RAMP
Regional Aquatics Monitoring Program




2010 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 can be identified and assessed. In 2010, RAMP was funded by Suncor Energy Inc., Syncrude Canada Ltd., Shell Canada Energy, Canadian Natural Resources Limited, Imperial Oil Resources, Nexen Inc., Husky Energy, Total E&P Canada Ltd., MEG Energy Corp., Dover Operating Corp., ConocoPhillips Canada, Devon Energy Corp., and Hammerstone Corporation. Non-funding participants included municipal, provincial and federal government agencies and one First Nations group.

The Regional Municipality of Wood Buffalo in northeastern Alberta is the RAMP Regional Study Area (RSA). 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-Christina rivers, Hangingstone River, Steepbank River, Muskeg River, MacKay River, Ells River, Tar River, Calumet River, and Firebag River;
- Select minor tributaries of the lower Athabasca River (McLean Creek, Mills Creek, Beaver River, Poplar Creek, and Fort Creek);
- 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 of 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 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 2010 Technical Report to define those projects owned and operated by the 2010 industry members of RAMP listed above which were under construction or operational in 2010 in the RAMP FSA. For 2010, these projects included a number of oil sands projects and a limestone quarry project.

2010 RAMP industry members do have other projects in the RAMP FSA that were in the application stage as of 2010, or had received approval in 2010 or earlier, but construction had not yet started as of 2010. These projects are noted throughout this technical report, but are not designated as focal projects, as these projects in 2010 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 2010 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, AENV and CCME water quality and sediment quality guidelines, generally-accepted EEM effects criteria) for determining whether or not a change in the measurement endpoints has occurred and is significant with respect to the health and integrity of valued environmental resources.

The RAMP 2010 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 2010) or were (prior to 2010) 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 2010 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 2010, it is estimated that approximately 88,000 ha 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 2010 varies from less than 1% for many watersheds (MacKay, Ells, Christina, Hangingstone, Horse, and Firebag rivers), to 1% to 5% for the Calumet, Poplar and Steepbank watersheds, to 5% to 10% for the Upper Beaver watershed, to more than 10% for the Muskeg River, Fort Creek, Mills Creek, Tar River, Shipyard Lake, and McLean Creek watersheds, as well as the smaller Athabasca River tributaries from Fort McMurray to the confluence of the Firebag River.

ASSESSMENT OF 2010 MONITORING RESULTS

A tabular summary of the 2010 results by watershed and component is presented at the end of this Executive Summary.

Lower Athabasca River and Athabasca River Delta

Hydrology The mean open-water period (May to October) discharge, open-water minimum daily discharge, annual maximum daily discharge, and mean winter discharge at RAMP Station S24, Athabasca River below Eymundson Creek, calculated from the observed *test* hydrograph at are 0.6%, 1.7%, 0.4% and 0.8% lower, respectively, than from the estimated *baseline* hydrograph. These differences are all classified as **Negligible-Low**.

Water Quality Differences in water quality in fall 2010 between most *test* and *baseline* stations in the Athabasca River and regional *baseline* conditions were **Negligible-Low** with the exception of the *baseline* station at Donald Creek on the east bank of the Athabasca River, which showed **Moderate** differences from regional *baseline* conditions. Concentrations of water quality measurement endpoints at *test* stations were generally similar to those at the upstream *baseline* stations and consistent with regional *baseline* conditions. Concentrations of total mercury exceeded the AENV chronic guideline at all stations and showed a general decrease from upstream to downstream on the Athabasca River; total aluminum, total nitrogen, chloride, total arsenic, and other metals also exhibited a similar longitudinal trends. Concentrations of these measurement endpoints were also generally higher along the east bank of the river, suggesting an influence of the Clearwater River on water quality. The ionic composition of water at all water quality monitoring stations in the Athabasca River mainstem in fall 2010 was consistent with previous sampling years.

Benthic Invertebrate Communities and Sediment Quality Benthic invertebrate communities were monitored at four locations in the Athabasca River Delta (ARD) in fall 2010:

1. Differences in the benthic invertebrate communities in Big Point Channel in fall 2010 from historical conditions are classified as **Negligible-Low** because there were no significant time trends in any measurement endpoints at this reach and values of all measurement endpoints were within historical conditions for the ARD reaches and within previously-measured values for this reach.

2. Differences in the benthic invertebrate communities in Fletcher Channel in fall 2010 from historical conditions are classified as **High** because there have been significant decreases over time in diversity, evenness, and percent EPT (i.e., percent of the benthic invertebrate community comprised of Ephemeroptera, Plecoptera, and Tricoptera, three types of benthic invertebrates that are sensitive to change in their environmental conditions). A significant increase in total abundance is potentially indicative of an increase in available nutrients.

