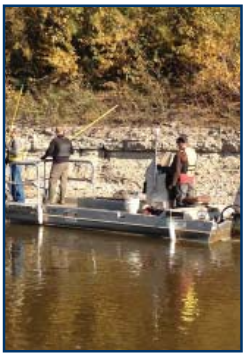
RAMP
Regional Aquatics Monitoring Program

2013 TECHNICAL REPORT
EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

OVERVIEW

The Regional Aquatics Monitoring Program (RAMP) was initiated in 1997 in association with mining development in the Athabasca oil sands region near Fort McMurray, Alberta. RAMP is an industry-funded, multi-stakeholder initiative that monitors aquatic environments in the Regional Municipality of Wood Buffalo. The intent of RAMP is to integrate aquatic monitoring activities so that long-term trends, regional issues, and potential cumulative effects related to oil sands development (surface mining and in situ extraction) can be identified and assessed. In 2013, RAMP was funded by Brion, Canadian Natural Resources Limited, Cenovus, Connacher, ConocoPhillips, Devon Energy, Hammerstone, Husky, Imperial Oil, JACOS, MEG Energy, Nexen, Shell, Statoil, Suncor, Syncrude, Teck, and Total E&P. Non-funding participants included municipal, provincial, and federal government agencies, and two Aboriginal groups. In 2013, the RAMP program was conducted in support of the Joint Oil Sands Monitoring Plan (JOSMP) but was also operating independently to the extent that the results from monitoring activities were completed to meet the requirements of approval conditions for industry members. The enhanced monitoring conducted under the JOSMP is in addition to monitoring requirements outlined in regulatory approvals (e.g., RAMP).

The original Regional Municipality of Wood Buffalo boundary (pre-2013) in northeastern Alberta represents the Regional Study Area (RSA) of RAMP. Within this area, a Focus Study Area (FSA) has been defined and includes those parts of the following watersheds where oil sands and other developments are occurring or planned:

- Lower Athabasca River;
- Major tributary watersheds/basins of the lower Athabasca River including the Clearwater River, Christina River, Hangingstone River, Steepbank River, Muskeg River, MacKay River, Ells River, Tar River, Calumet River, High Hills River, and Firebag River;
- Select minor tributaries of the lower Athabasca River (McLean Creek, Mills Creek, Beaver River, Poplar Creek, Fort Creek, Pierre River, Eymundson Creek, Red Clay Creek, and Big Creek);
- Select minor tributaries to Christina Lake (Sunday Creek, Birch Creek, Jackfish River, Sawbones Creek, and two unnamed creeks);
- Specific wetlands and shallow lakes in the vicinity of current or planned oil sands and related developments; and
- A selected group of 50 regional acid-sensitive lakes.

The RAMP FSA also includes the Athabasca River Delta as the receiving environment for any oil sands developments occurring in the Athabasca oil sands region.

RAMP incorporates both stressor- and effects-based monitoring approaches. Using impact predictions from the various oil sands environmental impact assessments, specific potential stressors have been identified that are monitored to document *baseline* conditions, as well as potential changes related to development. Examples include specific water quality variables and changes in water quantity. In addition, there is a strong emphasis in RAMP on monitoring sensitive biological indicators that reflect the overall condition of the aquatic environment. By combining both monitoring approaches, RAMP strives to achieve a more holistic understanding of potential effects on the aquatic environment related to oil sands development.

The scope of RAMP focuses on the following key components of boreal aquatic ecosystems:

1. Climate and hydrology are monitored to provide a description of changing climatic conditions in the RAMP FSA, as well as changes in the water level of selected lakes and in the quantity of water flowing through rivers and creeks.

2. Water quality in rivers, lakes and the Athabasca River Delta is monitored to assess the potential exposure of fish and invertebrates to organic and inorganic chemicals.

3. Benthic invertebrate communities and sediment quality in rivers, lakes, and the Athabasca River Delta are monitored because they reflect habitat quality, serve as biological indicators, and are important components of fish habitat.

4. Fish populations in rivers and select lakes are monitored as they are biological indicators of ecosystem integrity and are a highly valued resource in the region.

5. Water quality in regional lakes sensitive to acidification is monitored as an early warning indicator of potential effects related to acid deposition.

RAMP is funded by member companies that are constructing and operating oil sands projects in the RAMP FSA. However, there are other companies that are constructing or operating oil sands projects, but who are not members of RAMP. Therefore, the term "focal projects" is used in the RAMP 2013 Technical Report to define those projects owned and operated by the 2013 industry members of RAMP listed above that were under construction or operational in 2013 in the RAMP FSA. For 2013, these projects included a number of oil sands projects and a limestone quarry project.

2013 RAMP industry members do have other projects in the RAMP FSA that were in the application stage as of 2013, or had received approval in 2013 or earlier, but construction had not yet started as of 2013. These projects are noted throughout this technical report, but are not designated as focal projects, as these projects in 2013 would not have contributed to any possible influences on aquatic resources covered by RAMP components.

The term "other oil sands developments" is used in the RAMP 2013 Technical Report to define those oil sands projects operated by non-RAMP members located within the RAMP FSA.

A weight-of-evidence approach is used for the analysis of RAMP data by applying multiple analytical methods to interpret results and determine whether any changes have occurred due to focal projects and other oil sands developments. The analysis:

- is conducted at the watershed/river basin level, with an emphasis on watersheds in which development has already occurred, as well as the lower Athabasca River at the regional level;
- uses a set of measurement endpoints representing the health and integrity of valued environmental resources within the component; and
- uses specific criteria (criteria used in focal project EIAs, AESRD, and CCME water quality and sediment quality guidelines, generally-accepted EEM effects criteria) for determining whether or not a change in measurement endpoints has occurred and is significant with respect to the health and integrity of valued environmental resources.

The RAMP 2013 Technical Report uses the following definitions for monitoring status:

- ***Test*** is the term used in this report to describe aquatic resources and physical locations (i.e., stations, reaches) downstream of a focal project; data collected from these locations are designated as ***test*** for the purposes of analysis, assessment, and reporting. The use of this term does not imply or presume that effects are occurring or have occurred, but

simply that data collected from these locations are being tested against *baseline* conditions to assess potential changes; and

- ***Baseline*** is the term used in this report to describe aquatic resources and physical locations (i.e., stations, reaches, data) that are (in 2013) or were (prior to 2013) upstream of all focal projects; data collected from these locations are to be designated as ***baseline*** for the purposes of data analysis, assessment, and reporting. The terms *test* and *baseline* depend solely on location of the aquatic resource in relation to the location of the focal projects to allow for long-term comparison of trends between *baseline* and *test* stations.

Satellite imagery was used in 2013 in conjunction with more detailed maps of Athabasca oil sands operations provided by a number of RAMP industry members to estimate the type, location, and amount of land changed by focal projects and other development activities. As of 2013, it was estimated that approximately 117,850 ha (3.3%) of the RAMP FSA had undergone land change from focal projects and other oil sands developments. The percentage of the area of watersheds with land change as of 2013 varied from less than 1% for many watersheds (MacKay, Christina, Hangingstone, Horse, and Upper Beaver watersheds), to 1% to 5% for the Steepbank, Calumet, Firebag, and Ells watersheds, to more than 10% for the Muskeg River, Fort Creek, Mills Creek, Tar River, Shipyard Lake, Poplar Creek, and McLean Creek watersheds, as well as for the smaller Athabasca River tributaries between Fort McMurray and the confluence of the Firebag River.

ASSESSMENT OF 2013 MONITORING RESULTS

A tabular summary of the 2013 results by watershed and component is presented at the end of this Executive Summary.

Lower Athabasca River and Athabasca River Delta

Hydrology The 2013 WY water balance was calculated for two different cases: (i) only focal projects in the Athabasca River watershed; and (ii) focal projects plus other oil sands developments in the Athabasca River watershed. The mean open-water period (May to October) discharge, open-water minimum daily discharge, annual maximum daily discharge, and mean winter discharge calculated from the observed *test* hydrograph for the Athabasca River were 0.6%, 1.7%, 0.6% and 1.1% lower, respectively, than from the estimated *baseline* hydrograph. These differences were all classified as **Negligible-Low**. The results of the hydrologic assessment for focal projects were essentially identical to results for the case in which focal projects plus other oil sands developments were considered.

