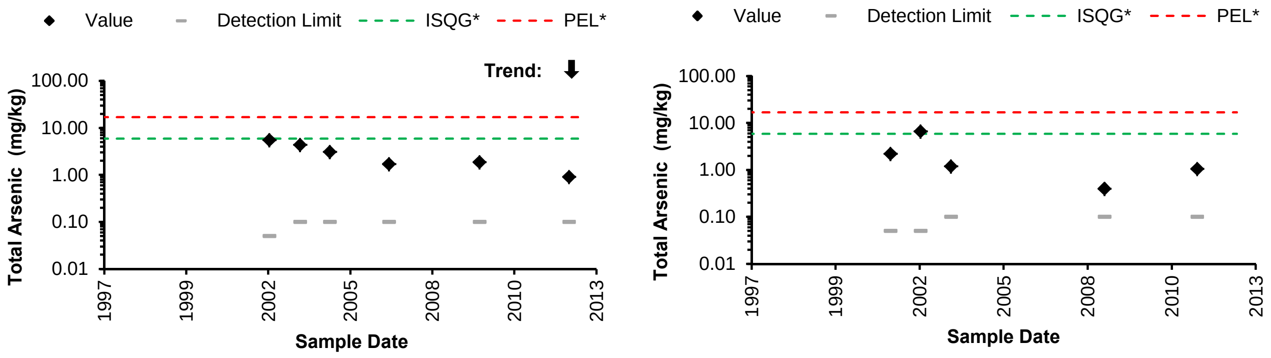
BPC-1 (Big Point Channel)

CAR-D1 (Calumet River)



CAR-D2 (Calumet River)

CHR-D1 (Christina River)



CHR-D2 (Christina River)

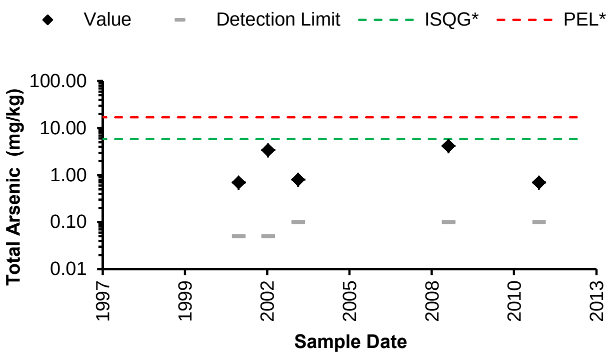
CLR-D1 (Clearwater River)

Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

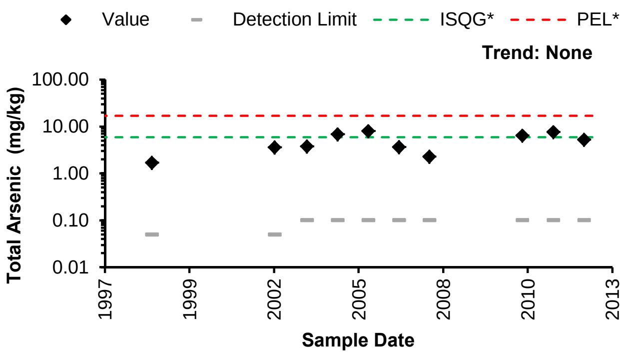
*Guideline value is from CCME (2011) sediment quality guidelines for the protection of aquatic life.

Figure 43 (Cont'd.)

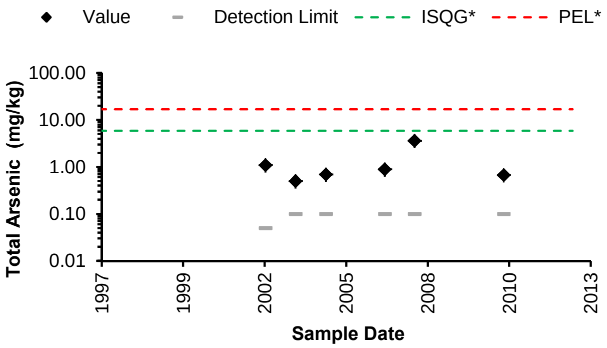
CLR-D2 (Clearwater River)



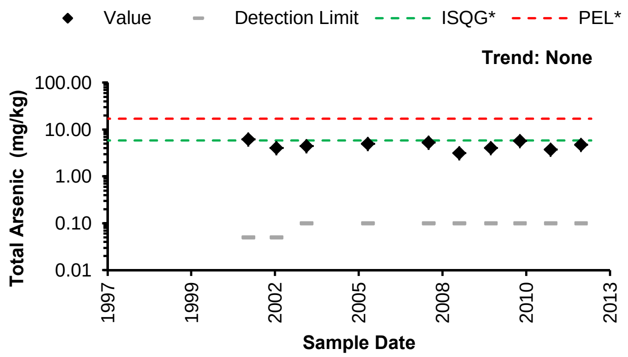
ELR-D1 (Ells River)



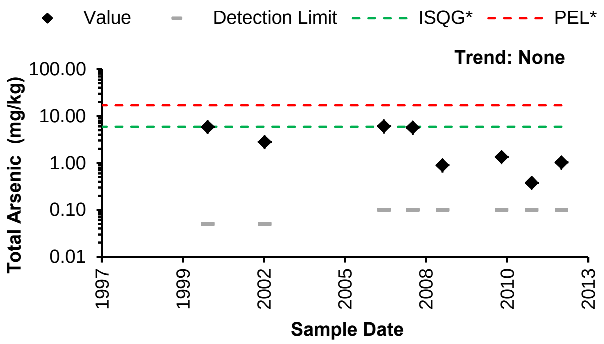
FIR-D1 (Firebag River)



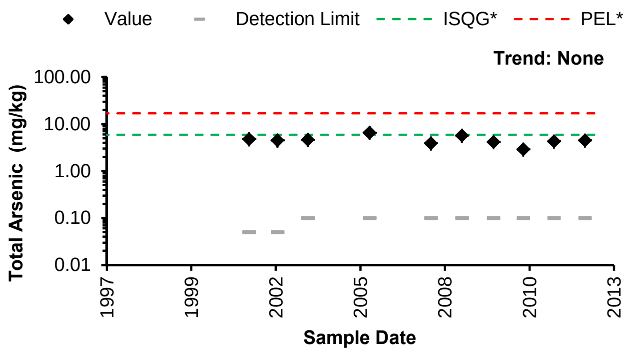
FLC-1 (Fletcher Channel)



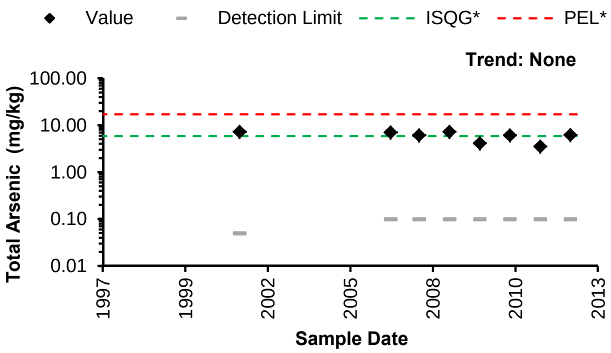
FOC-D1 (Fort Creek)



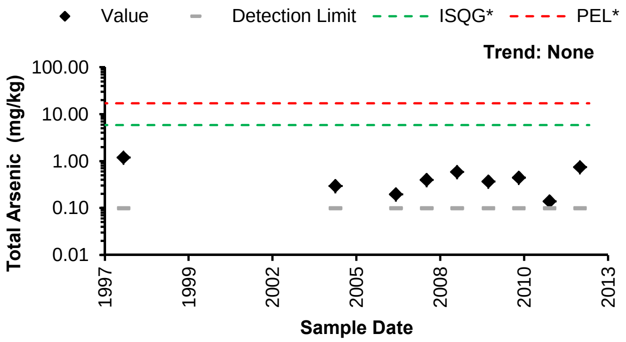
GIC-1 (Goose Island Channel)



ISL-1 (Isadore's Lake)



JAC-D1 (Jackpine Creek)

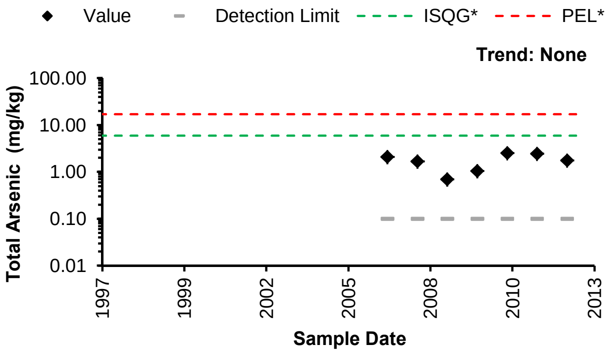


Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

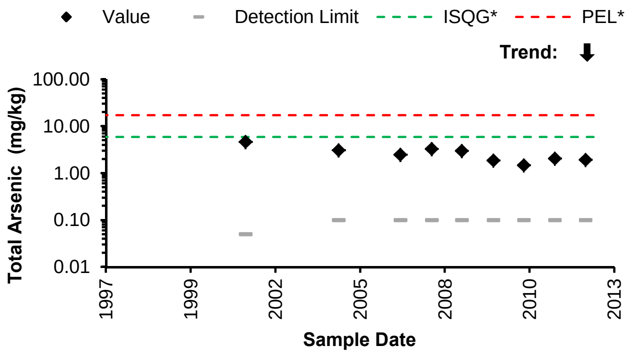
*Guideline value is from CCME (2011) sediment quality guidelines for the protection of aquatic life.

Figure 43 (Cont'd.)

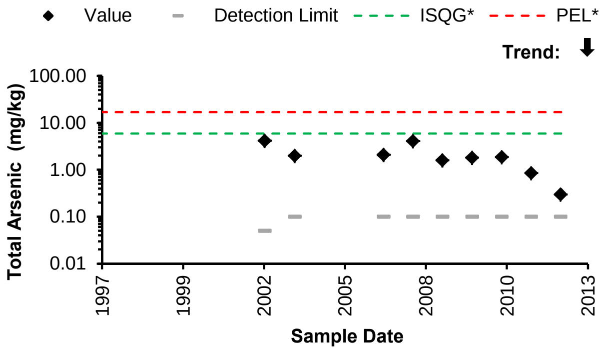
JAC-D2 (Jackpine Creek)



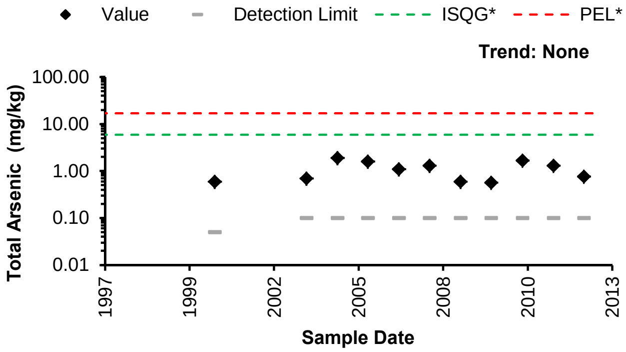
KEL-1 (Kearl Lake)



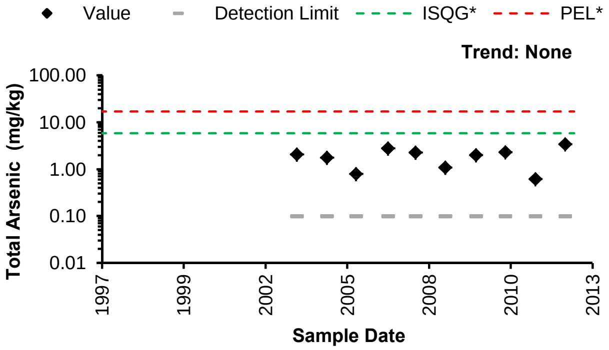
MCL-1 (McClelland Lake)



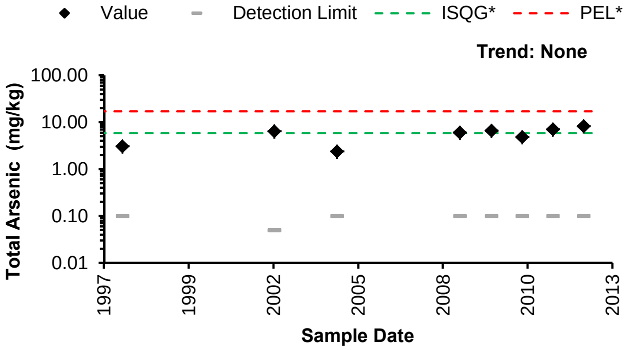
MUR-D2 (Muskeg River)



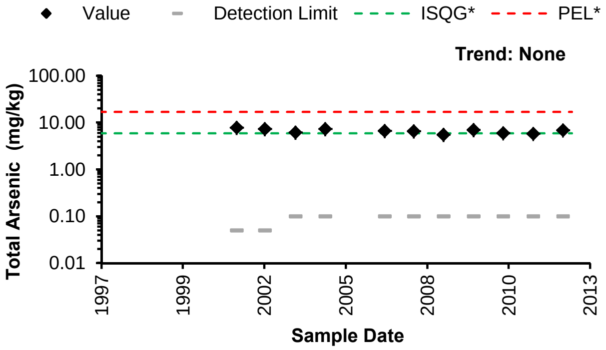
MUR-D3 (Muskeg River)