3. Differences in the benthic invertebrate communities in Goose Island Channel in fall 2010 are classified as **Negligible-Low** because there were no significant time trends in any measurement endpoint. Values of all measurement endpoints were within historical conditions for the ARD reaches and within previously-measured values for this reach with the exception of taxa richness, which was lower in 2010 than previous years.

4. The benthic invertebrate community in the Embarras River in 2010 was significantly different in richness, diversity and evenness from the benthic invertebrate communities of the other ARD reaches. The relatively high abundance of mayflies and caddisflies in the Embarras River indicates that the community is robust and healthy. Differences in measurement endpoints for benthic invertebrate communities in the Embarras River are classified as **Negligible-Low** because the measured differences did not imply a negative difference between the benthic invertebrate community from the Embarras River and historical conditions for the other ARD reaches.

Concentrations of sediment quality measurement endpoints at all five stations in the ARD were similar to previously-measured concentrations with generally low hydrocarbon, metals and PAH concentrations. However, since the beginning of RAMP sampling in 1999, an increase in concentrations of total PAHs has been observed in Big Point Channel, although this trend is not evident in concentrations of carbon-normalized total PAHs. Percent of total organic carbon has increased in Fletcher Channel likely related to the increasing proportion of fines in sediments over time, first observed in 2007 and could be indicative of decreasing water flow in this small channel. The PAH Hazard Index was historically high in Fletcher Channel and the Embarras River and above the potential chronic toxicity threshold value of 1.0. Increased Hazard Index (HI) values at these stations were related to low concentrations of total hydrocarbons rather than high concentrations of total PAHs. The increase in HI values suggests greater bioavailability of PAHs in sediments. Acute and chronic toxicity data for these sediments were inconclusive with historically low survival but historically high growth of *Hyalella* and high survival but low growth of *Chironomus* in Fletcher Channel.

Fish Populations (fish inventory) The Athabasca River fish inventory is generally considered to be a community-driven activity, primarily suited for assessing generally trends in abundance and population variables for large-bodied species, rather than detailed community structure. A shift in species dominance from white sucker to walleye was observed in spring, from goldeye to northern pike in summer, and from walleye to goldeye in fall, although lake whitefish dominates the catch in fall.

As of 2010, current and historical fish inventory data from the Athabasca River indicated species-specific variability in relative abundance, length-frequency distributions, and condition of fish among years. Statistically significant differences were observed among years for condition for some of the large-bodied Key Indicator Resource (KIR) species. However, the variability in this measurement endpoint among years does not indicate consistent negative or positive changes in the fish populations and likely reflects natural variability over time.

The fish health assessment has indicated that abnormalities observed in 2010 in all species were within the historical range and consistent with historical studies done in the upper Athabasca River, ARD, and Peace and Slave rivers.

Fish Populations (sentinel species) As outlined in RAMP (2009b), the Athabasca River sentinel species program was developed to evaluate spatial differences in measurement endpoints between *baseline* and *test* sites. In addition, results from the 2010 study can be compared to past sentinel programs to assess possible trends over time. Based on the differences in measurement endpoints in trout-perch, the following assessments were made:

- Female trout-perch at the *test* site upstream of the Muskeg River and male and female trout-perch at the *test* site downstream of the Muskeg River indicated a **Negligible-Low** difference from the upstream *baseline* site because none of the measurement endpoints exceeded the effects criteria;

- Male trout-perch at the *test* site upstream of the Muskeg River indicated a **Moderate** difference from the upstream *baseline* site because weight-at-age exceeded the effects criteria;

- Male trout-perch at the *test* site downstream of the Firebag River indicated a **Moderate** difference from upstream *baseline* site because weight-at-age exceeded the effects criteria; and

- Female trout-perch at the *test* site downstream of the Firebag River indicated a **Moderate** difference from the upstream *baseline* site because weight-at-age, GSI and condition exceeded the effects criteria; however, this response was not observed in previous sentinel programs.

Generally, there is little evidence to suggest that characteristics of trout-perch populations between sites and across years on the Athabasca River have changed due to increasing activities from the focal projects and other oil sands developments given that trout-perch from sites closer to intense oil sands activity do not show substantial differences from *baseline* fish, suggesting that female trout-perch at the *test* site downstream of the Firebag River are responding to localized conditions unrelated to oil sands development.