Water Quality Differences in water quality in fall 2013 at all stations in the Athabasca River were classified as **Negligible-Low** compared to regional *baseline* conditions. Concentrations of water quality measurement endpoints at *test* stations were generally similar to those at *baseline* stations on the east and west banks of the Athabasca River upstream of Donald Creek and consistent with regional *baseline* conditions. Concentrations of total aluminum exceeded the guideline at all stations in fall 2013 and total boron continued to show an increasing trend at the *test* station on the west bank of the Athabasca River, downstream of all development, and at both *test* stations on the east and west banks of the Athabasca River, upstream of the Muskeg River.

Benthic Invertebrate Communities and Sediment Quality Benthic invertebrate communities were monitored at four locations in the Athabasca River Delta (ARD) in fall 2013:

1. Differences in measurement endpoints for benthic invertebrate communities in Big Point Channel were classified as **Negligible-Low** because although there was a significant change in CA Axis 2 scores between 2013 and previous sampling years, the change did not indicate degradation of the benthic invertebrate community. Additionally, all

measurement endpoints of benthic invertebrate communities were within historical range of variability for reaches of the ARD.

2. Differences in measurement endpoints of benthic invertebrate communities in Goose Island Channel were classified as **Negligible-Low** because the significant increase in the percentage of EPT taxa and decrease of CA Axis 1 and 2 scores were not indicative of a negative change. In addition, all measurement endpoints were within the range of variability from previous sampling years in the ARD.

3. Differences in measurement endpoints for benthic invertebrate communities in Fletcher Channel were classified as **Moderate** because of the significant increase in equitability, exceeding the historical range of variability, and a decrease in richness over time. However, the benthic invertebrate community contained EPT taxa in relatively high abundances (3%), which was higher than 2012.

4. Differences in measurement endpoints of benthic invertebrate communities in the Embarras River were classified as **Moderate** because of the significant decreases in abundance, richness, and CA Axis 1 scores over time. However, there were some EPT taxa present and all measurement endpoints were within the range of variation from previous years, which indicated that conditions of this river have not significantly degraded.

In 2013, stations of the ARD were predominantly comprised of sand, with the exception of the Embarras River and Fletcher Channel where silt substrate was dominant. Concentrations of sediment quality measurement endpoints at all five stations in the ARD showed concentrations that were generally similar to previously-measured concentrations, with the exception of PAHs, which were generally higher in 2013 in the Embarras River and Fletcher Channel. The concentrations of PAHs at all stations in fall 2013 were dominated by alkylated species, indicating a petrogenic origin of these compounds. From 1999 to 2010, an increase in concentrations of total PAHs was observed at Big Point Channel, although this trend was not evident in concentrations of carbon-normalized total PAHs. In fall 2013, the concentration of total PAHs at Big Point Channel was below previously-measured concentrations. The PAH Hazard Index at all stations in the ARD exceeded the potential chronic toxicity threshold value of 1.0. Chronic toxicity data for sediments exceeded the maximum ten-day growth for the midge *Chironomus* at all stations in 2013. Generally survival of *Chironomus* and *Hyalella,* and fourteen-day growth of *Hyalella* were within previously-measured values in fall 2013. Because no *baseline* data were available for the ARD, no SQI or relative *baseline* comparisons were conducted.

Fish Populations (fish inventory) The objective of the fish inventory program was to assess general trends in population variables such as abundance and richness as well as to determine age, size, and health of individuals within these populations.

As of 2013, current and historical fish inventory data from the Athabasca River indicated species-specific variability in relative abundance, age-frequency distributions, and condition of fish among years. Goldeye and lake whitefish were among the large-bodied KIR species that have exhibited the greatest increase in abundance over time. Significant increases were observed in total catch and catch-per-unit-effort (CPUE) of goldeye in the last three years (i.e., 2011 to 2013), potentially due to warm, calm, spring seasons over the last three years, which can provide favourable conditions for goldeye recruitment. Similarly, CPUE of lake whitefish in fall 2013 was higher than previous years. Both goldeye and lake whitefish have shown significant increases at the majority of *test* reaches in fall since 1997. Furthermore, shifts toward older dominant age classes and significant increases in mean condition were observed in both species.

The fish health assessment indicated that abnormalities observed among all species in 2013 were within the historical range and consistent with studies published prior to major oil sands development in the upper Athabasca River, the Athabasca River Delta, and the Peace/Slave rivers.

Fish Populations (sentinel species) The effects criteria for age, weight-at-age, relative gonad weight, and relative liver weight defined by Environment Canada (2010) are a ± 25% difference between a *test* site and the *baseline* site (upstream of Poplar Creek and oil sands development) and a ± 10% difference for condition (body weight at length). Differences greater than the effects criteria between *baseline* and *test* sites suggested an ecologically relevant change in the trout-perch population at the *test* site.

A difference in measurement endpoints that exceeded the Environment Canada effects criteria was observed for age of female trout-perch and gonad weight of male trout-perch at the *test* site downstream of the confluence with the Firebag River. The age of female trout-perch at this site was 25.2% younger than for trout-perch at the *baseline* site, which was also observed in female trout-perch at this *test* site in 2010. The gonad weight of male trout-perch at the *test* site, downstream of the confluence with the Firebag River, was 25.3% greater than trout-perch at the *baseline* site, which was also observed in 2002, but the opposite pattern was observed in 2010. With no other exceedances in response patterns, and given that the 25% criteria were only marginally exceeded, these results suggested very little variability in trout-perch populations among *test* sites, downstream of development relative to the *baseline* site in 2013.

Based on the results in 2013, which provided fairly consistent response patterns in energy use and energy storage (growth, gonad weight, and liver size) in female and male trout-perch at *test* sites of the Athabasca River, differences from the *baseline* site were classified as **Negligible-Low**.

Fish Populations (fish assemblages) Results of the fish assemblage monitoring in the ARD indicated high species richness and abundance across all channels, with the highest catches observed in Big Point Channel and the Embarras River. The dominant species included small-bodied fish species (emerald shiner and lake chub) as well as northern pike as the dominant large-bodied species. Measurement endpoints were fairly consistent across channels, with high assemblage tolerance index (ATI) values reflecting the tolerant nature of fish species in the delta. The fish assemblage observed in the channels of the ARD was consistent with the species composition in the Athabasca River, as documented during the RAMP fish inventory surveys.

Muskeg River Watershed

Hydrology The calculated mean open-water discharge and the annual maximum daily discharge were 6.12% and 7.40% lower, respectively, in the observed *test* hydrograph for the Muskeg River than in the estimated *baseline* hydrograph. These differences were classified as **Moderate**. The mean winter discharge was 0.25% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. This difference was classified as **Negligible-Low.** The open-water period minimum daily discharge was 15.32% higher in the observed *test* hydrograph than in the estimated *baseline* hydrograph. This difference was classified as **High**.

In the 2013 WY, the water level in Kearl Lake steadily decreased from November 2012 to mid-February 2013, and then fluctuated between historical minimum and historical lower quartile values until the beginning of the freshet in mid-April. Lake water levels exceeded the historical maximum values from June 11 to June 26 in response to rainfall events in early to mid-June. Rainfall events in early October also increased the lake level to above the historical median level until the end of the 2013 WY.

Water Quality In fall 2013, concentrations of most water quality measurement endpoints for stations in the Muskeg River watershed were within the range of historical concentrations and

generally consistent with regional *baseline* conditions. Differences in water quality in fall 2013 at all stations in the Muskeg River watershed compared to regional *baseline* water quality conditions were classified as **Negligible-Low**.

Concentrations of most monthly water quality measurement endpoints at the lower *test* station of the Muskeg River were within the range of the regional *baseline* fall concentrations, with some monthly variability generally showing higher concentrations of ions and metals in winter when water levels were low. Despite some variability across months, the ionic composition of water collected throughout the year at the lower *test* station of the Muskeg River remained consistent.

Benthic Invertebrate Communities and Sediment Quality Benthic invertebrate communities were monitored at five *test* reaches in the Muskeg River watershed in fall 2013:

1. Differences in measurement endpoints of benthic invertebrate communities at the lower *test* reach of the Muskeg River were classified as **Negligible-Low** because the significant increase in total abundance over time and the high relative abundances of chironomids and mayflies and the presence of caddisflies and stoneflies were indicative of good water and habitat conditions. The percentage of the fauna as worms (tubificids and naidids) was low indicating no significant change in the quality of the habitat. Equitability was lower than the historical range of variability, indicating that diversity in the reach was increasing, which was considered a positive change.