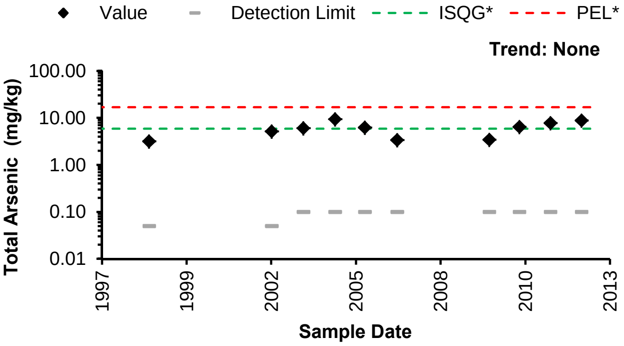
POC-D1 (Poplar Creek)



SHL-1 (Shipyard Lake)



TAR-D1 (Tar River)

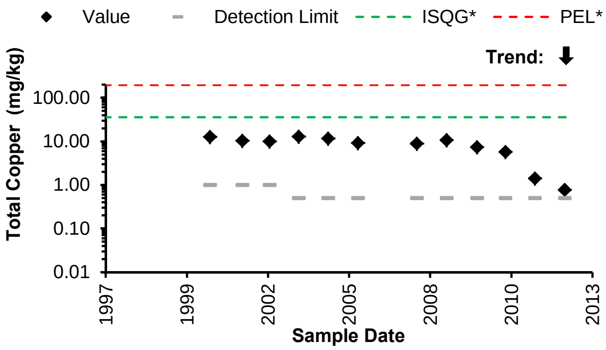


Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

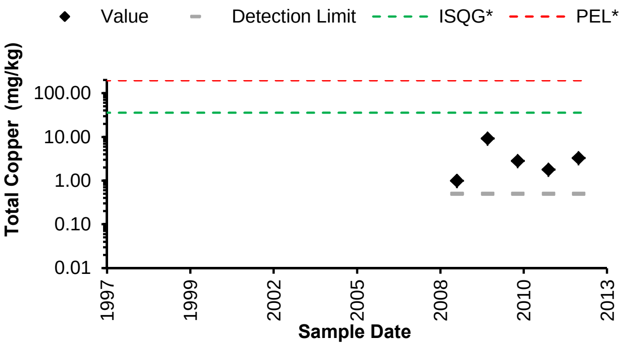
*Guideline value is from CCME (2011) sediment quality guidelines for the protection of aquatic life.

Figure 44 Total copper (Log Scale) in sediments at RAMP stations with historical data.

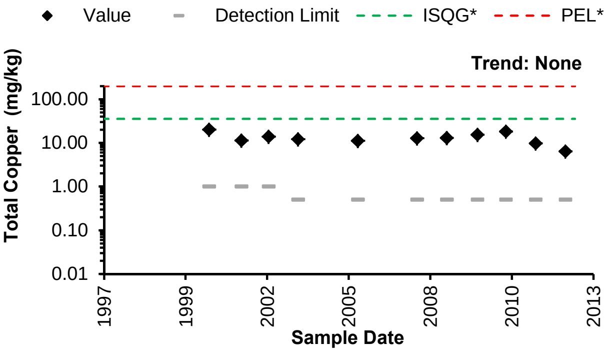
ATR-ER (Athabasca River)



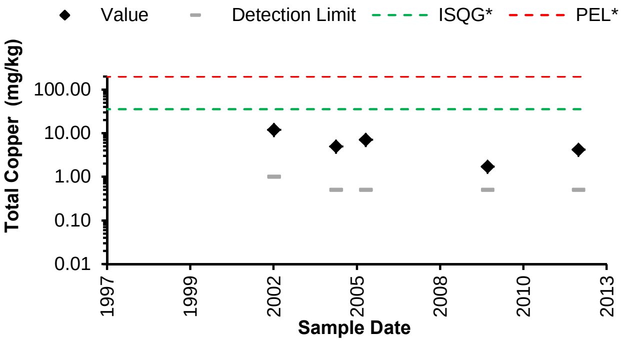
BER-D2 (Beaver River)



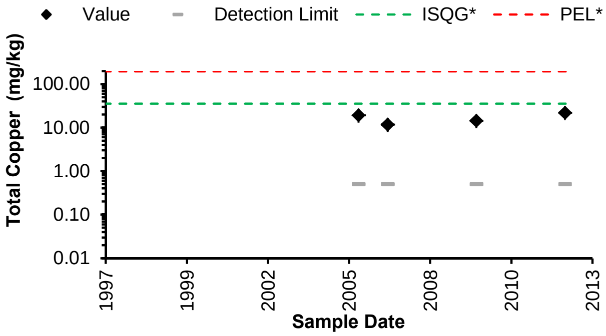
BPC-1 (Big Point Channel)



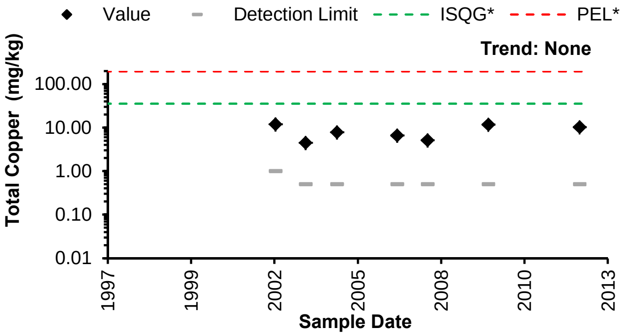
CAR-D1 (Calumet River)



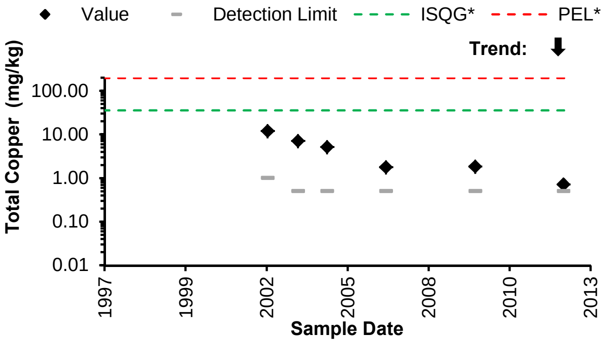
CAR-D2 (Calumet River)



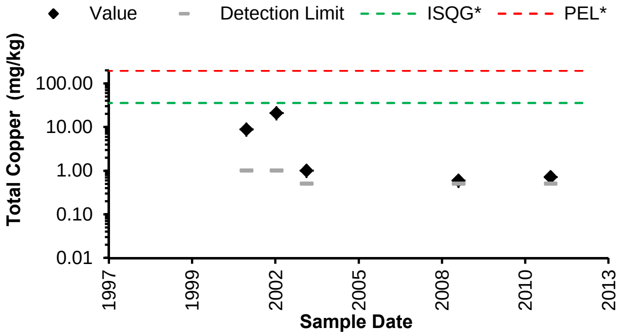
CHR-D1 (Christina River)



CHR-D2 (Christina River)



CLR-D1 (Clearwater River)

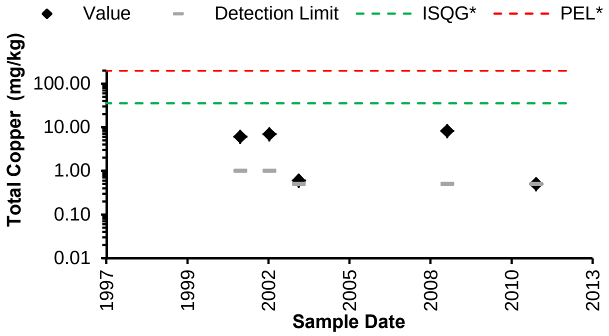


Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

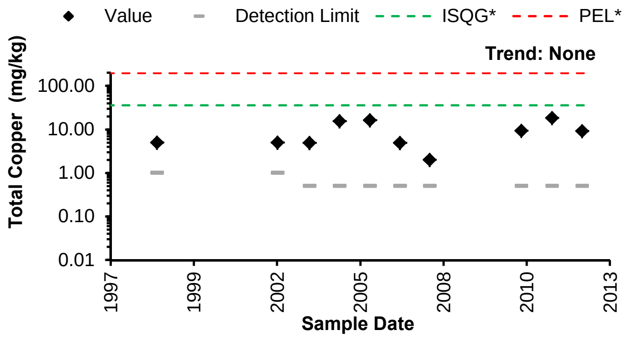
*Guideline value is from CCME (2011) sediment quality guidelines for the protection of aquatic life.

Figure 44 (Cont'd.)

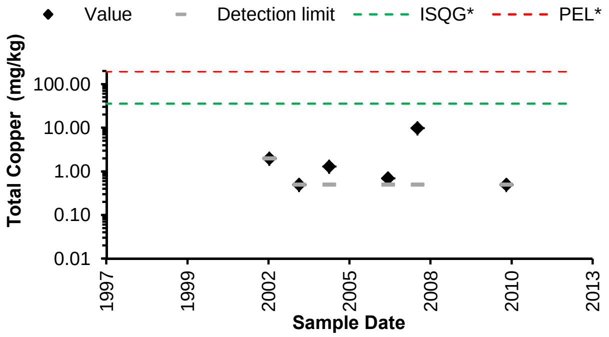
CLR-D2 (Clearwater River)



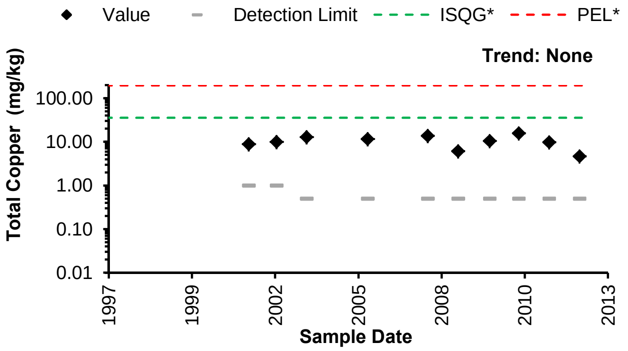
ELR-D1 (Ells River)



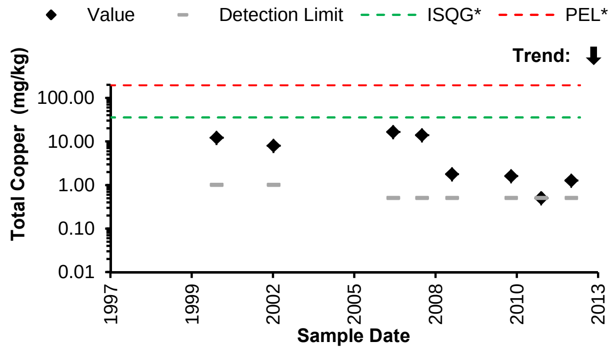
FIR-D1 (Firebag River)



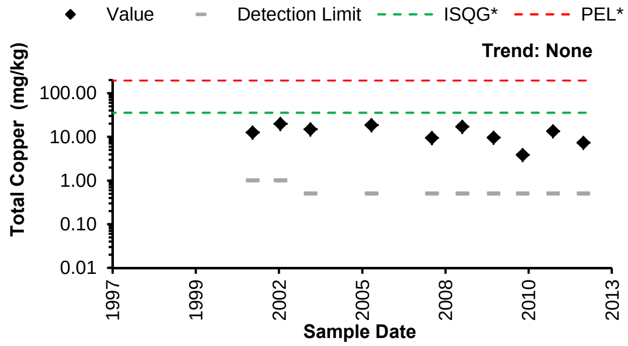
FLC-1 (Fletcher Channel)



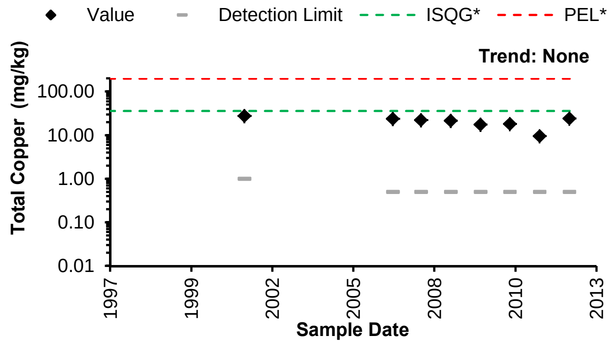
FOC-D1 (Fort Creek)



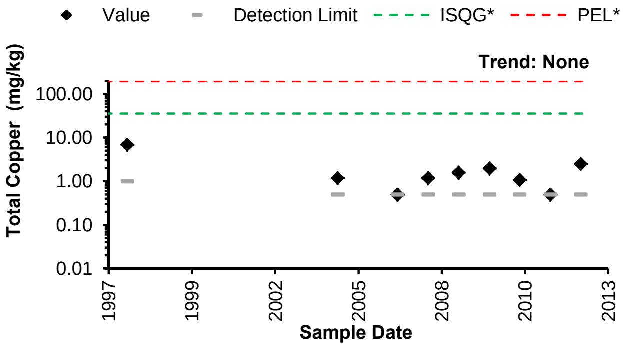
GIC-1 (Goose Island Channel)



ISL-1 (Isadore's Lake)



JAC-D1 (Jackpine Creek)

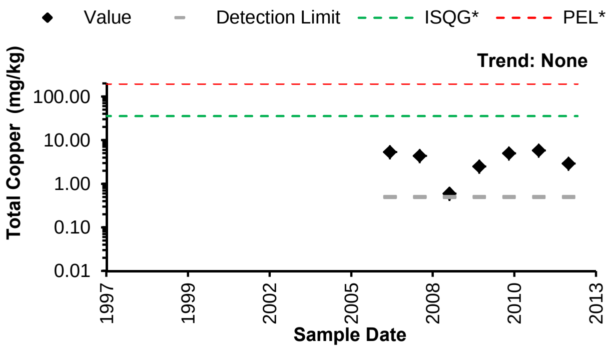


Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

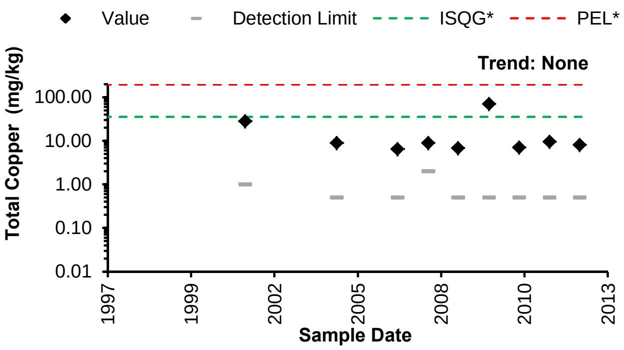
*Guideline value is from CCME (2011) sediment quality guidelines for the protection of aquatic life.