Muskeg River Watershed

Hydrology The calculated mean open-water discharge and the annual maximum daily flow at WSC Station 07DA008 (RAMP Station S7, lower Muskeg River) are 1.7% and 3.0% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph for the station, respectively. These differences are classified as **Negligible-Low** The calculated mean winter discharge and the open-water period minimum daily discharge are 52.1% and 64.1% higher in the observed *test* hydrograph at WSC Station 07DA008 (RAMP Station S7) than in the estimated *baseline* hydrograph, respectively. These differences are classified as **High**.

Water Quality Differences in water quality in fall 2010 at all stations in the Muskeg River watershed compared to regional *baseline* water quality conditions are classified as **Negligible-Low.** While concentrations of a number of water quality measurement endpoints in the Muskeg River watershed in fall 2010 were outside the range of previously-measured minimum and maximum concentrations, including total mercury, total nitrogen and total aluminum, water quality at most stations in the Muskeg River watershed were generally consistent with regional *baseline* conditions.

Benthic Invertebrate Communities and Sediment Quality Benthic invertebrate communities were monitored at five *test* reaches in the Muskeg River watershed in fall 2010:

1. Differences in the benthic invertebrate community at the lower *test* reach of the Muskeg River as of fall 2010 are classified as **Negligible-Low** because values of all measurement endpoints for benthic invertebrate communities in fall 2010 were within the range of regional *baseline* erosional reaches. There was, however, a significant trend in CA Axis 1 scores over time reflecting a modest increase in percent of the fauna as tubificid worms and decrease in the percent of the fauna as chironomids, mayflies, stoneflies and caddisflies.

2. Differences in the benthic invertebrate community at the middle *test* reach of the Muskeg River as of fall 2010 are classified as **Negligible-Low** because, although there was a

significant decrease in total abundance over time, the statistical signal explained less than 20% of the variation in annual means. In addition, all measurement endpoints for benthic invertebrate communities in fall 2010 were within the range of regional *baseline* depositional reaches with the exception of taxa richness, which exceeded the range of regional *baseline* conditions, implying an improvement in the benthic invertebrate community at the middle *test* reach.

3. Differences in the benthic invertebrate community at the upper *test* reach of the Muskeg River as of fall 2010 are classified as **Moderate** because taxa richness was significantly lower in the period when this reach was *test* compared to the *baseline* period. There was also a significant decrease in CA Axis 1 scores over time in the *test* period, reflecting a shift to higher relative abundance of chironomids and bivalves at this reach over time.

4. Differences in the benthic invertebrate community at the lower *test* reach of Jackpine Creek as of fall 2010 are classified as **Negligible-Low** because there have been no significant changes over time in measurement endpoints for benthic invertebrate community that would imply negative trends in benthic invertebrate community conditions, and values of all measurement endpoints in fall 2010 were within the range of values for regional *baseline* conditions.

5. Differences in the benthic invertebrate community in Kearl Lake as of fall 2010 are classified as **Moderate** compared to historical years because there has been a significant decrease in the percent EPT in the period that Kearl Lake has been designated as *test*.

Sediment quality at all five Muskeg River watershed stations sampled in fall 2010 was generally consistent with that of previous years and regional *baseline* conditions with the exception of predicted PAH toxicity, which was higher than historical values at several stations, particularly the middle *test* station of the Muskeg River. Concentrations of total PAHs at these stations were within previously-measured concentrations. Differences in sediment quality in fall 2010 at all five stations in the Muskeg River watershed were assessed as **Negligible-Low** compared to regional *baseline* conditions.

Steepbank River Watershed

Hydrology The calculated mean open-wa*ter* discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge at WSC Station 070A006 (RAMP Station S38, lower Steepbank River) are 0.28% greater in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences are classified as **Negligible-Low.**

Water Quality Differences in water quality in fall 2010 at all four water quality monitoring stations in the Steepbank River watershed compared to regional *baseline* water quality conditions are assessed as **Negligible-Low**. While concentrations of a number of water quality measurement endpoints in the Steepbank River watershed in fall 2010 were outside the range of previously-measured values, water quality conditions at stations in the Steepbank River watershed in fall 2010 were generally consistent with regional *baseline* fall conditions. The ionic composition at all water quality monitoring stations in the Steepbank River watershed in fall 2010 was consistent with previous years.

Benthic Invertebrate Communities The values of measurement endpoints of the benthic invertebrate community at the lower *test* reach of the Steepbank River have remained generally stable across time and consistent to those for the upper *baseline* reach, with a presence of fauna typically associated with a robust healthy community including a high relative abundance of EPT taxa. The differences in abundance and richness in the lower *test* reach of the Steepbank River indicate a **Moderate** difference from the upper *baseline* reach because the statistical signal in time trends between the two reaches was strong, explaining more than 20% of the variance. Lower

abundance and richness compared to the median *baseline* conditions have been evident since 2000 but are not significant. There were no exceedances of values of measurement endpoints outside of the range of *baseline* conditions.