2. Differences in measurement endpoints of benthic invertebrate communities at the middle *test* reach of the Muskeg River were classified as **Negligible-Low** because the significant increase in the percentage of EPT taxa was indicative of a positive change and all measurement endpoints were within the historical range of variation for this reach.

3. Differences in measurement endpoints for benthic invertebrate communities at the upper *test* reach of the Muskeg River were classified as **Negligible-Low** because the significant increase over time in EPT taxa and the higher percentage of EPT taxa in 2013 compared to the mean of *baseline* years or the mean all years combined were indicative of a positive change in the benthic invertebrate community. Three key measurement endpoints were outside of the historical range of variation, but were also indicative of greater diversity, richness, and abundance of EPT taxa. The relative abundance of tubificid worms was high in 2013, but consistent with previous years.

4. Differences in measurement endpoints for benthic invertebrate communities at the lower *test* reach of Jackpine Creek were classified as **Negligible-Low** because although there were significant increases in abundance and richness and a decrease in equitability over time during the period that this reach was designated as *test*, these changes were not indicative of degraded conditions.

5. Differences in measurement endpoints for benthic invertebrate communities in Kearl Lake were classified as **Negligible-Low** because there were no statistically large changes in any measurement endpoints. Additionally, the benthic invertebrate community of Kearl Lake included diverse fauna, with several taxa that are typically associated with relatively good water and sediment quality in lakes (e.g., the mayfly *Caenis* and bivalves). All measurement endpoints for benthic invertebrate communities in Kearl Lake were within the historical range of variation for Kearl Lake.

Concentrations of sediment quality measurement endpoints at all sampled stations in the Muskeg River watershed in fall 2013 were similar or lower than previously measured and within the range of regional *baseline* conditions. Differences in sediment quality in fall 2013 at all applicable stations in the Muskeg River watershed were assessed as **Negligible-Low** compared to regional *baseline* conditions.

Fish Populations (fish assemblages) Differences in measurement endpoints of the fish assemblage at the lower *test* reach of the Muskeg River were classified as **Moderate** because although values of all measurement endpoints were within the range of regional *baseline* variability, there was a decrease in abundance and CPUE over time, which are indicative of a potential negative change in the fish assemblage. Differences in measurement endpoints for fish assemblages between the middle *test* reach of the Muskeg River and regional *baseline* conditions were classified as **Moderate** because CPUE and abundance were lower than the range of variation for *baseline* depositional reaches. Differences in measurement endpoints for fish assemblages between the upper *test* reach of the Muskeg River and regional *baseline* conditions were classified as **High** given that only one fish was captured at this reach in 2013, and CPUE, abundance, diversity, and richness were near the 5th percentile of regional *baseline* conditions in 2012 and 2013. The low capture success was likely due to greater water depths in the last two years, which decreased capture efficiency. Differences in measurement endpoints of the fish assemblage at the lower *test* reach of Jackpine Creek were classified as **High** because richness and CPUE were below the 5th percentile of regional *baseline* variability and there were significant decreases in all measurement endpoints over time, which were indicative of a potential negative change in the fish assemblage.

Steepbank River Watershed

Hydrology The calculated mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.33% greater in the observed *test* hydrograph for the Steepbank River than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low.**

Water Quality Concentrations of most water quality measurement endpoints at stations in the Steepbank River watershed in fall 2013 were within previously-measured concentrations. When compared with regional *baseline* conditions, concentrations of water quality measurement endpoints were generally consistent. The ionic composition at all water quality monitoring stations in the Steepbank River watershed in fall 2013 was similar to previous years. Differences in water quality in fall 2013 compared to regional *baseline* water quality conditions were classified as **Negligible-Low** for all stations in the Steepbank River watershed.

Benthic Invertebrate Communities Differences in measurement endpoints of the benthic invertebrate community at the lower *test* reach of the Steepbank River were classified as **Moderate** because of significantly lower abundance, richness, and percent EPT compared to the upper *baseline* reach. The benthic invertebrate community; however, was diverse and contained many taxa that require cool, clean water indicating a lack of degradation at this reach. Differences in the benthic invertebrate communities between the upper and lower reaches may be related to natural differences in substrate texture. The substrate at the lower *test* reach was slightly more dominated by finer cobble, gravel, and sand than the upper *baseline* reach, and was more embedded; therefore, there was less surface area for benthic organisms to colonize.

Fish Populations (fish assemblages) Differences in measurement endpoints of the fish assemblage at the lower *test* reach of the Steepbank River were classified as **Moderate** because although values of all measurement endpoints were within the range of regional *baseline* variability, there were significant decreases in abundance, richness, and CPUE over time, which were indicative of a potential negative change in the fish assemblage, although the increased embedded substrate at this reach could have resulted in less cover and suitable habitat for fish over time.

Tar River Watershed

Hydrology The calculated mean open-water period discharge, annual maximum daily discharge, and open-water minimum daily discharge were 28.8% lower in the observed *test* hydrograph for the Tar River than in the estimated *baseline* hydrograph. These differences were classified as **High**.

Water Quality Differences in water quality observed in fall 2013 between the lower *test* station of the Tar River and regional *baseline* conditions were classified as **Moderate**. In fall 2013, most water quality measurement endpoints at the upper *baseline* station and the lower *test* station were within the range of previously-measured concentrations and were consistent with regional *baseline* concentrations, with the exception of total suspended solids and various total metals, which were higher than previously measured at the lower *test* station in fall 2013. A classification was not completed for the upper *baseline* station due to a laboratory error resulting in an incomplete set of data; only total and dissolved metals were analyzed for this station in 2013.

Benthic Invertebrate Communities and Sediment Quality Differences in measurement endpoints of benthic invertebrate communities at the lower *test* reach of the Tar River were classified as **Moderate** because abundance, richness, and equitability differed between the *baseline* and *test* periods for this reach. The percentage of EPT taxa was lower in 2013 than it has been since 2006 and diversity decreased from 2012. All measurement endpoints of benthic invertebrate communities were within the historical range of variation for the lower Tar River, with the caveat that there were no mayflies or caddisflies, which were present during the *baseline* period and in most previous sampling years. Differences in sediment quality observed in fall 2013 between the lower *test* station and regional *baseline* conditions were classified as **Moderate**. Concentrations of benz[a]anthracene, benzo[a]pyrene, chrysene, dibenzo(a,h)anthracene, and total arsenic exceeded previously-measured maximum concentrations for the lower *test* station and also exceeded relevant CCME guidelines.

Fish Populations Differences in measurement endpoints for fish assemblages between the lower *test* reach of the Tar River and regional *baseline* conditions were classified as **Negligible-Low** because all measurement endpoints were within the range of regional *baseline* variability and there were no significant trends over time in any of the measurement endpoints.

MacKay River Watershed

Hydrology The 2013 WY water balance was calculated for two different cases: (i) only focal projects in the MacKay River watershed; and (ii) focal projects plus other oil sands developments in the MacKay River watershed. The 2013 WY water balance mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge for the first case were 0.006%, 0.004%, 0.004%, and 0.004% lower, respectively, in the observed *test* hydrograph for the MacKay River than in the estimated *baseline* hydrograph. For the second case these same measurement endpoints were 0.010%, 0.012%, 0.012%, and 0.012% larger, respectively, in the observed *test* hydrograph than in the estimated *baseline* hydrograph. For both cases, these differences were classified as **Negligible-Low**.