Figure 44 (Cont'd.)

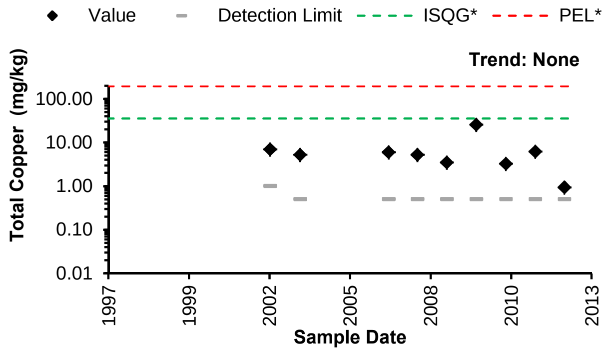
JAC-D2 (Jackpine Creek)



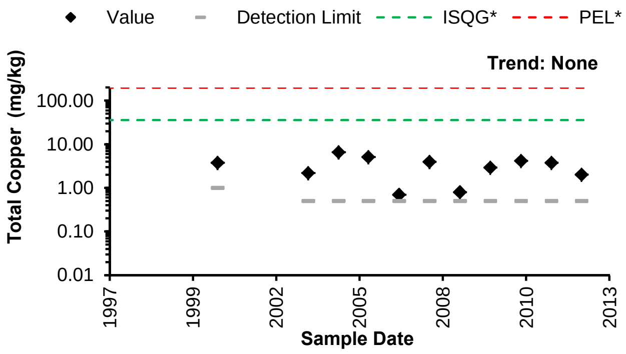
KEL-1 (Kearl Lake)



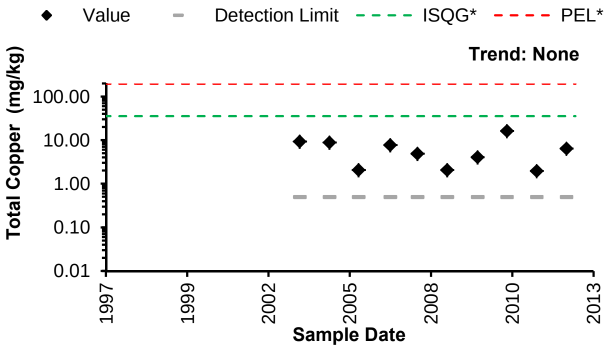
MCL-1 (McClelland Lake)



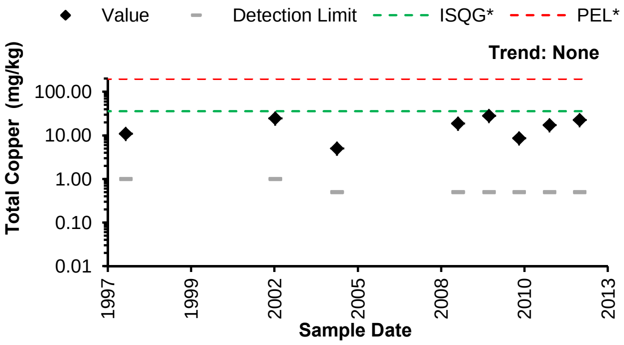
MUR-D2 (Muskeg River)



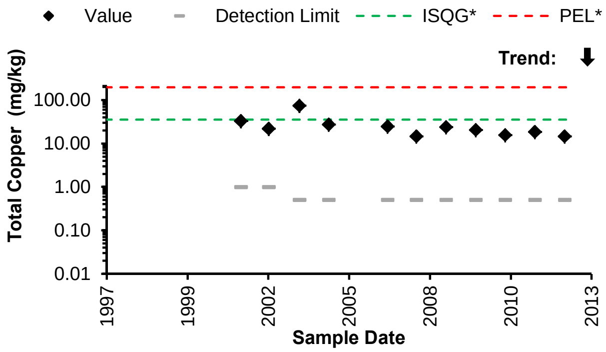
MUR-D3 (Muskeg River)



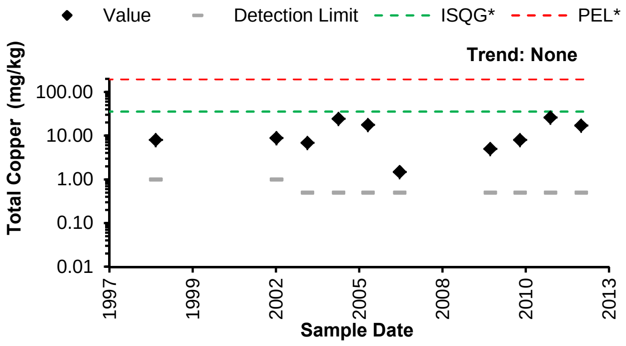
POC-D1 (Poplar Creek)



SHL-1 (Shipyard Lake)



TAR-D1 (Tar River)

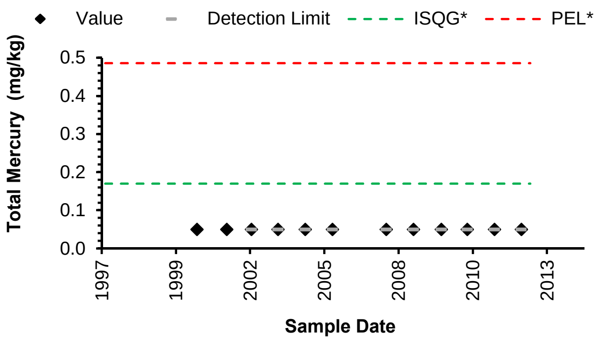


Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

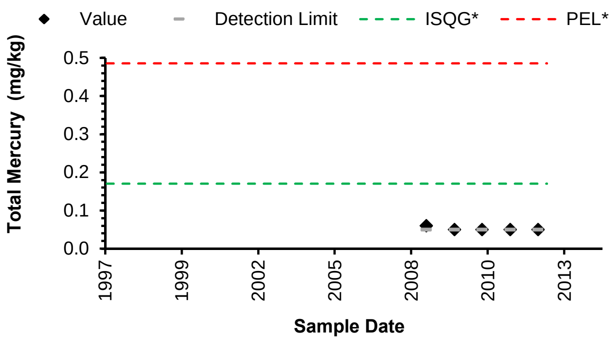
*Guideline value is from CCME (2011) sediment quality guidelines for the protection of aquatic life.

Figure 45 Total mercury in sediments at RAMP stations with historical data.

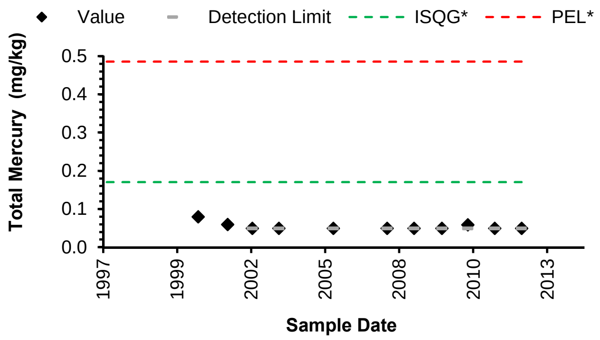
ATR-ER (Athabasca River)



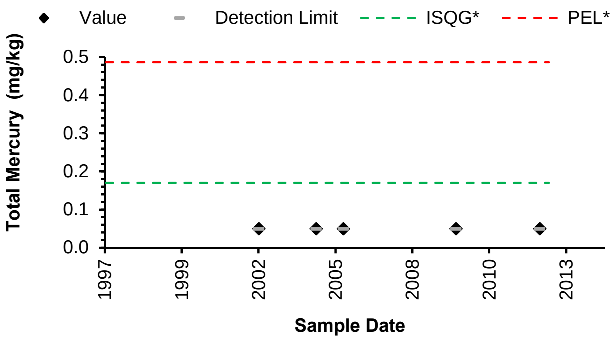
BER-D2 (Beaver River)



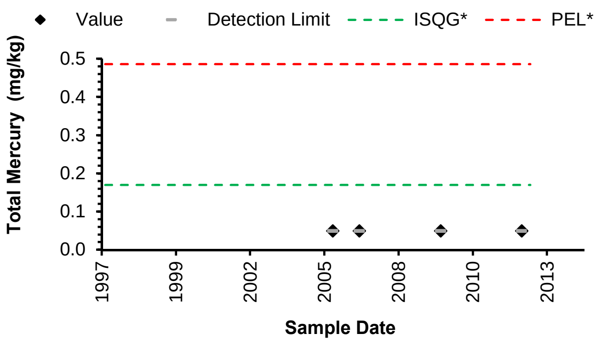
BPC-1 (Big Point Channel)



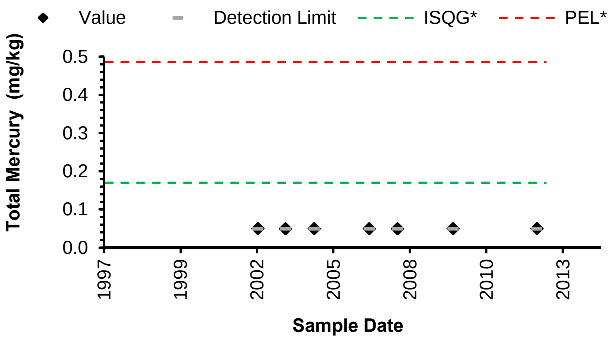
CAR-D1 (Calumet River)



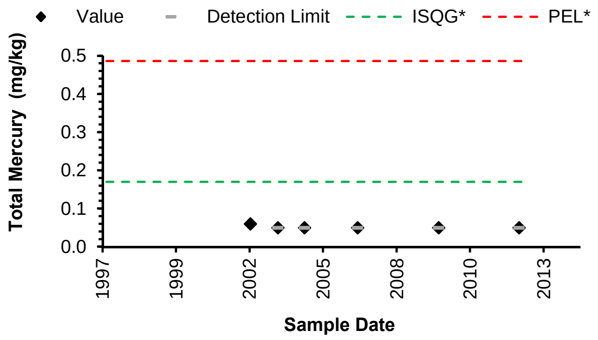
CAR-D2 (Calumet River)



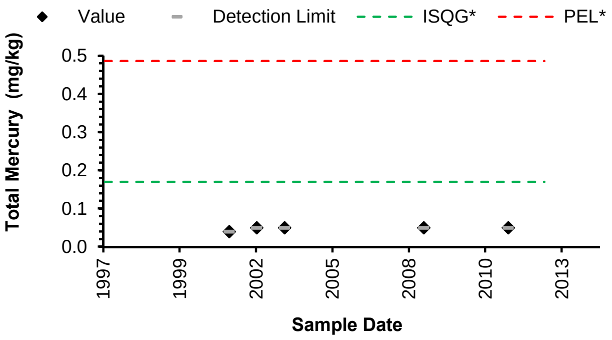
CHR-D1 (Christina River)



CHR-D2 (Christina River)



CLR-D1 (Clearwater River)



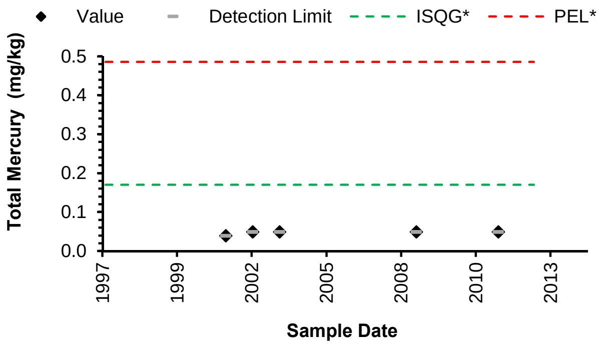
Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

*Guideline value is from CCME (2011) sediment quality guidelines for the protection of aquatic life.