Tar River Watershed

Hydrology The calculated mean open-water period discharge, annual maximum daily discharge, and open-water minimum daily discharge for the Tar River near the mouth (RAMP Station S15A) are 19.1% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences are classified as **High**.

Water Quality Differences in water quality observed in fall 2010 between the Tar River and regional *baseline* fall conditions were **Negligible-Low,** which is verified by the continued improvement in water quality conditions at the lower *test* station on the Tar River since 2008 when water quality was assessed as being measurably different from regional *baseline* conditions. Most water quality measurement endpoints at the lower *test* station in fall 2010 were within the range of previously-measured concentrations and were consistent with regional *baseline* concentrations.

Benthic Invertebrate Communities and Sediment Quality Differences in the benthic invertebrate community at the lower *test* reach of the Tar River as of fall 2010 are classified as **Moderate** because there were significant differences in total abundance, taxa richness, diversity and evenness from before to after the reach was designated as *test.* Values of measurement endpoints for benthic invertebrate communities in fall 2010 at the lower *test* reach were within the range of regional *baseline* conditions for depositional reaches. Differences in sediment quality observed in fall 2010 between the lower *test* station of the Tar River and regional *baseline* conditions were **Negligible-Low**. Concentrations of sediment quality measurement endpoints were within historical ranges in fall 2010, including total PAHs and predicted PAH toxicity, although the concentration of carbon-normalized PAH in fall 2010 represented a historical maximum concentration for the lower *test* station.

MacKay River Watershed

Hydrology The 2010 mean winter and open-water period discharge, annual maximum daily discharge, and open-water minimum daily discharge at WSC Station 07DB001 (RAMP Station S26, lower MacKay River) calculated from the observed *test* hydrograph are 0.03% lower than from the estimated *baseline* hydrograph; these differences are classified as **Negligible-Low**.

Water Quality Differences in water quality in fall 2010 at both *test* and *baseline* stations in the MacKay River watershed relative to regional *baseline* water quality conditions were assessed as **Negligible-Low**. Concentrations of several water quality measurement endpoints in the MacKay River watershed in fall 2010 were outside the range of previously-measured concentrations, possibly due to water levels and flows that were greater than typical conditions. Water quality was generally consistent with regional *baseline* conditions and the ionic composition of water at both stations in fall 2010 was consistent with previous years and continued to show little year-to-year variation.

Benthic Invertebrate Communities Differences in measurement endpoints for benthic invertebrate communities at the lower *test* reach of the MacKay River are classified as **Negligible-Low** because, although there were significant decreases in abundance and richness in the *test* period compared to the *baseline* period and a decrease in abundance during the *test* period, the statistical signal in the differences over time explained less than 10% of the variance in total abundance and richness. Differences in the benthic invertebrate community at the middle *test* reach of the MacKay River as of fall 2010 are classified as **Moderate** because there was a significant decrease in total abundance over time in the *test* period, explaining more than 20% of the variation in annual mean abundance.

Calumet River Watershed

Hydrology For the 2010 WY, the mean open-water period discharge, annual maximum daily discharge, and open-water minimum daily discharge for RAMP Station S16A, lower Calumet River, are estimated to be 1.0% lower than the corresponding values from the estimated *baseline* hydrograph; these differences are classified as **Negligible-Low**.

Water Quality In fall 2010, water quality at the lower *test* station and upper *baseline* station of the Calumet River showed **Negligible-Low** differences from regional *baseline* conditions. Concentrations of most water quality measurement endpoints in the Calumet River in fall 2010 were within the range of previously-measured concentrations and were consistent with regional *baseline* conditions. 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 had lower relative bicarbonate concentrations relative to previous years.

Firebag River Watershed

Hydrology The calculated mean open-water period discharge, annual maximum daily discharge, and open-water minimum daily discharge at WSC Station 07DC001 (RAMP Station S27, lower Firebag River) are 0.09% greater in the observed *test* hydrograph than in the estimated *baseline* hydrograph, while the calculated mean winter discharge is 0.08% greater in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences are classified as **Negligible-Low**.

Water Quality In fall 2010, water quality at the lower *test* station and upper *baseline* station of the Firebag River showed **Negligible-Low** differences from regional *baseline* water quality conditions. The ionic composition of water in fall 2010 at both Firebag River stations and in McClelland Lake was consistent with previous sampling years and concentrations of most water quality measurement endpoints in fall 2010 were within the range of regional *baseline* concentrations at the *test* and *baseline* stations in the Firebag River. Concentrations of several water quality measurement endpoints in the Firebag River watershed were near or outside previously-measured minimum concentrations (typically major ions) or maximum concentrations (including total suspended solids, several total metals, total phenols, and DOC), likely as a result of high river discharges in fall 2010.