Water Quality Concentrations of most water quality measurement endpoints for stations in the MacKay River watershed were within the range of previously-measured concentrations, with the exception of phosphorus, which was higher than previously-measured maximum concentrations at all stations in fall 2013. Water quality measurement endpoints for stations in the MacKay River watershed in fall 2013 were within the range of regional *baseline* concentrations, with the exception of potassium, which was below the 5th percentile at all stations and chloride, which was below the 5th percentile of regional *baseline* concentrations at the middle *test* and upper *baseline* stations of the MacKay River. Differences in water quality in fall 2013 at the lower *test*, middle *test*, and upper *baseline* station relative to regional *baseline* water quality conditions were classified as **Negligible-Low**. Monthly concentrations of most water quality measurement endpoints exhibited fluctuations throughout 2013 at the upper *baseline* station of the MacKay River. Typically, the maximum concentration of total and dissolved metals occurred in April or May. Generally the maximum concentration of ions occurred in May and minimum concentrations occurred in April. The decrease in alkalinity and other ions in spring likely resulted from base-cation dilution by snowmelt and not from consumption of alkalinity by acidic compounds in snow. Despite the

observed changes in ion concentrations, the ionic composition remained relatively stable throughout the year but was slightly less dominated by calcium in winter months

Benthic Invertebrate Communities Differences in measurement endpoints of benthic invertebrate communities at the lower *test* reach of the MacKay River were classified as **Moderate** because equitability has significantly increased over time; percent EPT was significantly lower in 2013 compared to the upper *baseline* reach; and richness was lower than the historical and regional *baseline* variability. It should be noted; however, that there was an increase in the relative proportion of EPT taxa and a decrease in relative worm abundance from 2012 indicating an improvement in taxa composition from 2012 to 2013 at the lower *test* reach. Differences in measurement endpoints of benthic invertebrate communities at the middle *test* reach of the MacKay River were classified as **Negligible-Low** because the significant increase in percent EPT over time was not indicative of a negative change. The benthic invertebrate community at this *test* reach was representative of good overall water quality, with a high proportion of EPT taxa and a low relative abundance of worms.

Fish Populations Differences in measurement endpoints for the fish assemblage at the lower *test* reach of the MacKay River were classified as **High** because four of the five measurement endpoints (catch-per-unit-effort [CPUE], abundance, ATI, and diversity) were near the 5th percentile of regional *baseline* variability; there were significant decreases in diversity and richness over time; and diversity was significantly lower than at the upper *baseline* reach. Differences in measurement endpoints for the fish assemblage at the middle *test* reach of the MacKay River were classified as **Moderate** because abundance was near the 5th percentile of regional *baseline* variability and there were significant decreases in CPUE and abundance of fish over time.

Calumet River Watershed

Hydrology For the 2013 WY, the mean open-water season discharge, annual maximum daily discharge, and open-water minimum daily discharge for the observed *test* hydrograph for the Calumet River were estimated to be 0.3% lower than from the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**.

Water Quality In fall 2013, water quality at the lower *test* station of the Calumet River showed **Negligible-Low** differences from regional *baseline* conditions**,** while the upper *baseline* station showed **Moderate** differences from regional *baseline* conditions. Concentrations of most water quality measurement endpoints were within previously-measured ranges at both stations; however, concentrations of many water quality measurement endpoints were outside the range of regional *baseline* concentrations at the upper *baseline* station in fall 2013 (e.g., major ions). The ionic composition of water at the lower *test* station was consistent with previous years while the ionic composition of water at the upper *baseline* station was less dominated by bicarbonate ions in 2013 than in the previous two sampling years.

Firebag River Watershed

Hydrology The 2013 WY mean winter and open-water period discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.05% lower in the observed *test* hydrograph for the Firebag River than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**.

Water levels recorded at McClelland Lake were generally near the upper quartile and maximum values in the 2013 WY due to rainfall events in mid-June. Lake levels from July to mid-September varied between the historical median and upper quartile values.

Water Quality In fall 2013, water quality at the lower *test* and upper *baseline* stations of the Firebag River showed **Negligible-Low** differences from regional *baseline* water quality conditions. The

ionic composition of water in fall 2013 at both Firebag River stations and McClelland Lake was consistent with previous sampling years. Concentrations of most water quality measurement endpoints at the lower *test* and upper *baseline* stations of the Firebag River were within the range of regional *baseline* concentrations in fall 2013. Concentrations of water quality measurement endpoints from McClelland Lake and Johnson Lake were not compared to regional *baseline* conditions given the ecological differences between lakes and rivers.

Benthic Invertebrate Communities and Sediment Quality Differences in benthic invertebrate communities for the lower *test* reach of the Firebag River were classified as **Negligible-Low** because the significant increase in taxa richness over time and the shift in CA Axis 2 scores due to a decrease in chironomids were not indicative of degradation. Total abundance and equitability were within the range of variability of previous sampling years and the lower *test* reach contained a variety of EPT taxa.

Differences in benthic invertebrate communities of McClelland Lake are classified as **Negligible-Low** because although there were statistically significant changes in some measurement endpoints, these changes were not indicative of negative conditions in the lake. Richness and the percentage of fauna as EPT taxa were significantly higher in 2013 than previous sampling years. The general composition of the benthic invertebrate community in terms of the presence of fully aquatic forms and presence of generally sensitive taxa including the mayfly *Caenis* and six types of caddisflies suggested that the benthic invertebrate community of McClelland Lake was in good condition and generally consistent with *baseline* conditions. The benthic invertebrate community of Johnson Lake had no EPT taxa in fall 2013, which have been observed in previous years; however, given that the number of EPT taxa has been very low in previous years, the absence of these taxa was not considered a negative change in the benthic invertebrate community of Johnson Lake. Worms (Tubifidae and Naididae) had a higher relative abundance in fall 2013 than previous years; however, bivalve clams had the highest abundance of all taxa, indicating that Johnson Lake is generally in fair condition.

Concentrations of sediment quality measurement endpoints at McClelland Lake, the lower *test* station of the Firebag River, and Johnson Lake were generally within the range of previously-measured concentrations in fall 2013. An exception was observed in McClelland Lake, where concentrations of PAHs exceeded previously-measured maximum concentrations and resulted in a higher PAH toxicity index. In fall 2013, sediment toxicity testing showed higher growth rates at all stations for the midge *Chironomus*, and higher growth rates for the amphipod *Hyalella* at McClelland Lake and the lower *test* station of the Firebag River. The sediment quality index value for the lower *test* station of the Firebag River indicated a **Negligible-Low** difference from regional *baseline* conditions.

Ells River Watershed

Hydrology The calculated mean open-water discharge (May to October), mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.10% higher in the observed *test* hydrograph for the Ells River than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**.

Water Quality Differences in water quality in fall 2013 between the Ells River and regional *baseline* fall conditions were classified as **Negligible-Low**. Water quality conditions were consistent with previous years at the lower *test* station of the Ells River and were within the range of previously-measured concentrations and regional *baseline* conditions. The upper b*aseline* station of the Ells River, initiated in 2013, showed similar water quality to the lower *test* station, and was within regional *baseline* conditions in fall 2013.

Benthic Invertebrate Communities and Sediment Quality Differences in measurement endpoints for the benthic invertebrate community at the lower *test* reach of the Ells River were classified as

Moderate because the significant decrease in abundance, EPT taxa, and richness over time were indicative of potentially degrading conditions. Abundance in fall 2013 (48 organisms per sample or about 2,000 individuals/m^2) was the lowest observed at the lower *test* reach, and has previously ranged from 8,000 to 32,000 individuals/m^2. Most of the major groups of larger organisms (e.g., clams, snails, mayflies, caddisflies) that have previously been sparse were absent in 2013 at this reach. All of the smaller and previously abundant organisms remained abundant in 2013. Chironomids were dominated by forms that are not known to be particularly tolerant of degraded water quality. Water velocity at the lower *test* reach in 2013 (0.6 m/s) was higher than previously reported (normally in the 0.05 to 0.2 m/s range), and likely considered to be the explanation for the absence of larger forms of benthic invertebrates at the lower *test* reach in 2013. Flows were generally high in the 2013 open-water season due to significant rain events in June.

Differences in sediment quality observed in fall 2013 between the lower *test* station of the Ells River and regional *baseline* conditions were classified as **Moderate** likely due to high PAH concentrations compared to the regional range of *baseline* variability.

Fish Populations Differences in the fish assemblage in fall 2013 at the lower *test* reach of the Ells River were classified as **Moderate** because although the lower ATI value indicated a greater proportion of sensitive fish species (i.e., burbot, spoonhead sculpin), there were significant decreases in abundance and diversity over time.

Fish Populations (fish tissue) Mercury concentrations in lake whitefish from Namur Lake in 2013 were below any Health Canada consumption guidelines indicating a **Negligible-Low** risk to human health. Mercury concentrations in lake trout from Namur Lake in 2013 were above Health Canada consumption guidelines for subsistence fishers and general consumers indicating a **High** risk to the health of both consumers of lake trout.