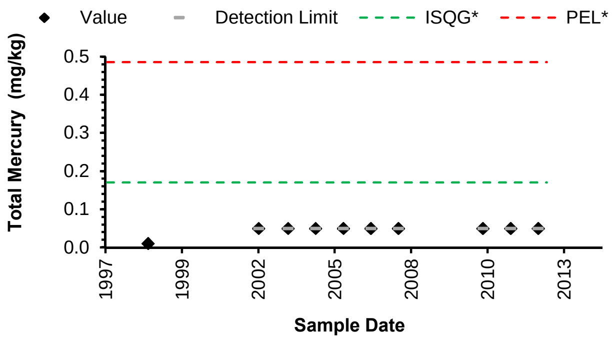
Note: Detection limits are indicated by a grey dash, absence of a grey dash indicates that detection limits were not provided for these data points.

Figure 45 (Cont'd.)

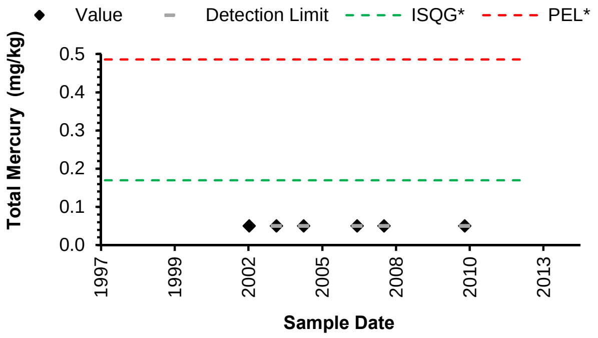
CLR-D2 (Clearwater River)



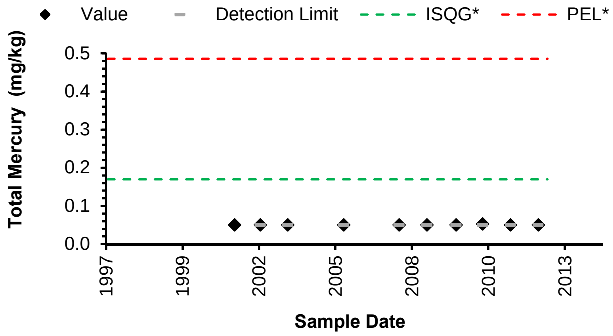
ELR-D1 (Ells River)



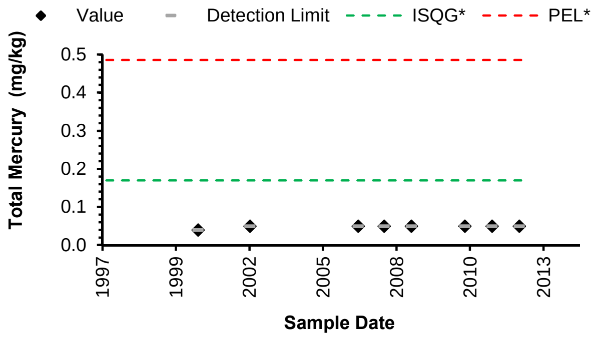
FIR-D1 (Firebag River)



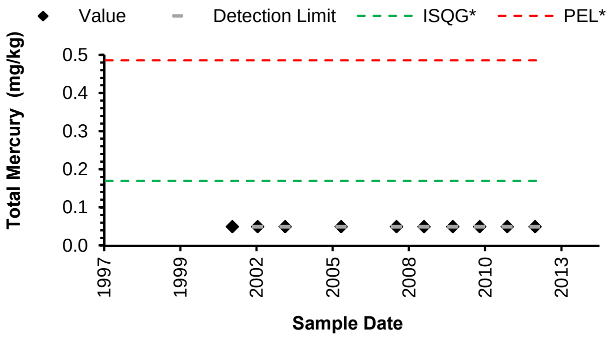
FLC-1 (Fletcher Channel)



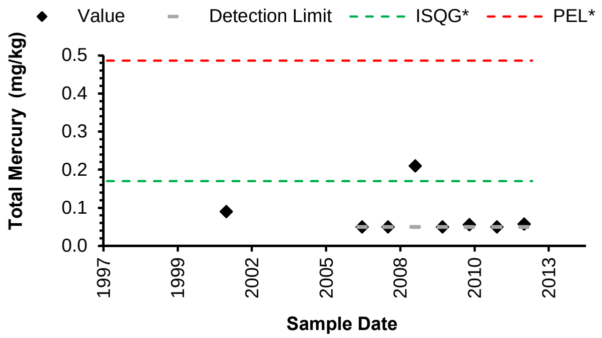
FOC-D1 (Fort Creek)



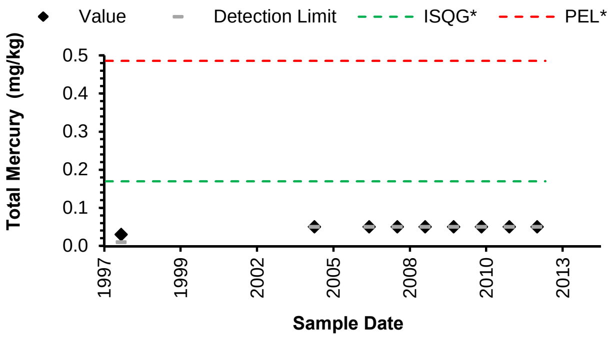
GIC-1 (Goose Island Channel)



ISL-1 (Isadore's Lake)



JAC-D1 (Jackpine Creek)



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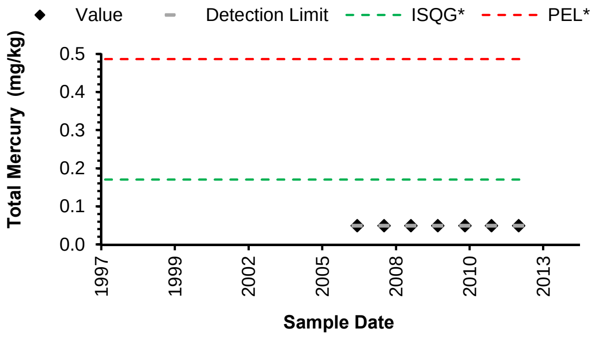
*Guideline value is from CCME (2011) sediment quality guidelines for the protection of aquatic life.

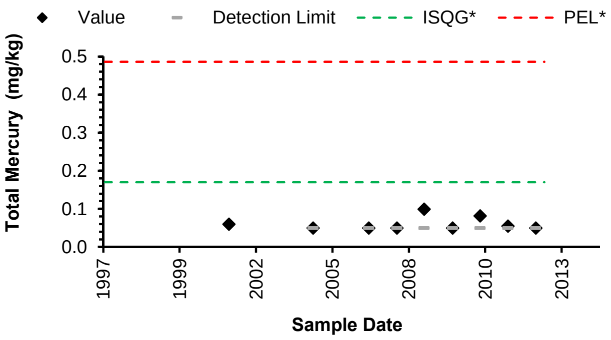
Note: Detection limits are indicated by a grey dash, absence of a grey dash indicates that detection limits were not provided for these data points.

Figure 45 (Cont'd.)

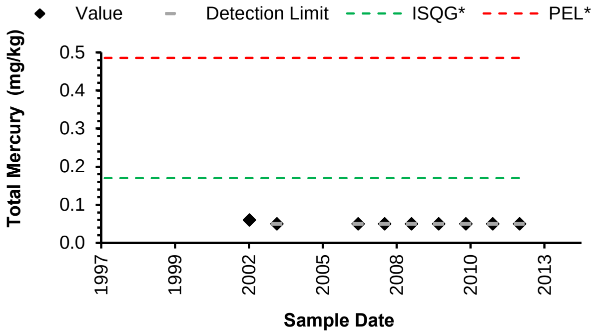
JAC-D2 (Jackpine Creek)



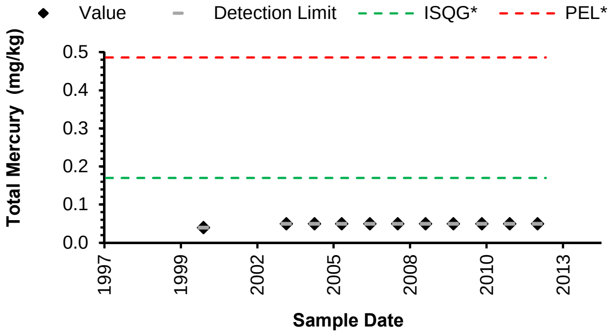
KEL-1 (Kearl Lake)



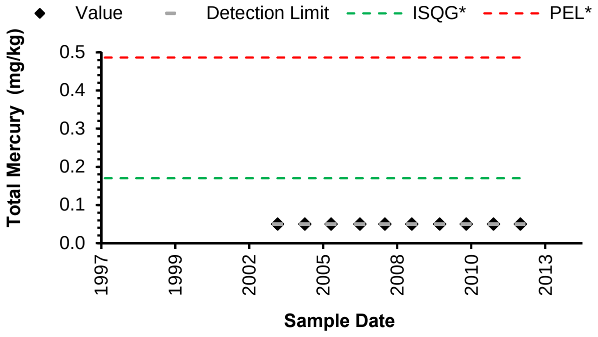
MCL-1 (McClelland Lake)



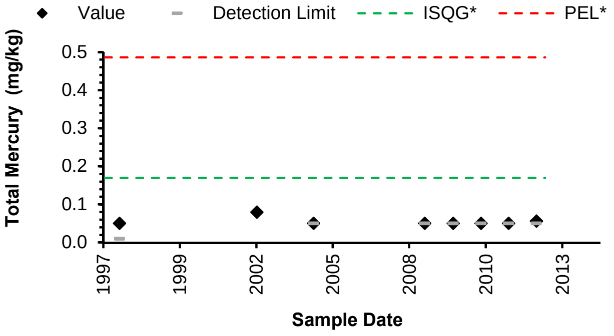
MUR-D2 (Muskeg River)



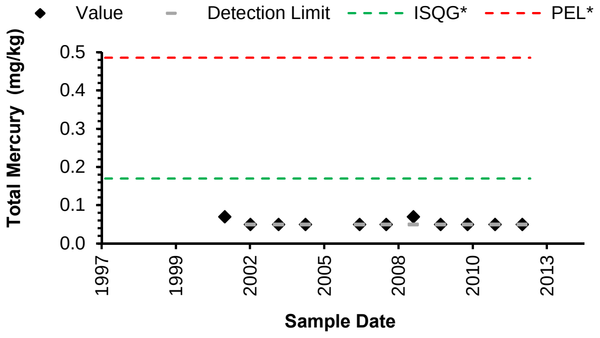
MUR-D3 (Muskeg River)



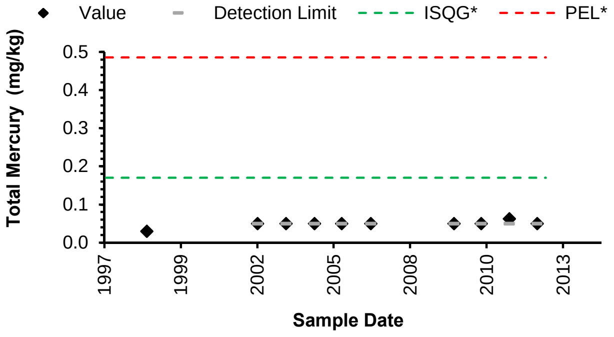
POC-D1 (Poplar Creek)



SHL-1 (Shipyard Lake)



TAR-D1 (Tar River)



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Note: Detection limits are indicated by a grey dash, absence of a grey dash indicates that detection limits were not provided for these data points.

3.9 OTHER ORGANIC COMPOUNDS

3.9.1 Phthalates

Phthalates are esters of phthalic acid used to increase the flexibility and workability of plastics (USEPA 1995). Phthalates are often referred to as plasticizers and are commonly found in a number of products including pharmaceuticals, building materials, medical devices, electronics, personal care and household products, packaging, and children's toys (USEPA 2007). The vast majority of phthalates are produced synthetically and the most commonly used and produced phthalate is bis(2-ethylhexyl) phthalate (also known as di[2-ethylhexyl] phthalate [DEHP]).

Phthalates are found everywhere in the environment and can enter freshwater ecosystems through effluent discharge from wastewater treatment plants as well as disposal and leaching of industrial and municipal waste at landfills (IJC 2000, AENV 2005). In general, phthalates are hydrophobic, with low solubility in water but higher solubility in solvents and other hydrophobic compounds. The movement of phthalates within the environment depends on the chemical structure of specific compounds, which affects water solubility and other characteristics. Adsorption to terrestrial soils may reduce or slow the movement of phthalates into aquatic systems (CCME 1999d). Phthalates can be broken down in soil or water through biological decomposition (CCME 1999d).