Benthic Invertebrate Communities and Sediment Quality Differences in the measurement endpoints for benthic invertebrate communities at the lower *test* reach of the Firebag River and in McClelland Lake are classified as **Negligible-Low** because, while there were significant changes in the values of a number of measurement endpoints over the period that these two locations have been designated as *test*, none of these significant differences (increases over time in taxa richness, diversity, evenness at the lower *test* reach of the Firebag River, and increase in total abundance in McClelland Lake) suggest negative changes in the benthic invertebrate communities. Differences in sediment quality observed in fall 2010 between the lower *test* station on the Firebag River and regional *baseline* conditions are classified as **Negligible-Low**. Most sediment quality measurement endpoints were within or below previously-measured concentrations at the lower *test* station of the Firebag River and in McClelland Lake.

Ells River Watershed

Hydrology The calculated mean winter discharge, open-water period discharge, annual maximum daily discharge, and open-water minimum daily discharge at Ells River above Joslyn Creek (RAMP Station S14A) are 0.01% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. This difference is classified as **Negligible-Low**.

Water Quality Differences in water quality in fall 2010 between the Ells River and regional *baseline* fall conditions are classified as **Negligible-Low**. Water quality conditions were consistent with previous years for the lower *test* station and middle *baseline* station of the Ells River and the fall 2010 concentrations of water quality measurement endpoints at these stations were generally within the range of previously-measured concentrations and regional *baseline* conditions. Water quality at the upper *baseline* station of the Ells River in fall 2010 was similar to that at the other two stations, located further downstream.

Benthic Invertebrate Communities and Sediment Quality Differences in benthic invertebrate communities at the lower *test* reach of the Ells River as of fall 2010 are classified as **Negligible-Low** because, while there were significant changes in the values of a number of benthic invertebrate community measurement endpoints over the period this reach has been designated as *test*, none of these significant differences (increases over time in taxa richness and diversity) suggest negative changes in the benthic invertebrate community. Differences in sediment quality observed in fall 2010 between the lower *test* station of the Ells River and regional *baseline* conditions were **Negligible-Low** with nearly all measurement endpoints within previously-measured concentrations.

Clearwater-Christina River System

Hydrology The calculated mean open-water period (May to October) discharge, annual maximum daily discharge and open-water minimum discharge at the mouth of the Christina River are 0.02% greater in the observed *test* hydrograph than in the estimated *baseline* hydrograph. This difference is classified as **Negligible-Low**.

Water Quality In fall 2010, water quality at both stations on the Clearwater River and both stations on the Christina River showed **Negligible-Low** differences from regional *baseline* conditions. Concentrations of several water quality measurement endpoints were outside the range of previously-measured concentrations in fall 2010. However, these differences generally were consistent with higher river discharges at the time of sampling and may have been the result of historically-high concentrations of suspended materials and some metals known to occur mainly in particulate form, as well as historically-low concentrations of some ions associated with groundwater inputs.

Fish Populations (fish inventory) Species richness in 2010 was lower in spring relative to the historical average (2003 to 2009) but within the historical range, lower in summer compared to 2009 when a summer inventory was first conducted, and higher in fall relative to the historical average. Relative abundance of each species was variable over time with no clear trends; the dominant species in each season has remained consistent over time. There has been significant variability in condition of large-bodied KIR species in the Clearwater River over time with no clear increasing or decreasing trends that would indicate a change in the health of fish in the river. Condition cannot necessarily be attributed to the environmental conditions in the capture location, as these populations are highly migratory throughout the region.

Hangingstone River Watershed

Hydrology The calculated mean open-water period discharge, annual maximum daily discharge, and open-water minimum daily discharge at WSC Station 07CD004 are 0.05% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These estimated watershed-level effects are classified as **Negligible-Low**.

Miscellaneous Aquatic Systems

Isadore's Lake and Mills Creek The calculated mean open-water discharge, minimum daily discharge, annual maximum daily discharge, and mean winter discharge are 33% lower in the

observed *test* hydrograph than in the estimated *baseline* hydrograph for Mills Creek. This difference is classified as **High**.

The water level of Isadore's Lake was above historical upper quartile values until early April, at which time monitoring temporarily ceased due to equipment malfunction. When monitoring resumed in late-June, the water level varied between the historical median and upper quartile values until the end of the 2010 WY.