Clearwater River Watershed

Hydrology There was no land change or water withdrawals or discharges in the Clearwater River watershed related to focal projects and other oil sands development in 2013. Accordingly, no assessment of current versus *baseline* hydrologic conditions was warranted.

Water Quality In fall 2013, water quality at all stations in the Clearwater River watershed indicated **Negligible-Low** differences from regional *baseline* conditions. Concentrations of most water quality measurement endpoints were within the range of previously-measured concentrations and were within the range of regional *baseline* conditions. All stations showed very similar ionic composition and no trends in measurement endpoints over time, with the exception of a decreasing trend in potassium at the lower *test* station of the Clearwater River. In 2013, there were many water quality guideline exceedances, particularly at the *baseline* station of the High Hills River in spring and summer. Concentrations of many water quality variables fluctuated across months in 2013 at the lower *test* and upper *baseline* stations of the Clearwater River. Despite these fluctuations, the ionic composition at both stations in the Clearwater River remained fairly consistent across the year. Concentrations of many water quality variables (e.g., metals) in May at the upper *baseline* station of the Clearwater River exceeded guidelines and frequently exceeded the regional *baseline* range for fall water quality.

Benthic Invertebrate Communities and Sediment Quality The benthic invertebrate community at the *baseline* reach of the High Hills River contained a high diversity of typical riffle fauna including mayflies, stoneflies, and caddisflies, and a relatively high diversity of chironomids. Historically, this reach contained a high relative abundance of naidid worms (42%), but the percentage of the fauna comprised by naidids in 2013 was considerably lower (19%) than previous years. The *baseline* reach of the High Hills River was used as a regional *baseline* reach for comparisons to *test* reaches in the RAMP FSA. Sediment quality monitoring was not conducted on the High Hills River given it is an erosional river.

Fish Populations (fish inventory) The Clearwater fish inventory is a community-based initiative primarily suited for assessing general trends in population variables such as species richness, abundance, and composition. Coupled with a decrease in total catch, species richness and abundance were relatively low in the Clearwater River watershed in 2013. Compared to 2012, total catch was notably lower in summer and fall, likely due to a decrease in available habitat resulting from lower discharge in the sampling reaches. White sucker and longnose sucker continued to dominate overall species composition while the abundance of goldeye had returned to historical ranges after an increase in catch in summer and fall 2012. The transient increase in goldeye abundance could be related to the warm, calm spring seasons that occurred in 2011 and 2012, that was not observed in 2013.

Following a shift towards a younger dominant age class in 2012, there was an increase in catch of older northern pike in 2013. In addition, significant increases in size-at-age across the last three years indicated that northern pike were larger at age in 2013. Conversely, a dominance of younger size classes continued to persist for walleye. This observation may be reflective of continued fishing pressure on older adult fish in the Clearwater River, causing a shift to a population dominated by younger individuals.

Mean condition factor was relatively similar for the large-bodied Key Indicator Resource (KIR) fish species between *test* and *baseline* reaches in summer and fall 2013; northern pike and walleye showed slight differences, with higher condition at the *test* reach compared to the *baseline* reaches in summer. Historical data indicated considerable increases in condition for both longnose sucker and walleye in 2013. The percentage of external abnormalities increased slightly in 2013 compared to 2012, with the majority of abnormalities observed in white sucker and a higher percentage of abnormalities observed in summer.

Fish Populations (fish assemblages) The fish assemblage at the *baseline* reach of the High Hills River was consistent with other *baseline* erosional reaches. Fish species captured at this reach were consistent with fish assemblages commonly observed in fast-flowing riffle habitat (e.g., slimy sculpin, longnose sucker, longnose dace).

Christina River Watershed

Hydrology The 2013 WY water balance was calculated for two difference cases: (i) only focal projects in the Christina River watershed; and (ii) focal projects plus other oil sands developments in the Christina River watershed. The calculated mean open-water period (May to October) discharge, annual maximum daily discharge, and open-water minimum discharge for the first case were 0.05%, 0.05%, and 0.06% greater, respectively, in the observed *test* hydrograph for the Christina River than in the estimated *baseline* hydrograph and for the second case were 0.05%, 0.06%, and 0.06% greater, respectively, in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low.** The mean winter discharge for both cases was 0.06% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. This difference was classified as **Negligible-Low**.

In the 2013 WY, water levels in Christina Lake generally decreased from November 2012 to mid-April 2013. Lake levels increased during freshet in early May to a freshet peak level of 554.907 masl on May 13, before decreasing until early June. Rainfall events in mid-June increased lake levels beyond the historical maximum levels and peaked at 555.335 masl on June 17. This peak lake level was the maximum daily level recorded in the 2013 WY and was 0.661 m higher than the historical mean annual maximum daily lake level. Lake levels steadily decreased from mid-July until the end of the 2013 WY.

Flows in Jackfish River increased during spring freshet and exceeded the historical maximum on May 13. Flows also increased in response to rainfall events in mid-June, exceeding the historical maximum flows from June 11 to July 21, 2013. The peak flow of 65.2 m^3/s on June 17, was the

highest flow recorded from available data in the 2013 WY, and was 370% higher than the historical mean open-water maximum daily flow. Following this peak, flows sharply decreased until early July, and then increased due to rainfall events in mid-July. Flows generally decreased from mid-July to September, with values generally remaining above the historical median values.

Water Quality In fall 2013, water quality at *test* and *baseline* stations of the Christina River and tributaries of Christina Lake (i.e., Sawbones Creek, Sunday Creek, Unnamed Creek east of Christina Lake, Unnamed Creek south of Christina Lake, and Jackfish River) exhibited **Negligible-Low** differences from regional *baseline* conditions. The upper *baseline* station of the Christina River and the *baseline* station of Birch Creek (tributary of Christina Lake) indicated **Moderate** differences from regional *baseline* water quality conditions given that concentrations of several water quality measurement endpoints (e.g., total metals and nutrients) exceeded relevant guidelines and regional *baseline* conditions in 2013.

Concentrations of most water quality measurement endpoints exhibited fluctuations across months at the lower *test* station of the Christina River. Typically, a higher dominance of calcium and lower dominance of chloride occurred in summer months. The highest number of water quality guideline exceedances occurred in May, June, and July, which were also the months where maximum yearly concentrations were most frequently reached.

Benthic Invertebrate Communities and Sediment Quality Differences in measurement endpoints for benthic invertebrate communities at the *test* reach of the Christina River, upstream of the Jackfish River confluence, were classified as **Negligible-Low** because all measurement endpoints were within the range of variation for regional *baseline* erosional reaches. In addition the benthic fauna at this *test* reach in fall 2013, were representative of good overall water quality, with high taxa richness and percentage of the fauna as EPT taxa. Differences in measurement endpoints at the lower *test* reach of Sunday Creek were classified as **Negligible-Low** because the reach contained a benthic invertebrate community representative of a healthy depositional reach. Flying insects and permanent aquatic forms (snails, fingernail clams) complimented a diverse fauna of chironomids. Low overall abundance of worms suggested favourable water quality conditions in fall 2013 at this *test* reach. Differences in measurement endpoints of benthic invertebrate communities at the *test* reach of Sawbones Creek were classified as **Negligible-Low.** All measurement endpoints, with the exception of richness, were within the range of regional *baseline* conditions for depositional reaches. Richness has been high at this *test* reach in both 2012 and 2013, which was not considered to be a negative change in the benthic invertebrate community. In addition, the benthic invertebrate community of the *test* reach of Sawbones Creek was diverse and supported a community with permanent aquatic forms (snails, fingernail clams) and flying insects, and a low diversity of worms. Differences in measurement endpoints of benthic invertebrate communities at *test* reaches of unnamed creeks to the east and south of Christina Lake were classified as **Negligible-Low** because all measurement endpoints, with the exception of richness and equitability, were within the range of variability for regional *baseline* depositional reaches. Richness was above the range and equitability was just below the range of *baseline* variability in 2013, both of which were indicative of a more diverse community compared to regional *baseline* reaches. The benthic invertebrate communities of both reaches had low total abundance of worms, high diversity of chironomids, and the presence of permanent aquatic forms and flying insects. Differences in measurement endpoints of the benthic invertebrate community of Christina Lake in fall 2013 were classified as **Negligible-Low**, given that the community was relatively similar to 2012 and contained a diverse benthic fauna including several permanent aquatic forms (e.g., clams, snails, amphipods), as well as several large aquatic insects (mayflies, dragonflies and caddisflies). Differences in measurement endpoints of benthic invertebrate communities at the *test* reach of Jackfish River were classified as **Negligible-Low** because the community was highly diverse and the decrease in percent EPT from 2012 was a minor change. All measurement endpoints, with the exception of abundance, were within regional *baseline* ranges. Abundance was higher than the 95th percentile of regional *baseline* reaches.