In terms of health effects, phthalates are often referred to as endocrine-disrupting compounds or hormonally active agents due to their ability to interfere with the endocrine system in the humans and other organisms (AENV 2005, USEPA 2007). Effects of endocrine disruption on aquatic organisms such as fish can range from subtle changes to physiology or sexual behaviour to permanent changes in sexual differentiation and impaired fertility (Jobling & Tyler 2003). Biological effects of endocrine disruption in fish include (but are not limited to) inhibited growth and reproductive development, reduced spawning success, abnormal blood steroid concentrations and masculinisation/feminization of genitalia (Jobling & Tyler 2003; Vos et al. 2000). Various phthalates, including DEHP, have been associated with a range of health effects in rodent studies (IJC 2000, USEPA 2007). These effects include toxicity to the liver, kidneys, heart, lungs, and reproductive systems, as well as birth defects. Based on increased liver tumours in adult male and female rats, the USEPA classified DEHP as a probable human carcinogen (under the 1986 USEPA guidelines) (USEPA 2007).

3.9.1.1 Water Quality Data Availability

Current data for phthalates in surface waters were available from six AESRD stations (Figure 46). No data were available for phthalates in surface water for the McLeod, Pembina, La Biche, Clearwater, or Lake Athabasca sub-watersheds.

3.9.1.2 Sediment Quality Data Availability

Only one year of current data (i.e., 2008) was available for phthalates in sediments from four AESRD LTRN stations (Figure 46). No data were available for phthalates in sediment for the McLeod, Pembina, Lesser Slave, La Biche, Clearwater, or Lake Athabasca sub-watersheds.

3.9.2 Phthalates in Water

3.9.2.1 2012 Spatial Comparisons

Given 2012 phthalates data were available for only one AESRD station (AB07BK0125), spatial comparisons were not conducted.

3.9.2.2 Compilation of Current Phthalates in Water and Comparison with Guidelines

Concentrations of di-n-butyl phthalate were detected (i.e., ≥0.1 µg/L) in one sample at three AESRD LTRN stations (Table 27). Concentrations of bis(2-ethylhexyl) phthalate were detected in all samples at two AESRD MTRN stations and concentrations of diethyl phthalate were detected in at least one sample at two AESRD LTRN stations. Concentrations of butylbenzyl phthalate were detected in one sample at one AESRD station. All other phthalate concentrations were below detection at all stations. No guidelines were exceeded for any phthalates at any station.

3.9.2.3 Historical Trend Analysis

Historical trend analysis was conducted for the two phthalates with available CCME guidelines, bis(2-ethylhexyl) phthalate and di-n-butyl phthalate.

The majority of bis(2-ethylhexyl) phthalate samples were below detection at all AESRD stations over all years of data. One AESRD station (AB07BK0005) had less than four years of bis(2-ethylhexyl) phthalate data and was therefore excluded from both qualitative and quantitative trend analysis. Historical bis(2-ethylhexyl) phthalate concentrations for the remaining five AESRD stations were plotted, but were excluded from statistical trend analysis because these stations either had less than seven years of data, or had greater than 50% non-detectable values (Figure 47).

Concentrations of di-n-butyl phthalate at the Athabasca River upstream of Fort McMurray (AB07CC0030) decreased significantly over time; the other remaining AESRD station at Lesser Slave River (AB07BK0125) showed no significant trends over time. (Figure 48). One AESRD station (AB07BK0005) had less than four years of di-n-butyl phthalate data and was therefore excluded from both qualitative and quantitative trend analysis. Historical di-n-butyl phthalate concentrations for an additional three AESRD stations (AB07AD0100, AB07BE0010, AB07DD0105) were plotted, but were excluded from statistical trend analysis because these stations either had less than seven years of data, or had greater than 50% non-detectable values (Figure 48).

3.9.3 Phthalates in Sediment

3.9.3.1 2012 Spatial Comparisons

Given that only 2008 data were available for phthalates in sediments, spatial comparisons were not conducted.

3.9.3.2 Compilation of Current Phthalates in Sediment and Comparison with Guidelines

All phthalates measured in sediments were below detection (i.e., <2 mg/kg) for all four AESRD LTRN stations (Table 28).

3.9.3.3 Historical Trend Analysis

Historical trend analysis was not conducted on any AESRD sediment stations, given that only one year of phthalates data were available.

3.9.4 Overall Assessment: Phthalates

- Most surface water and sediment phthalates data were obtained from LTRN stations located in the Upper, Upper-Central, Lower, and Lower-Central Athabasca sub-watersheds, indicating a general gap in sampling of phthalates throughout the rest of the Athabasca watershed.

- Sediment data were sparse for phthalates in the Athabasca watershed given that only 2008 data were available for the current period.

- The majority of phthalate concentrations in surface water were below detection at all stations and no guidelines were exceeded for any phthalates at any station.

- All phthalates measured in sediments were below detection for all stations.

- No significant trends in concentrations of the most commonly used plasticizer, bis(2-ethylhexyl) phthalate were observed AESRD sediment stations over time and the majority of bis(2-ethylhexyl) phthalate samples were below detection at all AESRD stations over all years of data.

- No significant trends in concentrations of di-n-butyl phthalate—a plasticizer formerly used in children’s toys and nail polish—were observed at AESRD sediment stations except at LTRN station AB07CC0030 on the Athabasca River upstream of Fort McMurray, which showed a decreasing trend in di-n-butyl phthalate over time.

3.9.5 Aliphatic Hydrocarbons

Aliphatic hydrocarbons are non-aromatic compounds composed of hydrogen and carbon atoms and include alkanes, which contain single bonds between carbon atoms, alkenes, which contain one or more double bonds between atoms, or cycloalkanes, which contain carbon atoms in cyclic structures (Williams et al. 2006). Aliphatic hydrocarbons are widely used in oil extraction processes, rubber manufacturing, and as solvents in paints and coatings.

Similar to aromatic hydrocarbons and PAHs, aliphatic hydrocarbons are found everywhere in freshwater ecosystems and originate from anthropogenic (e.g., industrial) and natural (e.g., geological) sources.

3.9.5.1 Water Quality Data Availability

Current data for aliphatic hydrocarbons in surface waters were only available from six AESRD stations (Figure 46). No data were available for aliphatic hydrocarbons in surface water for the McLeod, Pembina, La Biche, Clearwater, or Lake Athabasca sub-watersheds.

3.9.5.2 Sediment Quality Data Availability

Only one year of current data (i.e., 2008) were available for aliphatic hydrocarbons in sediments from four AESRD LTRN stations (Figure 46). No data were available for aliphatic hydrocarbons in sediment for the McLeod, Pembina, Lesser Slave, La Biche, Clearwater, or Lake Athabasca sub-watersheds.

3.9.6 Aliphatic Hydrocarbons in Water

3.9.6.1 2012 Spatial comparisons

Given that 2012 aliphatic hydrocarbons data were available for only one AESRD station (AB07BK0125), spatial comparisons were not conducted.

3.9.6.2 Compilation of Current Aliphatic Hydrocarbons in Water and Comparison with Guidelines

All three aliphatic hydrocarbons were below detection (i.e., <0.1 to <0.2µg/L) for all AESRD stations (Table 27). No guidelines were exceeded for any aliphatic hydrocarbons at any station, although only one guideline was available for aliphatic hydrocarbons in surface waters.

3.9.6.3 Historical Trend Analysis

Historical trend analysis was not conducted on any AESRD surface water stations, given all aliphatic hydrocarbons were below detection at all stations.

3.9.7 Aliphatic Hydrocarbons in Sediment

3.9.7.1 2012 Spatial comparisons

Given only 2008 data were available for aliphatic hydrocarbons in sediments, spatial comparisons were not conducted.

3.9.7.2 Compilation of Current Aliphatic Hydrocarbons in Sediment and Comparison with Guidelines

Of the two aliphatic hydrocarbon species measured in sediments, both were below detection (i.e., <2 to <4 µg/L) for all AESRD stations (Table 28). No CCME guidelines were available for the aliphatic hydrocarbon species measured.

3.9.7.3 Historical Trend Analysis

Statistical trend analysis was not conducted on any AESRD sediment stations, given only one year of aliphatic hydrocarbons data were available.

3.9.8 Overall Assessment: Aliphatic Hydrocarbons

- Most surface water and sediment aliphatic hydrocarbons data were obtained from LTRN stations located in the Upper, Upper-Central, Lower, and Lower-Central Athabasca sub-watersheds, indicating a general gap in sampling of aliphatic hydrocarbons throughout the rest of the Athabasca watershed.
- Sediment data were sparse for aliphatic hydrocarbons in the Athabasca watershed, given only 2008 data were available for the current period.
- When compared with common detection limits, all aliphatic hydrocarbons in surface water and sediment were below detection for all AESRD samples.
- No guidelines were exceeded for any aliphatic hydrocarbons in surface waters and sediments at any station, although only one guideline was available for aliphatic hydrocarbons in surface waters and none were available for sediments.
- Statistical trend analysis was not conducted for aliphatic hydrocarbons in surface waters or sediments due to lack of detection and lack of long-term data, respectively.

3.9.9 Flame Retardants

Flame retardants, also referred to as polybrominated diphenyl ethers (PBDEs) are widely applied to combustible materials such as plastics, textiles, furniture, electronic equipment such as TVs and computers, and other materials to prevent fires (de Wit 2002). Many of these flame retardants are not chemically bound to the plastics or textiles and can separate or leach from these products into the surrounding environment (de Wit 2002).

Flame retardants are found everywhere and can be released into freshwater ecosystems through manufacturing operations (i.e., when flame retardants are added or mixed into products), through leaching of products during their lifetime or through leaching of wastes from landfills (Environment Canada 2006). Due to their low solubility in water and low vapour pressures, flame retardants entering the environment will tend to bind to organic-rich particulate matter such as soils and sediments (Environment Canada 2006).

Similar to chemical profiles of other synthetic organic compounds such as PCBs, flame retardants are persistent in the environment, and are resistant to physical, chemical, or biological degradation (Birnbaum & Staskal 2004, Martin et al. 2004).

Flame retardants act as endocrine disrupting compounds and may have long-term effects on the endocrine system by interfering with thyroid hormone metabolism (Zhou et al. 2001). Furthermore, flame retardants have been found to bioaccumulate in the environment and have been found in increasing concentrations in Arctic marine mammals (Ikonomou 2002a, b). Because of their toxic and persistent effects in the environment, manufacturing of flame retardants in the US and Canada ceased in 2004, and the use and production of many flame retardants have also been phased out by the European Union (Environment Canada 2006).

3.9.9.1 Water Quality Data Availability

No current data were available for flame retardants in surface water from any AESRD, EC (JOSM), or RAMP stations in the Athabasca watershed (Figure 46).

3.9.9.2 Sediment Quality Data Availability

Only one year of current data (i.e., 2008) were available for flame retardants in sediments from four AESRD LTRN stations (Figure 46). No data were available for flame retardants in sediment for the McLeod, Pembina, Lesser Slave, La Biche, Clearwater, or Lake Athabasca sub-watersheds.

3.9.10 Flame Retardants in Sediment

3.9.10.1 2012 Spatial comparisons

Given only 2008 data were available for flame retardants in sediments, spatial comparisons were not conducted.

3.9.10.2 Compilation of Current Flame Retardants in Sediment and Comparison with Guidelines

All flame retardants measured in sediment were below detection (i.e., < 0.00025 to <0.0005 mg/kg) for all four AESRD stations (Table 28). No guidelines were available for the flame retardants measured.

3.9.10.3 Historical Trend Analysis

Statistical trend analysis was not conducted on any AESRD sediment stations, given only one year of flame retardants data were available.

3.9.11 Overall Assessment: Flame Retardants

- All flame retardants data were obtained from four LTRN stations located in the Upper Athabasca, Upper Central Athabasca, Lower Central Athabasca, and Lower Athabasca sub-watersheds, indicating a general gap in sampling of flame retardants throughout the rest of the Athabasca watershed.

- Sediment data were sparse for flame retardants in the Athabasca watershed given that only 2008 data were available for the current period.
- All flame retardants in sediments were below detection at all stations.
- No guidelines were available for flames retardants in sediments.

3.9.12 Nonylphenols

Nonylphenol is an organic compound produced from cyclic intermediates in the refinement of petroleum and coal-tar crudes (USEPA 2005). The main source of nonylphenols in the environment is the degradation of nonylphenol ethoxylates which are used in a variety of industrial surfactants, cleaning products, pesticides, plastics, cosmetics, and birth-control products (Nimrod & Benson 1996, Hale et al. 2000).

Nonyphenols are widely distributed in freshwater ecosystems through sewage sludge recycling, leaching of wastes from landfills, and discharge of effluent from wastewater treatment plants (Soares et al. 2008). Nonylphenols tend to accumulate in organic-rich river sediments and sewage sludge due to their low solubility and high hydrophobicity (i.e., ability to repel water) (Hale et al. 2000, Soares et al. 2005, Soares et al. 2008).

Nonylphenols are referred to as endocrine-disrupting compounds and have been reported to disrupt endocrine function, embryo survival and sexual development in aquatic organisms (Hale et al. 2000, Soares et al. 2008); however, toxicity of nonylphenols is dependent on many factors including the life history stage of the organism and the regulatory mechanisms of the cell and organs of the organism (Soares et al. 2008). Because of the harmful effects of nonylphenols and nonylphenol ethoxylates in the environment, the use and production of these compounds have been replaced by other surfactants in most European countries, Canada and Japan (Soares et al. 2008).