Differences in water quality in fall 2010 between Mills Creek and regional *baseline* fall conditions are classified as **Negligible-Low**. While concentrations of a number of water quality measurement endpoints were outside regional *baseline* concentrations at the *test* station on Mills Creek, the WQI value of Mills Creek in fall 2010 was 84.1. With respect to Isadore's Lake, the ionic composition of water in fall 2010 was dominated by bicarbonate as in past sampling years, and concentrations of water quality measurement endpoints were within the range of previously-measured concentrations and regional *baseline* concentrations. However, increasing concentrations of several major ions have been observed in recent years (including chloride, sodium and sulphate), which are entering the lake from Mills Creek.

Differences in the benthic invertebrate community in Isadore's Lake as compared to historical conditions are classified as **Negligible-Low.** There were no significant time trends in any of the values of measurement endpoints for benthic invertebrate community in Isadore's Lake in fall 2010 and all measurement endpoints were within the range observed in previous years.

Shipyard Lake Concentrations of most water quality measurement endpoints in fall 2010 in Shipyard Lake were within previously-measured concentrations with few exceptions. The ionic composition of water in Shipyard Lake continues to exhibit an increase in sodium and chloride concentrations relative to historical concentrations, likely a result of reduced surface-water inflow and increased groundwater influence in the lake associated with focal projects in the upper portion of the Shipyard Lake watershed.

Differences in the benthic invertebrate community in Shipyard Lake as compared to historical conditions are classified as **Negligible-Low** because, while there were significant changes in a number of measurement endpoints over the period that the lake has been designated as *test*, none of these significant differences (increases over time in total abundance and taxa richness) suggest negative changes in the benthic invertebrate community.

Poplar Creek and Beaver River The calculated mean open-water discharge (May to October) at WSC Station 07DA007 (RAMP Station S11, lower Poplar Creek) is 23.5% greater in the observed *test* hydrograph than in the estimated *baseline* hydrograph. This difference is classified as **High**. The annual maximum daily discharge is 0.9% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. This difference is classified as **Negligible-Low**. The open-water minimum daily discharge is 1.8% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. This difference is classified as **Negligible-Low**.

Differences in water quality in fall 2010 between the *test* stations on Poplar Creek and the lower Beaver River and the *baseline* station on the upper Beaver River and regional *baseline* conditions were classified **Negligible-Low.** Concentrations of most water quality measurement endpoints were within previously-measured concentrations at *test* stations on Poplar Creek and the lower Beaver River and the *baseline* station on the upper Beaver River and were generally consistent with regional *baseline* conditions in fall 2010.

Differences in the benthic invertebrate community at the lower *test* reach of Poplar Creek is classified as **Moderate** because of the significantly lower percent EPT compared to the upper *baseline* reach of the Beaver River. Differences in sediment quality observed in fall 2010 in the lower

test station on Poplar Creek and the upper *baseline* station on Beaver River compared to regional *baseline* conditions were **Negligible-Low**. Concentrations of most sediment quality measurement endpoints were within or below previously-measured concentrations at both reaches.

McLean Creek The differences in water quality between the *test* station on McLean Creek and regional *baseline* conditions are classified as **Negligible-Low**. Concentrations of water quality measurement endpoints at the *test* station on McLean Creek were within previously-measured concentrations and within regional *baseline* conditions in fall 2010. The ionic composition of water at the *test* station in McLean Creek has been stable in recent sampling years compared to variability observed during historical years.

Fort Creek The calculated mean open-water period (May to October) discharge volume at RAMP Station S12 is 11.4% greater in the observed *test* flow volume than in the estimated *baseline* flow volume. This difference is classified as **Moderate**. 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 2010 between the *test* station on Fort Creek and regional *baseline* fall conditions are classified as **Negligible-Low**. This indicates an improvement in water quality from 2009 with most water quality measurement endpoints within the range of previously-measured concentrations and within regional *baseline* water quality conditions.

Differences in the benthic invertebrate community at the lower *test* reach of Fort Creek are classified as **High** because of significant decreases over time in taxa richness and evenness, and because taxa richness, diversity and evenness in fall 2010 were below the 5th percentile of regional *baseline* conditions. There was also a shift in dominant taxa from chironomids in the *baseline* period to the more tolerant tubificid worms at the lower *test* reach of Fort Creek in the *test* period suggesting a negative change in the benthic invertebrate community. Differences in sediment quality observed in fall 2010 between the *test* station on Fort Creek and regional *baseline* conditions were **Negligible-Low** with nearly all sediment quality measurement endpoints within previously-measured concentrations.