In fall 2013, concentrations of sediment quality measurement endpoints for depositional stations in the Christina River watershed were generally similar to previous years (where applicable) and were typically within regional *baseline* concentrations. Sediment quality in fall 2013 showed **Negligible-Low** differences at all stations from regional *baseline* conditions. Sediment quality measurement endpoints were not compared to regional *baseline* concentrations at Christina Lake because lakes were not included in the calculation of *baseline* concentrations; however, sediment quality at Christina Lake was similar to conditions observed in 2012.

Fish Populations (fish assemblages) Information on fish assemblages for the southern oil sands region is just beginning to be collected; therefore, a comparison with *baseline* conditions in the northern region was conducted. Differences in measurement endpoints at the *test* reach of the Christina River, upstream of the confluence of Jackfish River, were classified as **Negligible-Low** given that most measurement endpoints were with the range of *baseline* variability and the low ATI value was not indicative of a negative change in the fish assemblage. Differences in measurement endpoints of fish assemblages for *test* reaches on Sunday Creek and Jackfish River (tributaries of Christina Lake) were classified as **Negligible-Low** compared to regional *baseline* conditions, with almost all measurement endpoints within the range of *baseline* variability, and lower ATI values, reflecting a greater proportion of sensitive fish species. Differences in measurement endpoints of fish assemblages for depositional *test* reaches on Sawbones Creek and unnamed creeks east and south of Christina Lake were classified as **High** because almost all measurement endpoints were lower than the range of variability for *baseline* depositional reaches (i.e., CPUE and abundance at all three; in addition to diversity and richness at reaches of Sawbones Creek and Unnamed Creek east of Christina Lake). In addition, only one fish was captured at the *test* reach of Unnamed Creek east of Christina Lake and no fish were captured at the *test* reach of Sawbones Creek. It should be noted that these reaches have a large proportion of deep-water habitat, resulting in poor capture efficiency and spatial coverage. In future years of monitoring, an effort will be made to sample in better fish habitat to assess fish assemblages in these creeks

Fish Populations (fish tissue) Mercury concentrations in lake whitefish from Christina Lake in 2013 were below any Health Canada consumption guidelines indicating a **Negligible-Low** risk to human health. Mercury concentrations in northern pike and walleye from Christina Lake in 2013 were above Health Canada consumption subsistence guidelines indicating a **High** risk to the health of subsistence fishers consuming northern pike and walleye. Given that all northern pike and most walleye exceeded the guideline for subsistence fishers, there was a **Moderate** risk to general consumers of northern pike and walleye, dependent on the quantity of fish consumed. Mercury concentrations in fish from Christina Lake were generally within the historical range of mercury concentrations in fish sampled from other regional lakes.

Hangingstone River Watershed

Hydrology The calculated mean open-water period discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.05% higher in the observed *test* hydrograph for the Hangingstone River than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**.

Water Quality Differences in water quality in fall 2013 between the lower and upper *test* stations of the Hangingstone River and regional *baseline* fall conditions were classified as **High**. Differences were attributed to higher concentrations of ions and dissolved metals in the Hangingstone River, relative the regional *baseline* concentrations. Concentrations for water quality measurement endpoints were generally outside of their historical range (2004 to 2008) for the upper *test* station. Despite higher concentrations of dissolved ions than previously observed, the ionic composition at the upper *test* station in 2013 was similar to previous years.

Pierre River Area

Water Quality Differences in water quality in fall 2013 between the *baseline* stations of Big Creek, Pierre River, and Red Clay Creek and regional *baseline* fall conditions were classified as **Negligible-Low**. Differences in water quality in fall 2013 between the *baseline* station of Eymundson Creek and regional *baseline* fall conditions were classified as **Moderate** as a result of several guideline exceedances and high concentrations of total arsenic, total suspended solids, total mercury (ultra-trace), etc. Eymundson Creek differed from the other stations (Big Creek, Pierre River, and Red Clay Creek) in this area in its ionic composition of water, with a higher concentration of sulphate and less bicarbonate, which may suggest greater groundwater influence at this station. Eymundson Creek also had a higher concentration of total suspended solids than the other stations.

Benthic Invertebrate Communities and Sediment Quality The benthic invertebrate communities at the *baseline* reaches of Big Creek, Eymundson Creek, and Pierre River were typical of sand-bottomed rivers and had a high abundance of chironomids and worms, which are indicative of poor water quality conditions; and a low percentage of EPT taxa. The benthic invertebrate community at the *baseline* reach of Red Clay Creek was indicative of good water quality, with a lower abundance of worms and a high percentage of EPT taxa. The benthic invertebrate community reaches in the Pierre River area were used as regional *baseline* reaches for comparison to *test* reaches of the RAMP FSA. Stations on Big Creek, Eymundson Creek, and the Pierre River had a sediment quality index value indicating **Negligible-Low** differences from regional *baseline* conditions. No concentrations of sediment quality measurement endpoints exceeded sediment or soil quality guidelines at Big Creek, while only total arsenic exceeded the guideline at Eymundson Creek. Pierre River had many guideline exceedances, including CCME F3 hydrocarbons, total arsenic, chrysene, and phenanthrene. Survival of the midge *Chironomus* was fairly low at all stations (ranging from 46% to 64%) and predicted PAH toxicity values exceeded the chronic toxicity threshold at Eymundson Creek and Pierre River. No trend analysis or historical comparisons were possible at these stations because sediment quality sampling was initiated in these locations in fall 2013.

Fish Populations (fish assemblages) The fish assemblages at the *baseline* reaches of Big Creek, Eymundson Creek, Pierre River, and Red Clay Creek were similar to other *baseline* reaches in the area, and with each other. As with other reaches near the confluence to the Athabasca River, there was a high proportion of juvenile burbot captured at these reaches in fall 2013. Burbot is a sensitive species and likely contributed to the low ATI values at all of these reaches, which were near the 5th percentile of regional *baseline* conditions.

Miscellaneous Aquatic Systems

Isadore's Lake and Mills Creek The estimated cumulative effect of oil sands development in the 2013 WY was a loss of flow of 1.63 million m^3 to Mills Creek. The calculated mean open-water discharge, minimum daily discharge, annual maximum daily discharge, and mean winter discharge were 56.5% lower in the observed *test* hydrograph for Mills Creek than in the estimated *baseline* hydrograph. These differences were classified as **High**.

In the 2013 WY, lake levels of Isadore's Lake decreased from November to December 2012 and remained near historical minimum values until mid-March 2013. Lake levels exceeded the historical maximum lake levels from May 1 to May 8. Following this peak, lake levels decreased sharply until the lowest open-water lake level of 233.674 masl on June 4. Rainfall events in early to mid-June increased lake levels to above historical values by June 13, and remained between the historical upper quartile and maximum values until mid-October 2013.

Differences in water quality in fall 2013 between Mills Creek and regional *baseline* fall conditions were classified as **High**, due to relatively high concentrations of many ions and dissolved species

that exceeded the 95th percentile of regional *baseline* concentrations. The ionic composition of water in Isadore's Lake and Mills Creek showed many similarities, supporting the idea that historical changes in water quality at Isadore's Lake may have occurred as a result of receiving water from Mills Creek.