3.9.12.1 Water Quality Data Availability

No current data were available for nonylphenols in surface water from any AESRD, EC (JOSM), or RAMP stations in the Athabasca watershed (Figure 46).

3.9.12.2 Sediment Quality Data Availability

Only one year of current data (i.e., 2008) were available for nonylphenols in sediments from four AESRD LTRN stations (Figure 46). No data were available for nonylphenols in sediment for the McLeod, Pembina, Lesser Slave, La Biche, Clearwater, or Lake Athabasca sub-watersheds.

3.9.13 Nonylphenols in Sediment

3.9.13.1 2012 Spatial comparisons

Given that only 2008 data were available for nonylphenols in sediments, spatial comparisons were not conducted.

3.9.13.2 Compilation of Current Nonylphenols in Sediment and Comparison with Guidelines

All nonylphenols measured in sediment were below detection (i.e., <0.01 to <0.05 mg/kg) and below guidelines for all four AESRD LTRN stations (Table 28).

3.9.13.3 Historical Trend Analysis

Statistical trend analysis was not conducted on any AESRD sediment stations, given only one year of nonylphenols data was available.

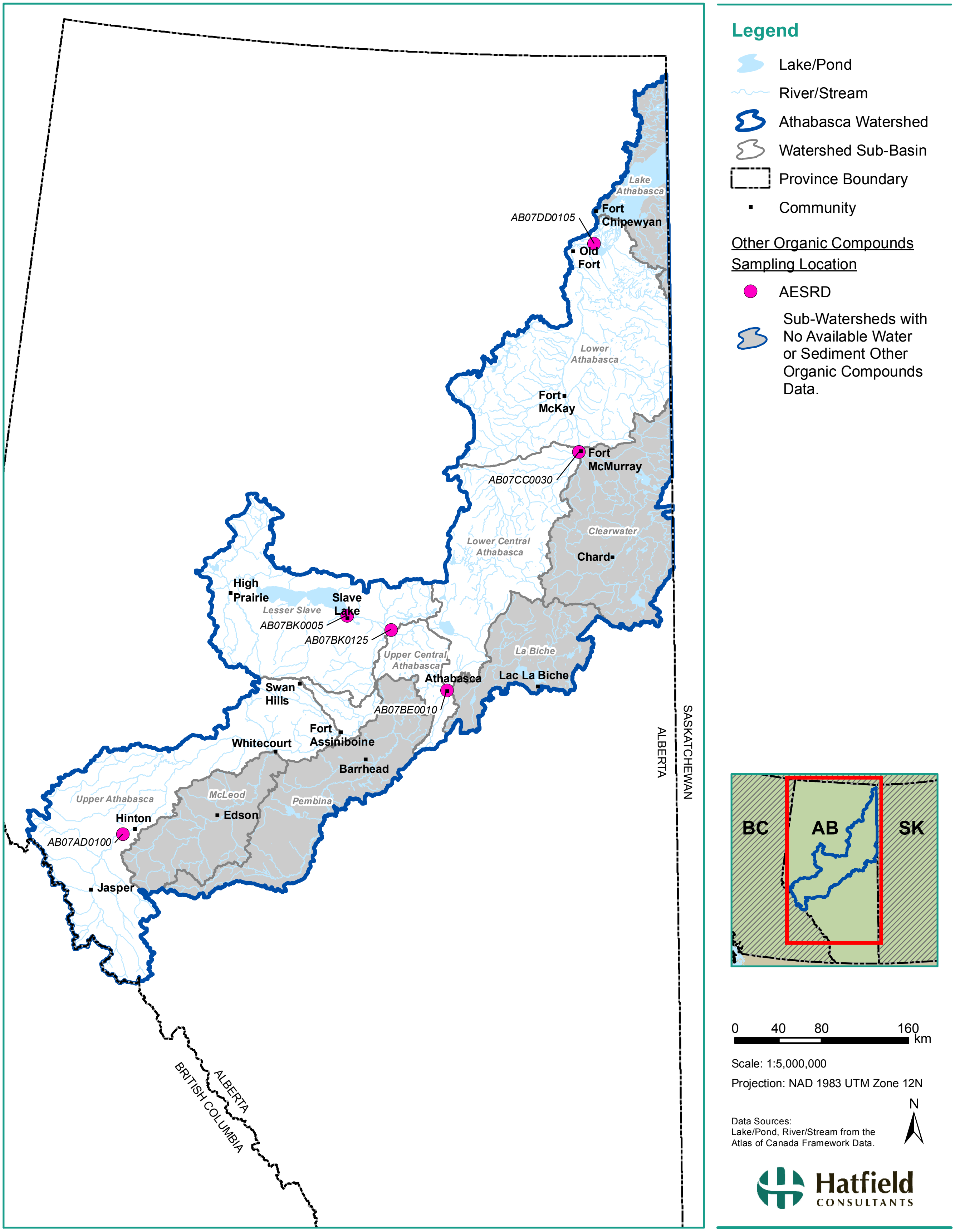
3.9.14 Overall Assessment: Nonylphenols

- All nonylphenols data were obtained from four LTRN stations located in the Upper Athabasca, Upper Central Athabasca, Lower Central Athabasca, and Lower Athabasca sub-watersheds, indicating a general gap in sampling of nonylphenols throughout the rest of the Athabasca watershed.

- Sediment data were sparse for nonylphenols in the Athabasca watershed given that only 2008 data were available for the current period.

- All nonylphenols in sediments were below detection and below guidelines at all stations.

Figure 46 Sampling locations for other organic compounds in water and sediment.



Scale: 1:5,000,000

Projection: NAD 1983 UTM Zone 12N

Data Sources:
Lake/Pond, River/Stream from the Atlas of Canada Framework Data.

K:\Data\Project\AWPAC6511\GIS_MXD\AWPAC6511_Loc06_OtherOrganicCompounds_20140127_ss.mxd

Table 27 Other organic compounds in surface water at AESRD stations with at least one year of current data available.

Analyte	Guidelines (µg/L)			Common Detection Limit (µg/L)	Station					
					Upper Athabasca	Upper Central Athabasca	Lesser Slave		Lower Central Athabasca	Lower Athabasca
	AESRD (2013)	CCME	BC		AB07AD0100	AB07BE0010	AB07BK0005	AB07BK0125	AB07CC0030	AB07DD0105
Aliphatic Hydrocarbons										
Isophorone	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	n=2 ○	n=3 ○	n=3 ○
Methyl Tertiary Butyl Ether (MTBE)	10,000	10,000	-	0.1	n=3 ○	n=3 ○	n=1 ○	n=2 ○	n=3 ○	n=3 ○
N-Nitroso-Di-N-Propylamine	-	-	-	0.2	n=3 ○	n=3 ○	n=1 ○	n=2 ○	n=3 ○	n=3 ○
Phthalates										
Bis (2-ethylhexyl) phthalate	-	16	-	0.1	n=3 ○	n=3 ○	n=1 ●	n=2 ●	n=3 ○	n=3 ○
Butylbenzyl phthalate	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	n=2 ○	n=3 ◑	n=3 ○
Diethyl phthalate	-	-	-	0.1	n=3 ◑	n=3 ○	n=1 ○	n=2 ○	n=3 ◕	n=3 ○
Dimethyl phthalate	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	n=2 ○	n=3 ○	n=3 ○
Di-n-butyl phthalate	-	19	-	0.1	n=3 ◑	n=3 ◑	n=1 ○	n=2 ○	n=3 ◑	n=3 ○
Di-n-octyl phthalate	-	-	-	0.1	n=3 ○	n=3 ○	n=1 ○	n=2 ○	n=3 ○	n=3 ○

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes.

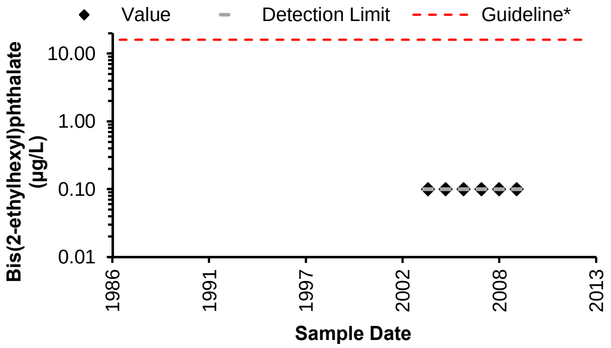
Legend

○ = All data below detection limit
◔ = 1-25% of data above detection
◑ = 26-50% of data above detection
◕ = 51-75% of data above detection
● = 76-100% of data above detection

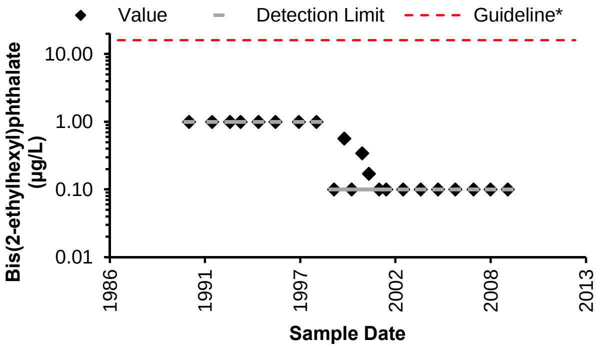
Red highlighting indicates guideline exceedence.

Figure 47 **Bis(2-ethylhexyl) phthalate (Log Scale) in surface water at AESRD stations with historical datasets.**

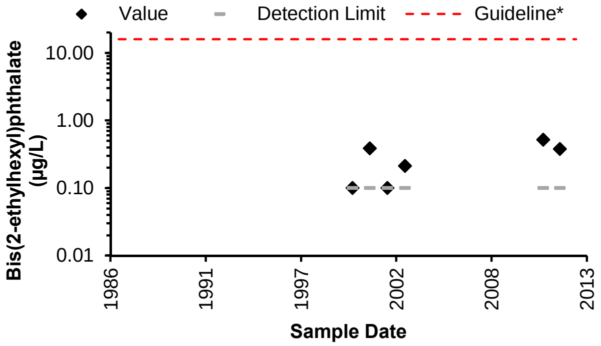
AB07AD0100 (Athabasca River at Old Entrance town site)



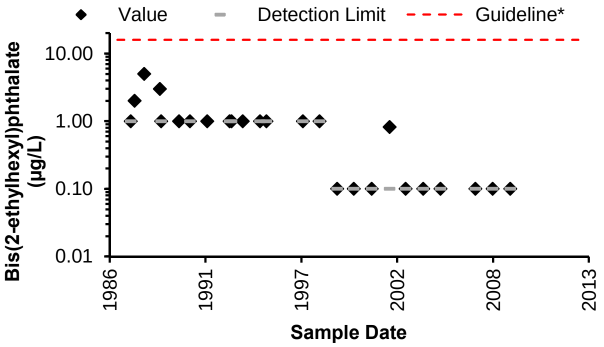
AB07BE0010 (Athabasca River at the town of Athabasca)



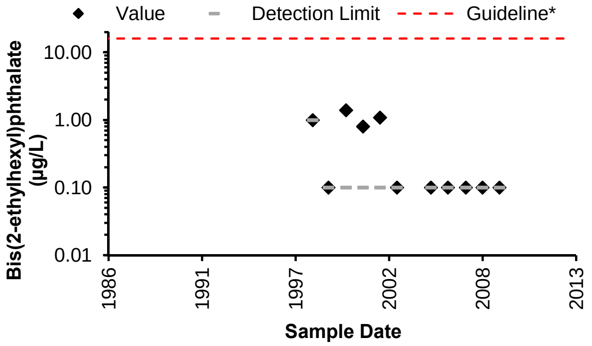
AB07BK0125 (Lesser Slave River)



AB07CC0030 (Athabasca River upstream of Fort McMurray)



AB07DD0105 (Athabasca River downstream of Devils Elbow)

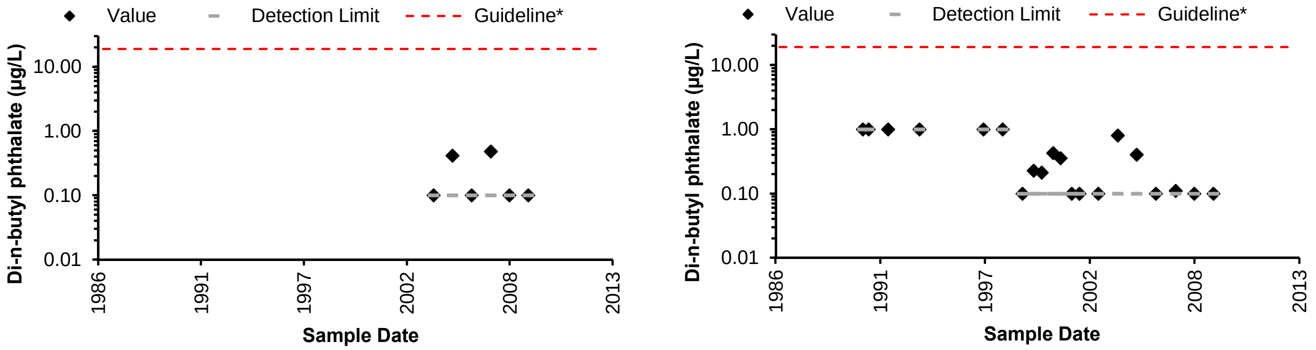


Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

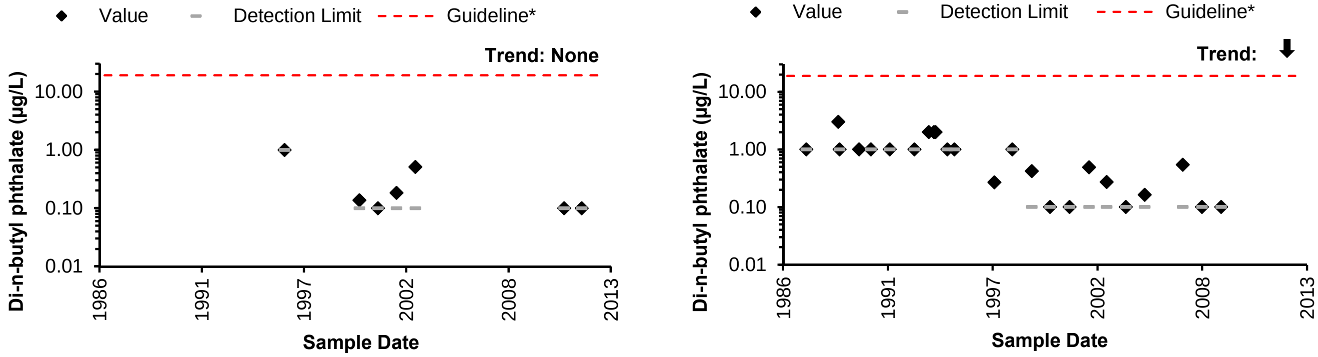
Note: Detection limits are indicated by a grey dash, absence of a grey dash indicates that detection limits were not provided for these data points.