Regional Lakes (fish tissue) Muscle tissue analysis for mercury was conducted on target fish species captured in fall 2010 from Brutus, Keith and Net lakes in collaboration with ASRD's Regional Lakes FWIN program. The classification of the results of this program is based on the potential risk to subsistence fishers and general consumers. Mercury concentrations in all northern pike and 73% of walleye from Brutus Lake in 2010 exceeded the Health Canada guideline for subsistence fishers, and mercury concentrations in two walleye exceeded the guidelines for general consumers. The results indicate 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 is a **Moderate** risk to general consumers consuming northern pike and walleye, dependent on the quantity of fish consumed. Mercury concentrations in fish from Brutus Lake were generally within the historical range of mercury concentrations in fish sampled from other regional lakes. Mercury concentrations in lake whitefish were below any Health Canada consumption guidelines indicating a **Negligible-Low** risk to human health.

Mercury concentrations in lake whitefish and northern pike from Keith Lake were below any Health Canada consumption guidelines indicating a **Negligible-Low** risk to human health. Mercury concentrations in fish from Keith Lake were generally within the historical range of mercury concentrations in fish sampled from other regional lakes.

Mercury concentrations in all captured walleye and all but one northern pike from Net Lake in 2010 exceeded the Health Canada guideline for subsistence fishers. The majority of walleye and two northern pike exceeded the guideline for general consumers. The results indicate a **High** risk to the health of subsistence fishers consuming northern pike and walleye and to general consumers

consuming walleye, given most fish exceeded the guideline for general consumers. Given that all northern pike exceeded the guideline for subsistence fishers, there is a **Moderate** risk to general consumers consuming northern pike, dependent on the quantity of fish consumed. With the exception of two fish, mercury concentrations in lake whitefish were below any Health Canada consumption guidelines indicating a **Negligible-Low** risk to human health. Overall, the mercury concentrations in fish sampled from Net Lake were higher in northern pike and walleye compared to mercury concentration in fish from other regional lakes.

Acid-Sensitive Lakes

The results of the analysis of the 2010 ASL component lakes data compared to historical data suggest that there has been no significant change in the overall chemistry of the 50 ASL component lakes over time. A long-term decline is noted for DOC but this appears to be a regional trend that may reflect other causes or factors other than acidifying emissions. Based on the analysis of among-year differences in concentrations of measurement endpoints, as well as trend analysis and control plotting of measurement endpoints on individual lakes, there is no evidence to suggest that there have been any significant changes in lake chemistry in the ASL lakes attributable to acidification.

The *baseline* subregion of the Caribou Mountains had the highest rate of measurement endpoints exceeding two standard deviations of the mean for each lake in a direction indicative of acidification. The observed differences were classified as **Moderate**, which is unexpected given that the Caribou Mountain lakes are remote from sources of acidifying emissions and considered *baseline* lakes. All three exceedances in measurement endpoints in the Caribou Mountain subregion were attributable to Lake 146/CM1, which had water chemistry in 2010 that was uncharacteristic of the subregion. The remaining subregions were classified as **Negligible-Low**.

Summary and Recommendations

The following table provides a summary of the 2010 RAMP monitoring program results, by watershed and component.

The report concludes with a number of recommendations directed towards refining the monitoring program and increasing the value of RAMP monitoring activities. These recommendations are for consideration during the design of monitoring in future years of RAMP:

- Continue monitoring existing climate and hydrometric stations to enhance record length and data availability;
- Expand the climate and hydrologic monitoring network to support provision of baseline and test hydrometric information and regional climate data;
- Evaluate additional hydrometric measurement endpoints and indicators (such as the timing and frequency of flow conditions) that would further support RAMP assessment and understanding of aquatic conditions;
- Conduct water balance assessments as a consistent approach applicable to tributary watersheds, independent of the length of the data record, and, as possible, continue to refine inputs such as the time-step of industrial data;
- Add *baseline* stations to the RAMP sampling design, particularly stations that are expected to remain *baseline* well into the future given the steady decline in the number of stations designated as *baseline* in the current RAMP design, and the need to continually update the ranges of natural variability (i.e., *baseline* conditions) in the RAMP FSA.

- Add seasonal sampling of water quality to assess any differences in water quality that may occur across seasons.

- Include PAHs analyses in water samples. Analyses of PAHs were eliminated from the Water Quality component given the concentrations were always below detection limits. However, with improvements in analytical detection limits over time, analyses of these compounds should be revisited.

- Analyze sediment core data to address questions related to historical increases in PAHs and other hydrocarbons in sediments in the ARD. There is several research programs planned to collect sediment cores from the ARD in 2010, which would be very helpful in clarifying historical trends in sediment quality.