Differences in measurement endpoints of the benthic invertebrate community of Isadore's Lake were classified **Negligible-Low** because the significant increases in richness and percent EPT were indicative of positive changes in the lake. The percentage of the fauna as EPT taxa has always been <1% (normally EPT are absent); however, in 2013, EPT taxa accounted for 3% of the benthic community. CA Axis 1 and 2 scores were higher in 2013; however, this was due to a minor shift in taxa composition. All measurement endpoints were within historical variability for the lake. Isadore's Lake, historically, has had low diversity and a high abundance of nematodes making it unique compared to other lakes monitored by RAMP. In 2013, the relative abundance of nematodes was still high; however, other aspects of the benthic invertebrate community such as the percentage of the fauna as EPT taxa and richness have increased making the lake more consistent to other RAMP lakes. Sediment quality measurement endpoints were generally within the range of previously-measured concentrations at Isadore's Lake, with the exception of PAHs, which exceeded previously-measured concentrations except when normalized to 1% TOC. Concentrations of total arsenic, CCME F3 hydrocarbons, and dibenz(a,h)anthracene exceeded sediment/soil quality guidelines in fall 2013. An SQI was not calculated for Isadore's Lake because lakes were not included in regional *baseline* conditions given ecological differences between lakes and rivers.

Shipyard Lake Concentrations of most water quality measurement endpoints in fall 2013 at the *test* station of Shipyard Lake were within previously-measured concentrations, with the exception of some ions and metals. The ionic composition of water at Shipyard Lake continued to exhibit an increase in concentrations of sodium and chloride relative to historical concentrations, perhaps due to reduced surface-water inflow and increased groundwater influence in the lake associated with focal projects in the upper portion of the watershed (90% of the Shipyard Lake watershed has been disturbed). The WQI was not calculated for lakes in 2013 due to potential ecological differences in regional water quality characteristics between lakes and rivers.

Differences in measurement endpoints for benthic invertebrate communities in Shipyard Lake in 2013 were classified as **Negligible-Low**. The significant increases in abundance and taxa richness were strong and implied that the observed changes were not caused by degradation of water or habitat quality. The lake contained a number of fully aquatic forms including amphipods, clams and snails, indicating generally good water and sediment quality. In fall 2013, most sediment quality measurement endpoints were within the range of previously-measured concentrations at Shipyard Lake. Concentrations of total arsenic, F3 hydrocarbons, and several PAHs (benz[a]anthracene, benz[a]pyrene, chrysene, dibenz(a,h)anthracene, and phenanthrene) exceeded sediment quality guidelines. Increasing trends were apparent for total alkylated PAHs, and F3 and F4 hydrocarbons. Shipyard Lake was not compared to regional *baseline* conditions due to ecological differences between lakes and rivers.

Poplar Creek and Beaver River The calculated mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 247.8%, 77.0%, 18.6%, and 27.6% higher, respectively, in the observed *test* hydrograph for Poplar Creek than in the estimated *baseline* hydrograph. These differences were classified as **High**.

Concentrations of several water quality measurement endpoints, primarily ions, exceeded regional *baseline* concentrations at the lower *test* station of the Beaver River, resulting in a **Moderate** difference from regional *baseline* conditions. Although concentrations of several measurement endpoints were high at the lower *test* station of Poplar Creek and the upper *baseline* station of

Beaver River, differences in water quality in fall 2013 between the lower *test* station of Poplar Creek, the upper *baseline* station of Beaver River and regional *baseline* conditions were classified as **Negligible-Low**. Monthly concentrations of most water quality measurement endpoints exhibited some variability throughout the year at the lower *test* station of Poplar Creek, which were more apparent in the ionic composition of water and showed seasonal variability. Generally the highest concentrations of ions and metals occurred in December. Guideline exceedances occurred most frequently in April, May, and July; however, most monthly concentrations of water quality measurement endpoints were within the range of the regional *baseline* fall conditions.

Differences in measurement endpoints of the benthic invertebrate community at the lower *test* reach of Poplar Creek were classified as **Moderate** because of the significant and large differences in abundance, equitability, percentage of fauna as EPT taxa, and CA axis scores compared to the upper *baseline* reach of the Beaver River. Richness and abundance have been decreasing since 2001 at the lower *test* reach of Poplar Creek and EPT taxa, which were increasing until 2012 have decreased in 2013. The lower equitability, which was below the 5th percentile of regional *baseline* conditions, did not denote a negative change, but suggested that the lower *test* reach of Poplar Creek was becoming more diverse. The benthic invertebrate community at the lower *test* reach of Poplar Creek was typical of a sand-bottom creek and dominated by worms and chironomids. Differences in sediment quality observed in fall 2013 between the lower *test* station of Poplar Creek, the upper *baseline* station of Beaver River and regional *baseline* conditions were classified as **Negligible-Low** with nearly all sediment quality measurement endpoints falling within the range of previously-measured concentrations. Some sediment and soil quality guidelines were exceeded at the lower *test* station of Poplar Creek, including chrysene and F3 hydrocarbons.

Differences in measurement endpoints of the fish assemblage at the lower *test* reach of Poplar Creek were classified as **Negligible-Low** because the significant increases in richness, diversity, and CPUE were not indicative of a negative change in the fish assemblage. In addition, the lower ATI value and the higher diversity compared to the range of regional *baseline* variability indicated that the fish assemblage had a greater number of species and a greater proportion of more sensitive species (e.g., burbot).

McLean Creek Concentrations of water quality measurement endpoints at the *test* station of McLean Creek were generally within regional *baseline* concentrations, and within the range of previously-measured concentrations in fall 2013. The Water Quality Index value indicated **Negligible-Low** differences between the lower *test* station and regional *baseline* concentrations. Despite generally being with within regional *baseline* variability, fall concentrations of total dissolved solids and several ions have shown consistent increases since 2009.

Fort Creek The 2013 WY mean open-water period (May to October) discharge, annual maximum daily discharge, and open-water minimum daily discharge were 16.6% lower in the observed *test* hydrograph for Fort Creek than in the estimated *baseline* hydrograph. These differences were classified as **High**. The difference in measurement endpoint values between the 2013 WY and previous years was due to the updated watershed areas and changes in land disturbance from focal project activities. In addition to changes in flow volume, variability in daily flow has also increased due to focal project activity in the watershed.

Differences in water quality in fall 2013 between the lower *test* station of Fort Creek and regional *baseline* conditions were classified as **Moderate**. Relatively high concentrations of several water quality measurement endpoints, primarily ions, were observed in fall 2013. Many of these measurement endpoints were outside of the range of previously-measured concentrations and contributed to the lower WQI value observed in 2013.

Differences in measurement endpoints of benthic invertebrate communities at the lower *test* reach of Fort Creek were classified as **Negligible-Low** because the higher richness and CA Axis 2 scores

in 2013 compared to previous years were not indicative of degradation and abundance, and diversity (i.e., equitability) have been increasing over the last three years, and the number of EPT taxa was generally higher in more recent years compared to the *baseline* period. The increase in CA Axis 2 scores reflected higher relative abundances of mayflies and caddisflies, which was also consistent with improving conditions. Differences in sediment quality observed in fall 2013 between the lower *test* station of Fort Creek and regional *baseline* conditions were **Negligible-Low** with nearly all sediment quality measurement endpoints within the range of previously-measured concentrations.

Differences in measurement endpoints of the fish assemblage at the lower *test* reach of Fort Creek were classified as **Moderate** because there was a significant decrease in abundance, which could be indicative of a potential negative change in the fish assemblage. There were also decreases, although not statistically significant, in CPUE, richness, and diversity. The ATI value was lower than the regional range of *baseline* variability; however, which indicated a greater proportion of sensitive fish species in 2013 compared to previous years.

Acid-Sensitive Lakes

Results of the analysis of the RAMP lakes in 2013 compared to historical data suggested that there were no significant changes in the overall water chemistry of the lakes across years that were attributable to acidification. Significant increases in pH, Gran alkalinity, TDS, conductivity, and selected base cations were observed; however, these changes appeared to be the result of factors other than acidifying emissions (e.g., hydrology). Concentrations of nitrates appeared to be unusually variable both between lakes and between years within individual lakes.

A summary of the state of the RAMP lakes in 2013, with respect to the potential for acidification, was prepared for each physiographic subregion by examining deviations from the mean concentrations of the measurement endpoints (in a direction indicative of acidification) for each lake within a subregion. A two standard deviation (2SD) criterion was used in each case. In general, there was a greater number of exceedances of the 2SD criterion in 2013 than in 2011 and 2012. The highest number of exceedances (6) occurred in lakes in the Northeast of Fort McMurray subregion. Four of these exceedances were attributed to high concentrations of dissolved aluminum, which exceeded the 2SD criterion in two lakes in the Stony Mountain subregion and two lakes in the Birch Mountain subregion. The reasons for the high concentrations of aluminum in 2013 are unknown, although they are likely related to hydrologic changes. Exceedances were also observed in base cation concentrations in two lakes (one in the Caribou Mountains subregion and one in the West of Fort McMurray subregion), which were also likely due to factors other than acidification. Taking into account these factors, five of the subregions were classified as having a **Negligible-Low** indication of incipient acidification while the Northeast of Fort McMurray subregion was classified as having a **Moderate** indication of incipient acidification due to relatively high concentrations of nitrates in one lake.