*Guideline value is from CCME (2011) guidelines for the protection of aquatic life.

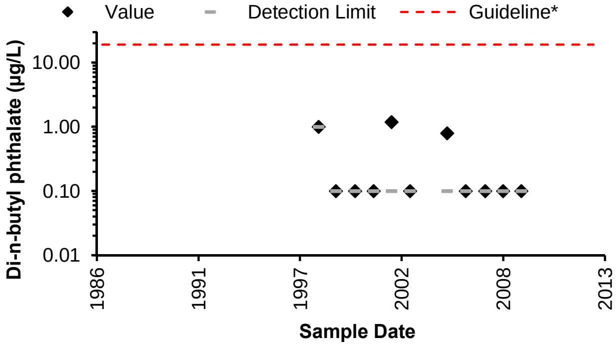
Figure 48 **Di-n-butyl phthalate (Log Scale) in surface water at AESRD stations with historical datasets.**


AB07AD0100 (Athabasca River at Old Entrance town site)

AB07BE0010 (Athabasca River at the town of Athabasca)


AB07BK0125 (Lesser Slave River)

AB07CC0030 (Athabasca River upstream of Fort McMurray)


AB07DD0105 (Athabasca River downstream of Devils Elbow)

Note: Vertical axis (Y-axis) values are presented in log scale, where each unit increase is equivalent to an order of magnitude (i.e., 1, 10, 100) to better display the range of values

Note: Detection limits are indicated by a grey dash, absence of a grey dash indicates that detection limits were not provided for these data points.

*Guideline value is from CCME (2011) and AESRD (2013a) guidelines for the protection of aquatic life.

Table 28 Other organic compounds in sediments at AESRD stations with at least one year of current data available.

Analyte	Guideline		Common Detection Limit (mg/kg)	Station			
				Upper Athabasca	Upper Central Athabasca	Lower Central Athabasca	Lower Central Athabasca
	CCME - ISQG	CCME - PEL		AB07AD0100	AB07BE0010	AB07CC0030	AB07DD0010
Aliphatic Hydrocarbons							
Isophorone	-	-	2.0	n=1 ○	n=1 ○	n=3 ○	n=1 ○
N-Nitroso-Di-N-Propylamine	-	-	4.0	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Flame Retardants							
BDE-17	-	-	0.00025	n=1 ○	n=1 ○	n=3 ○	n=1 ○
BDE-28	-	-	0.00025	n=1 ○	n=1 ○	n=3 ○	n=1 ○
BDE-47	-	-	0.00025	n=1 ○	n=1 ○	n=3 ○	n=1 ○
BDE-66	-	-	0.00025	n=1 ○	n=1 ○	n=3 ○	n=1 ○
BDE-71	-	-	0.00025	n=1 ○	n=1 ○	n=3 ○	n=1 ○
BDE-85	-	-	0.00025	n=1 ○	n=1 ○	n=3 ○	n=1 ○
BDE-99	-	-	0.00025	n=1 ○	n=1 ○	n=3 ○	n=1 ○
BDE-100	-	-	0.00025	n=1 ○	n=1 ○	n=3 ○	n=1 ○
BDE-138	-	-	0.00025	n=1 ○	n=1 ○	n=3 ○	n=1 ○
BDE-153	-	-	0.00025	n=1 ○	n=1 ○	n=3 ○	n=1 ○
BDE-154	-	-	0.00025	n=1 ○	n=1 ○	n=3 ○	n=1 ○
BDE-183	-	-	0.0005	n=1 ○	n=1 ○	n=3 ○	n=1 ○
BDE-190	-	-	0.0005	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Nonylphenols							
Bisphenol A	-	-	0.01	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Nonylphenol	1.4	-	0.05	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Nonylphenol Pentaethoxylate	1.4	-	0.02	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Nonylphenol Tetraethoxylate	1.4	-	0.02	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Nonylphenol-Diethoxylate	-	-	0.02	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Nonylphenol-Triethoxylate	-	-	0.02	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Phthalates							
Bis (2-ethylhexyl) phthalate	-	-	2	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Butylbenzyl phthalate	-	-	2	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Diethyl phthalate	-	-	2	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Di-n-butyl phthalate	-	-	2	n=1 ○	n=1 ○	n=3 ○	n=1 ○
Di-n-octyl phthalate	-	-	2	n=1 ○	n=1 ○	n=3 ○	n=1 ○

Note: Analytes not included in 2007-2012 data have been excluded from the list of analytes.

Legend

○ = All data below detection limit

◔ = 1-25% of data above detection

◑ = 26-50% of data above detection

◕ = 51-75% of data above detection

● = 76-100% of data above detection

Red highlighting indicates guideline exceedence.

4.0 GAP ANALYSIS/LIMITATIONS

The following gaps in knowledge have been identified for assessment of organic compounds in surface waters and sediments and trace metals in sediments in the Athabasca watershed:

Long Term Monitoring

Considerable information exists regarding organic compounds in surface water and sediments in various portions of the Athabasca watershed. Historically, these data have been collected by multiple organizations and individuals for varying purposes, at different frequencies, using different methods. These data are generally patchy for sub-watersheds where long-term monitoring stations do not exist and where data collection has not occurred in response to specific concerns (e.g., NRBS/NREI studies) or monitoring requirements (e.g., oilsands, pulpmill EEMs). These specific monitoring approaches are useful for evaluating effects of certain activities and stressors on components of the aquatic environment; however, they are less useful for synoptic assessment of long-term changes or cumulative effects at the scale of a watershed.

Surface Water Data Availability

Most surface water data for organic compounds were obtained from four AESRD LTRN stations in the Upper Athabasca, Upper Central Athabasca, Lower Central Athabasca, and Lower Athabasca sub-watersheds, or from RAMP stations within the Lower Athabasca and Clearwater sub-watersheds. No surface water data were obtained for any organic compounds in the La Biche and Lake Athabasca sub-watersheds, and sparse data were available for the central part of the watershed in general, indicating a general gap in water quality information for these areas (Table 29).

Concerns about water quality data availability in the central Athabasca watershed were previously identified in the SOW Phase 3 assessment and in NRBS and NREI studies, given the numerous industrial and agricultural activities that occur in this area and discharge into the Athabasca watershed. Furthermore, water quality monitoring in the Lake Athabasca sub-watershed could provide a more thorough understanding of the fate of potential organic contaminants entering the delta and lake through the Athabasca River and portions of the Lake Athabasca sub-watershed outside of Alberta.

Sediment Data Availability

Sediment data describing organic compounds and trace metals were relatively sparse within the Athabasca watershed. Data were obtained from four AESRD LTRN stations in the Upper Athabasca, Upper Central Athabasca, Lower Central Athabasca, and Lower Athabasca sub-watersheds, or from RAMP stations within the Lower Athabasca and Clearwater sub-watersheds. No sediment data were obtained for any organic compounds in the Pembina, La Biche, and Lake Athabasca sub-watersheds and most data were obtained from stations in the Lower Athabasca sub-watershed, indicating a general gap in sediment quality monitoring for the remainder of the watershed (Table 29).

Given that all AESRD sediment data were only available for one year within the current period, it is evident that no long-term, regular sediment quality monitoring programs occur within the watershed upstream of the Lower Athabasca sub-watershed, although sporadic sediment quality sampling has been conducted in the upper watershed in various studies (e.g., NRBS, NREI). Suspended sediments are known to transport metals and organic contaminants far from their source, and concentrations of contaminants can be elevated in depositional areas. Given the role of sediments in contaminant transport, long-term sediment quality monitoring on the Athabasca River and its tributaries could provide information on downstream transport and the potential impacts of sediment-bound organic contaminants on aquatic ecosystems within the Athabasca watershed.

In the absence of long-term sediment monitoring, sediment coring data can provide long-term historical benchmarks for many locations throughout the watershed thereby providing both temporal and spatial data for organic compounds and trace metals in sediment. In the Lower Athabasca sub-watershed, Environment Canada collected sediment cores from six lakes in 2011, and cores from seven lakes in 2012; however, these data have yet to be published publicly through the JOSM information portal.

Monitoring Frequency of Organic Compounds

The monitoring frequency for most organic compounds in surface water has declined in recent years. For example, surface water sampling of phthalates, resin and fatty acids, and AOX included at least four AESRD stations in 2009, but were reduced to only one station in 2011 and 2012. If monitoring frequency of these and other organic compounds continues to decline, the significance of these gaps in monitoring frequency may become greater and future watershed assessments may have to rely on older data to make assumptions about the condition of the watershed.

Sampling Coordination

Coordination of research efforts and information sharing by different organizations, institutions, and individuals helps to reduce gaps in knowledge. We are aware of ongoing activities in the lower Athabasca that are attempting to address this issue. For example, JOSM is committed to implementing a comprehensive, integrated, and transparent environmental monitoring plan for the oil sands region with an open data management program (JOSM 2013). Hopefully, the newly established Alberta Environmental Monitoring, Evaluation, and Reporting Agency (AEMERA) will facilitate the development of coordinated monitoring programs for the remainder of the Athabasca watershed and for Alberta in general. Ongoing integration of monitoring efforts through programs such as JOSM and AEMERA will help to reduce future knowledge gaps.

Comparison to Guidelines and Other Benchmarks

Organic compounds data for both surface water and sediments were compared against AESRD, CCME, and BC guidelines for the protection of aquatic life. However, many organic compounds did not have associated guidelines for comparison, making it difficult to determine the significance of specific results. Despite this, organics data compiled and synthesized in this SOW Phase 4 assessment for 2007 to 2012 can be used to establish time-based benchmarks for future watershed assessments.

Detection of Total Mercury in Sediments

The concentration of total mercury in sediments is measured in the laboratory as part of a multi-species metal scan using the standard analytical method Cold Vapour Atomic Absorbance Spectrometry (CVAAS) and generally report detection limits that are above actual ambient concentrations of mercury in sediments. Future studies whose goal includes quantifying actual mercury concentrations in sediments should consider using more sensitive, mercury-specific techniques.

Obed Mountain Coal Mine Spill

On October 31st, 2013, a failure in the Green Pit berm led to a rapid release of fine materials from the Green Pit tailings pond at the Obed Mountain Coal Mine (Obed), located near Hinton, Alberta. This spill released materials from the tailings pond into Apetowun Creek, which then flowed into Plante Creek and ultimately into the Athabasca River. Water and sediment quality in Apetowun Creek, Plante Creek, and the Athabasca River have been monitored since the beginning of the spill and much of the data collected overlaps with the water and sediment data applicable to the current Phase 4 SOW report. Given the Phase 4 SOW only considers a data period between 2007 and 2012, data collected from the Obed spill should be included in future watershed assessments. Data and information on the Obed spill are publicly available on the AESRD website: http://esrd.alberta.ca/focus/obed-mountain-mine-release.aspx. External data and information is also available from Sherrit International: http://obed.ca/.

Table 29 Availability of water and sediment quality data within each sub-watershed with at least one year of current data (i.e., 2007-2012).