- Consider the use of sediment traps in some channels (especially Fletcher Channel), to estimate sediment deposition rates (which may be changing over time as natural succession occurs in the ARD) and also to specifically assess concentrations of hydrocarbons and metal in sediments deposited in the ARD in a given year.

- Add a *baseline* reach upstream of oil sands development on the Athabasca River for the Fish Populations fish inventories. Although fish are highly migratory through the Athabasca River, it will help to provide more information on their habitat range and utility of the river.

- Collect ageing structures from large-bodied KIR species during the Athabasca and Clearwater inventories. Collection of ageing structures has been done historically and needs to be reinstated to assess recruitment rates in these fish populations.

- Continue to develop more thorough protocols for assessing fish pathology in individual fish. In addition, RAMP is currently working with a fish pathologist to develop a better understanding of abnormalities in fish in Northern Alberta. A subsample of fish with abnormalities submitted to the fish pathologist for analysis should be considered in conjunction with RAMP's Fish Health Program, which engages anglers within the region to submit fish for analyses.

- Continue to develop a database of mercury in fish tissue from lakes and rivers within the RAMP FSA, both beyond focal project development and downstream of development given increased community concern regarding the safe consumption of fish. Given the variability in mercury concentrations in fish across lakes, it is necessary to continue sampling lakes in the region so that data can be provided to Alberta Health and Wellness and Health Canada in order to establish human consumption guidelines for lakes commonly used for sportfishing.

- Continue to analyze for mercury in fish from the Athabasca and Clearwater rivers to monitor trends over time in to relation the specific consumption guidelines established by the Government of Alberta for these watercourses.

- Continue collaboration with Environment Canada during the fish assemblage and sentinel species monitoring to assess the ecological and physiological changes that may occur in fish populations due to oil sands development.

Summary assessment of RAMP 2010 monitoring results.

Watershed/Region	Differences Between *Test* and *Baseline* Conditions					Fish Populations: Human Health Risk from Mercury in Fish Tissue[6]			Acid-Sensitive Lakes: Variation from Long-Term Average Potential for Acidification[7]
	Hydrology[1]	Water Quality[2]	Benthic Invertebrate Communities[3]	Sediment Quality[4]	Sentinel Fish Species[5]	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	○	○	-	-	-	-	-	-	-
Firebag River	○	○	○	○	-	-	-	-	-
McClelland Lake	nm	n/a	○	n/a					
Ells River	○	○	○	○	-	-	-	-	-
Christina River	○	○	-	-	-	-	-	-	-
Clearwater River	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	-	-	-	-	-
Brutus Lake	-	-	-	-	-	LKWH WALL NRPK	○ ● ●	○ ● ●	-
Keith Lake	-	-	-	-	-	LKWH NRPK	○ ○	○ ○	-
Net Lake	-	-	-	-	-	LKWH WALL NRPK	○ ● ●	○ ● ●	-
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 2010.

nm - not measured in 2010.

n/a - classification could not be completed because there were no *baseline* conditions to compare against.

[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 2010, hydrology results above are for those endpoints that were calculated.

Note: All calculated hydrology measurement endpoints in the Muskeg River watershed were assessed as Negligible-Low with the exception of Annual Maximum Daily Discharge which was assessed as Moderate.

Note: All calculated hydrology measurement endpoints in the Fort Creek watershed were assessed as High with the exception of Annual Maximum Daily Discharge which was assessed as Negligible-Low.

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

Note: Water quality at all stations in the Athabasca River was assessed as Negligible-Low with the exception of station ATR-DC-E, which was assessed as Moderate.

[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 at the lower and middle reaches of the Muskeg River were assessed as Negligible-Low and benthic invertebrate communities at the upper reach was assessed as Moderate.

Note: Benthic invertebrate communities at all reaches in the Athabasca River Delta was assessed as Negligible-Low with the exception of Fletcher Channel, which was assessed as High.

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

[5] **Fish Populations (sentinel species):** Uses Pulp and Paper Environmental Effects Monitoring Criteria (Environment Canada 2010). See Section 3.2.4.3 for a detailed description of the classification methodology.

Note: Differences in trout-perch populations at all *test* sites in the Athabasca River were assessed as Negligible-Low with the exception of *test* Site 3 and *test* Site 5, which was assessed as Moderate.

[6] **Fish Populations (fish tissue):** Uses Health Canada criteria for risks to human health.

LKWH-lake whitefish; WALL-walleye; NRPK-northern pike

Note: For Fish Population Human Health Classification - Sub. refers to subsistence fishers; Gen. refers to general consumers as defined by Health Canada.

[7] **Acid-Sensitive Lakes:** Classification based the frequency in each region with which values of seven measurement endpoints in 2010 were more than twice the standard deviation from their long-term mean in each lake.