Summary and Recommendations

The following table provides a summary of the 2013 RAMP monitoring program results, by watershed and component.

The report concluded with a number of recommendations directed towards refining the monitoring program and increasing the value of regional monitoring activities for oil sands development. These recommendations are for consideration during the design of monitoring in future years under the JOSMP:

- Continue to monitor existing climate and hydrometric stations to enhance record length and data availability.

- Expand the climate and hydrology monitoring network to support the provision of *baseline* and *test* hydrometric information and regional climate data.
- Consider the incorporation of groundwater interaction to the surface water analysis for a more harmonized analysis of the hydrologic impacts of oil sands development.
- Consider maintaining water quality stations in smaller watersheds in the design of the JOSMP to continue to monitor observed localized changes.
- Continue to expand monthly water quality sampling in larger tributaries, to better capture the range of conditions in these locations and allow better discrimination of natural versus anthropogenic changes in water quality.
- Consider the addition of deep-water benthic sampling in lakes in which a thermocline has had an opportunity to develop. Such sampling would ensure that any changes in deep-water habitats are detected, if they occur.
- Maintain consistent sampling depths of benthic invertebrate communities in each reach, lake, or channel, to the extent feasible from year to year, recognizing that there are natural variations in depths and flows from year to year in many of the habitats.
- Consider the use of sediment traps in some channels of the delta (especially Fletcher Channel), to estimate sediment deposition rates and also to specifically assess concentrations of hydrocarbons and metal in sediments deposited in the ARD in a given year.
- Continue to collaborate with Environment Canada and AESRD on lethal fish sampling in rivers and lakes in the region to minimize potential impacts on fish populations related to monitoring activities.
- Continue to work with AESRD and Environment Canada on fish monitoring activities to further harmonize fishing methods and data collection, which will eventually result in more efficient sampling in the region and increased data and information sharing to meet the objectives of all stakeholder needs.

Summary assessment of RAMP 2013 monitoring results.

Watershed/Region	Differences Between *Test* and *Baseline* Conditions						Fish Populations: Human Health Risk from Mercury in Fish Tissue[7]			Acid-Sensitive Lakes: Variation from Long-Term Average Potential for Acidification[8]
	Hydrology[1]	Water Quality[2]	Benthic Invertebrate Communities[3]	Sediment Quality[4]	Fish Assemblages[5]	Sentinel Fish Species[6]	Species	Subs. Fishers	General Cons.	
Athabasca River	○	○	-	-	-	○		-		-
Athabasca River Delta	-	-	○/●	○	n/a	-		-		-
Muskeg River	●	○	○	○	●/●	-		-		-
Jackpine Creek	nm	○	○	○	●	-		-		-
Kearl Lake	nm	○	○	n/a	-	-		-		-
Steepbank River	○	○	●	-	●	-		-		-
Tar River	●	●	●	●	○	-		-		-
MacKay River	○	○	●/○	-	●/●	-		-		-
Calumet River	○	○/●	nm	nm	nm	-		-		-
Firebag River	○	○	○	○	○	-		-		-
McClelland Lake	nm	n/a	○	n/a	-	-		-		-
Johnson Lake	-	n/a	n/a	n/a	-	-		-		-
Ells River	○	○	●	●	●	-		-		-
Namur Lake	-	-	-	-	-	-	LKWH LKTR	○ ●	○ ●	
Clearwater River	nm	○	nm	nm	-	-		-		-
High Hills River	-	○	n/a	-	n/a	-		-		-
Christina River	○	○/●	●/○	○	-	-		-		-
Christina Lake	nm	n/a	○	n/a	n/a	-	LKWH NRPK WALL	○ ● ●	○ ● ●	-
Jackfish River	nm	○	○	○	○	-		-		-
Sawbones Creek	nm	○	○	○	●	-		-		-
Sunday Creek	nm	○	○	○	●	-		-		-
Birch Creek	nm	●	n/a	○	n/a	-		-		-
Unnamed Creeks (east and south of Christina Lake)	nm	○	○	○	○/●	-		-		-
Hangingstone River	○	●	-	-	-	-		-		-
Fort Creek	●	●	○	○	●	-		-		-
Beaver River	-	●	-	-	-	-		-		-
McLean Creek	-	○	-	-	-	-		-		-
Mills Creek	●	●	-	-	-	-		-		-
Isadore's Lake	nm	n/a	○	n/a	-	-		-		-
Poplar Creek	●	○	●	○	○	-		-		-
Shipyard Lake	-	n/a	○	n/a	-	-		-		-
Big Creek	-	○	n/a	○	n/a	-		-		-
Pierre River	-	○	n/a	○	n/a	-		-		-
Red Clay Creek	-	○	n/a	○	n/a	-		-		-
Eymundson Creek	-	●	n/a	○	n/a	-		-		-
Stony Mountains	-	-	-	-	-	-		-		○
West of Fort McMurray	-	-	-	-	-	-		-		○
Northeast of Fort McMurray	-	-	-	-	-	-		-		●
Birch Mountains	-	-	-	-	-	-		-		○
Canadian Shield	-	-	-	-	-	--		-		○
Caribou Mountains	-	-	-	-	-	-		-		○

Legend and Notes

○ Negligible-Low change

● Moderate change

● High change

"-" program was not completed in 2013.

nm - not measured in 2013.

n/a - classification could not be completed because there were no *baseline* conditions to compare against or reach was sampled to add to the regional baseline dataset.

[1] **Hydrology:** Calculated on differences between observed *test* and estimated *baseline* hydrographs: ± 5% - Negligible-Low; ± 15% - Moderate; > 15% - High.

Note: As not all hydrology measurement endpoints are calculated for each watershed because of differing lengths of the hydrographic record for the 2013 WY, hydrology results above were for those measurement endpoints that were calculated.

Note: Mean Open-Water Season Discharge and Annual Maximum Daily Discharge in the Muskeg River watershed were assessed as Moderate; Mean Winter Discharge was assessed as Negligible-Low, and Minimum Open-Water Season Discharge was assessed as High.

[2] **Water Quality:** Classification based on adaptation of CCME water quality index.

[3] **Benthic Invertebrate Communities:** Classification based on statistical differences in measurement endpoints between *baseline* and *test* reaches or between *baseline* and *test* periods or trends over time for a reach as well as comparison to regional *baseline* conditions.

Note: Benthic invertebrate communities in the Athabasca River Delta were assessed as Negligible-Low at Goose Island Channel and Big Point Channel and Moderate at Embarras River and Fletcher Channel.

Note: Benthic invertebrate communities at the lower reach of the MacKay River were assessed as Moderate and benthic invertebrate communities at the middle reach was assessed as Negligible-Low.

[4] **Sediment Quality:** Classification based on adaptation of CCME sediment quality index.

[5] **Fish Populations (fish assemblages):** Classification based on exceedances of measurement from the regional variation in *baseline* reaches; see Section 3.2.4.4 for a detailed description of the classification methodology.

Note: Fish assemblages in the Muskeg River were assessed as Moderate at the lower and middles reaches and High at the upper reach.

Note: Fish assemblages in the MacKay River were assessed as High at the lower reach and Moderate at the middle reach.

[6] **Fish Populations (sentinel species):** Classification based on effects criteria established for Environment Canada's Environmental Effects Monitoring Program for pulpmills (Environment Canada 2010); see Section 3.2.4.3 for a description of the classification methodology.

[7] **Fish Populations (human health):** Uses Health Canada criteria for risks to human health. LKTR – lake trout; LKWH – lake whitefish; NRPK – northern pike; WALL – walleye; Sub. refers to subsistence fishers; Gen. refers to general consumers as defined by Health Canada (see Section 3.2.4.2).

[8] **Acid-Sensitive Lakes:** Classification based the frequency in each region with which values of seven measurement endpoints in 2013 were more than twice the standard deviation from their long-term mean in each lake.