Variable	Sub-Watersheds of the Athabasca River Basin										Number of sub-watersheds with WQ data	Number of sub-watersheds with SQ data	Data Source(s)
	Upper Athabasca	McLeod	Pembina	Lesser Slave	Upper Central Athabasca	La Biche	Lower Central Athabasca	Clearwater	Lower Athabasca	Lake Athabasca			
Total Hydrocarbons	WQ	-	-	WQ	WQ	-	WQ	WQ, SQ	WQ, SQ	-	6	2	WQ: AESRD, RAMP; SQ: RAMP
Polycyclic Aromatic Hydrocarbons(PAHs)	WQ	WQ	-	WQ	WQ	-	WQ	WQ, SQ	WQ, SQ	-	7	2	WQ: AESRD, RAMP, EC (JOSM); SQ: RAMP
Other Aromatic Hydrocarbons	WQ, SQ	-	-	WQ	WQ, SQ	-	WQ, SQ	-	WQ, SQ	-	5	4	WQ: AESRD, SQ: AESRD
Pesticides (fungicides, herbicides, insecticides)	WQ, SQ	-	WQ	WQ	WQ, SQ	-	WQ, SQ	-	WQ, SQ	-	6	4	WQ: AESRD, EC (JOSM) ; SQ: AESRD
Organic Acids													
Naphthenic Acids and Oilsands Extractable	-	SQ	-	-	WQ	-	WQ	WQ	WQ	-	4	1	WQ: AESRD, RAMP; SQ: AESRD
Resin and Fatty Acids	WQ	-	-	-	WQ	-	WQ	-	WQ	-	4	0	WQ: AESRD
Total Phenols and Non-Chlorinated Phenols	WQ, SQ	-	-	WQ	WQ, SQ	-	WQ, SQ	WQ	WQ, SQ	-	6	4	WQ: AESRD, RAMP; SQ: AESRD
Organochlorines and AOX	WQ, SQ	-	-	WQ	WQ, SQ	-	WQ, SQ	-	WQ, SQ	-	5	4	WQ: AESRD, SQ: AESRD
Polychlorinated Biphenyls (PCBs)	SQ	-	-	-	SQ	-	SQ	-	SQ	-	0	4	SQ: AESRD
Trace Metals (for sediments only)		-	-	-	-	-	-	SQ	SQ	-	0	2	SQ: RAMP
Other Organic Compounds													
Aliphatic Hydrocarbons	WQ, SQ	-	-	WQ	WQ, SQ	-	WQ, SQ	-	WQ, SQ	-	5	4	WQ: AESRD, SQ: AESRD
Flame Retardants	SQ	-	-	-	SQ	-	SQ	-	SQ	-	0	4	SQ: AESRD
Nonylphenols	SQ	-	-	-	SQ	-	SQ	-	SQ	-	0	4	SQ: AESRD
Phthalates	WQ, SQ	-	-	WQ	WQ, SQ	-	WQ, SQ	-	WQ, SQ	-	5	4	WQ: AESRD, SQ: AESRD

WQ= Water Quality

SQ = Sediment Quality

AESRD= Alberta Environment and Sustainable Resource Development

RAMP= Regional Aquatics Monitoring Program

EC= Environment Canada

5.0 CONCLUSIONS AND RECOMMENDATIONS

Overall, organic compounds in surface water and sediments of the Athabasca watershed are being measured by many different organizations and individuals. Ongoing efforts are being made to integrate these programs and this information in a useful way to inform future management plans and monitoring programs.

In general, concentrations of organic compounds in surface waters and sediments and trace metals in sediments were low throughout the Athabasca watershed. A brief summary of findings from each group of organic compounds are presented below:

Total Hydrocarbons

In water, the majority of total hydrocarbons samples were below common detection limits at all stations in all sub-watersheds with available data. Concentrations of toluene exceeded guidelines once from 2007 to 2012 at six RAMP stations located upstream or downstream of oilsands developments and three AESRD stations. In sediments, the majority of measurable total hydrocarbons at RAMP stations were heavier CCME F3, F4 fractions.

Polycyclic Aromatic Hydrocarbons (PAHs)

In water, the majority of PAH species were below detection at all stations. Benzo(a)pyrene exceeded guidelines in one sample at one RAMP water quality station and naphthalene exceeded guidelines at two RAMP water quality stations in the Lower Athabasca sub-watershed. In sediments, the majority of detectable PAH species were heavy, alkylated forms and six PAH species (benz(a)anthracene, benzo(a)pyrene, chrysene, dibenz[a,h]anthracene, phenanthrene, pyrene) exceeded guidelines at RAMP sediment stations between 2007 and 2012.

Aromatic Hydrocarbons

All aromatic hydrocarbons in surface waters were below detection at all stations, with the exception of 1,2,4-trimethylbenzene, which was detected in one sample downstream of Devil’s Elbow at Winter Road (AESRD station: AB07DD0105) in 2007. All aromatic hydrocarbons in sediments were below detection at all stations.

Pesticides

In water, the majority of herbicides were below detection for all stations and all fungicides and insecticides were below detection at all stations. In sediments, all fungicides, herbicides, and insecticides were below detection with the exception of one insecticide at one station. No guidelines were exceeded for any pesticides at any station.

Concentrations of pesticides were generally low or below detection at all stations, except at Wabash Creek near Pibroch (AESRD station: AB07BC0540) where nine herbicides were frequently measurable. This station is located in an area of heavy agricultural land use within the Pembina sub-watershed and was last sampled in 2008.

Naphthenic Acids

In water, the majority of naphthenic acid and oilsands extractable concentrations were detectable at all stations. In sediments, naphthenic acids were measured in only one sample in 2010 and were detectable.

Resin and Fatty Acids

All resin and fatty acids in surface waters were below detection at all stations. No sediment data were available for resin and fatty acids.

Non-chlorinated Phenols and Total Phenols

All non-chlorinated phenols in surface waters and sediments were below common detection limits and guidelines at all stations. Concentrations of total phenols in surface water were measurable in almost all samples at all stations. No sediment data were available for total phenols.

Concentrations of total phenols showed increasing concentrations over time at many stations sampled by RAMP in the Lower Athabasca sub-watershed.

Organochlorines and Adsorbable Organic Halides (AOX)

In water and sediment, all organochlorines were below detection and below guidelines at all stations. Concentrations of AOX in surface water were detected in at least one sample at six of the seven stations with available data. No sediment data were available AOX.

A significant increasing trend in AOX over time was found downstream of Fort McMurray and Fort McKay (AESRD station: AB07DD0105), despite generally decreasing for AOX values upstream of Fort McMurray.

Polychlorinated Biphenyls (PCBs)

In sediments, all PCBs were below common detection limits and guidelines at all stations. PCBs surface water data were only available from 1987-1994; outside the scope of the current assessment.

Trace Metals

In sediment, the majority of metals were measureable in at least one sample at all stations in the Lower Athabasca and Clearwater sub-watersheds. Concentrations of arsenic exceeded CCME ISQG guidelines at six stations in the Lower Athabasca sub-watershed; mercury and copper exceeded guidelines at one station each. No CCME PEL guidelines were exceeded for any metals in sediments for the current data period.

Phthalates

In water, the majority of phthalate concentrations were below detection at all stations and no guidelines were exceeded for any phthalates at any station. In sediments, all phthalates measured were below detection for all stations.

Aliphatic Hydrocarbons

In surface water and sediments, all aliphatic hydrocarbons were below detection at all stations.

Flame Retardants

In sediments, all flame retardants were below detection at all stations. No surface water data were available for flame retardants.

Nonylphenols

In sediments, all nonylphenols were below detection and below guidelines at all stations. No surface water data were available for nonylphenols.

Recommendations

Data availability for organic compounds in surface water and sediments and trace metals in sediments is patchy throughout the Athabasca watershed and organics data are often only collected for specific compounds and in response to specific concerns. Furthermore, many organic compounds are not measured routinely in surface water (i.e., resin and fatty acids, AOX, phthalates, pharmaceuticals), and most organic compounds have not been measured recently in sediments; therefore, inclusion of these compounds in a routine monitoring program should be considered. Future design of monitoring programs within the Athabasca watershed should consider a network approach to monitoring of organic compounds, where a long-term monitoring program for each sub-watershed is put in place (potentially at varied intervals) to ensure complete sampling coverage of the watershed.

Coordination of monitoring between federal, provincial, and industry programs is needed for measuring organic compounds in surface water and sediments and trace metals in sediments throughout the Athabasca watershed, particularly with respect to the specific analytes measured, analytical methods, and sampling frequency. Harmonization of monitoring programs and sampling methods among all parties could provide larger datasets and would increase the chance of detecting any effects, thereby allowing watershed managers to more effectively assess the overall condition of the watershed.

The Alberta Environmental Monitoring, Evaluation, and Reporting Agency (AEMERA) is anticipated to be in place in early 2014 to coordinate and integrate environmental monitoring activities throughout Alberta; therefore, it would be useful for the AWC-WPAC to inform AEMERA on the knowledge gaps and recommendations from the SOW phase 4 assessment for consideration in design of future integrated monitoring plans for the Athabasca watershed.

6.0 CLOSURE

We trust the above information meets your requirements. If you have any questions or comments, please contact the undersigned.

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8.0 GLOSSARY

Acute	Acute refers to a stimulus severe enough to rapidly induce an effect; in aquatic toxicity tests, an effect observed in 96 hours or less is typically considered acute. When referring to aquatic toxicology or human health, an acute effect is not always measured in terms of lethality.
Adsorption	The attachment of ions or molecules to the surface of a material.
Bioaccumulation	The net accumulation of a substance or contaminant in and on an organism from all sources including water, air and solid phases of the environment. Solid phases include food sources.
Bioavailability	The amount of chemical that enters the general circulation of the body following administration or exposure.
Bioconcentration	The net accumulation of a substance or contaminant in and on an organism from water only.
Biomagnification	A trophic process in which retained substances become more concentrated with each link in the food chain.
BOD	Biochemical oxygen demand. The test measures the oxygen utilized during a specified incubation period for the biochemical degradation of organic material and the oxygen used to oxidize inorganic material such as sulfides and ferrous iron. Usually conducted as a 5-day test (i.e., BOD5).
Bottom Sediments	Substrates that lie at the bottom of a body of water. For example, soft mud, silt, sand, gravel, rock and organic litter, that make up a river bottom.
Chronic	Defines a stimulus that lingers or continues for a relatively long period of time, often one-tenth of the life span or more. Chronic should be considered a relative term depending on the life span of the organism. The measurement of a chronic effect can be reduced growth, reduced reproduction, etc., in addition to lethality.
Concentration	Quantifiable amount of a chemical in environmental medium, expressed as mass of a substance per unit volume (e.g., mg/L), or per unit sample mass (e.g., mg/kg).

Concentration Units

Concentration Units	Abbreviation	Units
Parts per million	ppm	mg/kg or μg/g or mg/L
Parts per billion	ppb	μg/kg or ng/g or μg/L
Parts per trillion	ppt	ng/kg or pg/g or ng/L
Parts per quadrillion	ppq	pg/kg or fg/g or pg/L

Detection Limit	The lowest concentration at which individual measurement results for a specific analyte are statistically different from a blank (that may be zero) with a specified confidence level of a given method and representative matrix.
Diagenic	Derived from microbial degredation.
Ecosystem	An integrated and stable association of living and non-living resources functioning within a defined physical location.
Hydrophobic	Having an aversion to water; tending to coalesce and form droplets in water.
Hydrophobicity	The ability of a particular compound to repel or avert water.
Inorganics	Pertaining to a compound that contains no carbon.
Lipophilic	The ability of a particular compound to dissolve in lipids such as oils or fats.
Oxidation State	The number of electrons an atom loses, gains, or shares in combining with other atoms to form molecules or polyatomic atoms.
Organics	Chemical compounds, naturally occurring or otherwise, which contain carbon, with the exception of carbon dioxide (CO2) and carbonates (e.g., CaCO3).
PEL	Probable Effect Level. Concentration of a chemical in sediment above which adverse effects on an aquatic organism are likely.
Petrogenic	Petroleum-derived.
Photodegradation	Chemically broken down by exposure to light.
Pyrogenic	Derived from combustion of organic matter or the application of heat.
Quality Assurance (QA)	Refers to the externally imposed technical and management practices which ensure the generation of quality and defensible data commensurate with the intended use of the data; a set of operating principles that, if strictly followed, will produce data of known defensible quality.
Quality Control (QC)	Specific aspect of quality assurance which refers to the internal techniques used to measure and assess data quality and the remedial actions to be taken when data quality objectives are not realized.

Sediments	Solid fragments of inorganic or organic material that fall out of suspension in water, wastewater, or other liquid.
Solubility	A chemical property referring to the ability of a given substance, the solute, to dissolve in a solvent.
Toxic	A substance, dose, or concentration that is harmful to a living organism.
Toxicity	The inherent potential or capacity of a material to cause adverse effects in a living organism.

APPENDICES

Appendix A1

Raw Data for Organic Compounds in Surface Water and Sediments and Trace Metals in Sediments from 2007 to 2012

Appendix A1 includes Microsoft Excel spreadsheets for all primary sediment and water quality data obtained from all data sources used in this assessment.

Each file contains the following:

- A meta-data worksheet explaining the contents of the file and an index for organic compounds data within the file;
- A location file with the latitude and longitude locations for each sampling station;
- A master variable list including all analytes measured for each group of organic compounds; and
- Data for each class of organic compounds for the current period (i.e., 2007-2012) including sample date, station number and description, units, detection limit, flag, measurement value, data source, and guideline value (where applicable).

These files are appended to this report as an attachment.